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Na wydziale prowadzone są studia na kierunkach:

- mechanika i budowa maszyn,
- zarządzanie i inżynieria produkcji,
- automatyka i robotyka,
- informatyka,

na trzech poziomach studiowania: inżynierskim, magisterskim i doktoranckim. W swojej 47-letniej historii na wydziale wypromowano ok. 8 tys. inżynierów i magistrów inżynierów, którzy zasilili kadrę techniczną wielu firm przede wszystkim Bielska-Białej i regionu, przyczyniając się istotnie do ich rozwoju. Kadrę Wydziału stanowi: 13 profesorów tytularnych, 26 doktorów habilitowanych, 59 doktorów, 14 magistrów i 29 pracowników administracyjnych i inżynieryjno-technicznych. Podstawowe obszary badań uprawianych na Wydziale związane są z prowadzonymi kierunkami kształcenia i obejmują zagadnienia z zakresu: projektowania, analizy i badań doświadczalnych konstrukcji mechanicznych; projektowania procesów technologicznych; zarządzania i organizacji tych procesów; metrologii, ergonomii i logistyki; automatyzacji i sterowania maszynami i urządzeniami; projektowania, analizy i badań doświadczalnych pojazdów; układów napędowych, silników, a także systemów przetwarzania danych, administrowania sieciami komputerowymi i bezpieczeństwa informacji.

KOŁO NAUKOWE "INŻYNIER XXI WIEKU"

Jeżeli fascynują Cię nowe rozwiązania techniczne, masz własne pomysły na małe projekty badawcze i chcesz podjąć wyzwanie w ich realizacji z kolegami z innych dziedzin nauki - **dołącz do naszego koła!** W ramach działalności koła naukowego zespoły projektowe złożone ze studentów różnych kierunków studiów realizują zadania badawcze na styku mechaniki, automatyki i informatyki.

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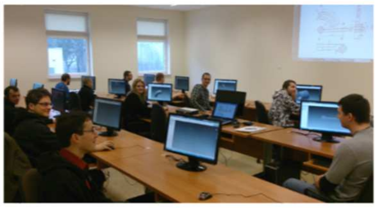


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Processing, transmission and security of information

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TRAFFIC FLOW RESERVATION AND REDISTRIBUTION METHODS IN THE BACKBONE MOBILE OPERATOR NETWORK

Summary: The paper analyzes resource reservation algorithms and methods of traffic flows redistribution in the backbone mobile operator network. Network traffic model was taken for consideration based on queuing system M/M/1-model. By using this model load network was investigated, and method of load balancing was developed in LTE transport network.

Keywords: reservation algorithm, traffic flows, load balancing, transport network

METODY REZERWACJI ORAZ REDYSTRYBUCJI PRZEPŁYWU W MOBILNEJ SIECI SZKIELETOWEJ

Streszczenie: W artykule analizuje się algorytmy rezerwacji zasobów oraz metody redystrybucji przepływu/przesyłu w mobilnej sieci szkieletowej. Model przepływów sieciowych został opracowany na podstawie systemu kolejkowego (M/M/1-model). Posługując się tym modelem, badano obciążenie sieci. Testowano także metody zrównoważenia obciążenia. Ostatnio wspomniane metody zostały dostosowane do sieci przesyłowych typu LTE.

Słowa kluczowe: algorytm rezerwacji, przepływ, zrównoważenie obciążenia, sieć przesyłowa/transportowa

1. Backbone mobile operator network

Cellular communication networks have to pass traffic in projected volumes and satisfy growing consumer demand on time for high speed data transfer. It is extremely important in achieving this goal select an efficient technology [1].
LTE cellular system has been designed to provide high bandwidth and service of high speed data transfer for mobile multimedia [2]. In contrast to most previous generation networks that are experiencing quite high diverse and hierarchical network nodes, LTE network architecture can be called "flat", in which the base stations (eNodeB)

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directly connected to the enhanced packet core network (EPC) [3]. From the side of user connection is established with serving gateway (SGW), from the control side – with mobility management entity (MME).

To ensure proper support for new broadband radio access technologies in the transport network must be improved transmission efficiency of information while reducing the cost of delivery of each megabyte of traffic and provide quality of service (QoS), required for each type of traffic. Classical transport network of mobile operator consists of two segments [4]:

- backhaul network, which connects base stations with controllers and mobile switching centers (MSC),
- backbone network, which provides high-speed transport between switching centers.

The main criteria for efficiency estimation of the transport network may include the following [5]:

- communication channel capacity,
- maximum length of transport section,
- reconnect time,
- ability to manage load,
- support,
- equipment availability,
- specialists availability,
- equipment compatibility from different manufacturers.

By analyzing criteria listed above, it is necessary to search for new architectural solutions and approaches that will improve the efficiency of transport segments in cellular networks.

In this context it is expedient to examine SDN network. Software-configurable network can fundamentally change the optical transport network. SDN will apply centralized control over the network, ensure its programmability and automation providing different services for different QoS.

Therefore, understanding this, organization ONF (Open Network Fundation) conducts development of OTS (Open Transport Switches), which act as intermediaries between the controller and an optical switch. OTS communicates with the controller via the protocol OpenFlow, and to interact with the optical switch specific command syntax is used for a specific switch.

OTS will allow mobile operators or large service providers to develop and apply in their new networks more sophisticated network resources reservation algorithms and traffic flows redistribution (load balancing), which as a result will help to improve the quality of customer service. So let us analyze modern algorithms that are widely used and conduct simulation of load balancing in the network.

2. Resource reservation algorithms

There are many types of effective resource reservation algorithms. Among them [6-10]:

- Advance Reservation (AR);
- Lightpath Routing and Resource Reservation - An Integrated Solution for IP over DWDM Networks;

- Routing and Wavelength Assignment in GMPLS-based 10 Gb/s Ethernet Long Haul Optical Networks with and without Linear Dispersion Constraints;
- MBR: A Markov-based Reservation Algorithm for Wavelength;
- Assignment in All-Optical Networks;
- Advance reservation-based co-allocation algorithm.

2.1. Advance Reservation

AR is a special type of reservation some software queuing systems. User can reserve resources listed at any given time for a given duration. After verification, the resources are available for the user over a period of booking. The works, which are designed for running during the booking, can be presented immediately after booking confirmation, or at any time before the end of the reserved period. Implementing reservation requires creation of dynamic queue for filing each confirmed reservation. Resources are allocated to reservation queue by temporarily removing resources from the general queue.

2.2. An Integrated Solution

Appropriate network resources reservations to establish a virtual connection between pairs of source-destination achieved by means of signaling protocol MPLS, creating a path for resources in DWDM optical fiber network. There are two purposes of using network resources reservation schemes:

- Ensure that resources are delivered successfully;
- Adjust the optical switch in parallel with resources reservation.

The similarity between lambda reservation and electronic MPLS signaling protocol is that they can perform labels substitution by introducing lambda conversion in each O-LSR. However, the structure of the lambda reservation can not change the label stacking and merging in DWDM network core. As a result of this limitation, the scheme is designed to allow resource reservation only with lambda component. In other words, a full lambda component is used in each link of computer path between source-destination pair.

2.3. Routing and Wavelength Assignment in GMPLS-based 10 Gb/s Ethernet Long Haul Optical Networks with and without Linear Dispersion Constraints

For simplicity, reservation protocol based on parallel reservation has been implemented in order to test various destination schemes of routing and wavelength that were involved. The generator sends a message "Request" for a new connection to another randomly selected node. In the case when GMPLS router receives the message "Request", it calculates explicit route to the requested destination and assigns wavelength for communication and then measures the overall residual dispersion and PMD. If both the route and wavelength are available, GMPLS router provides reservation in the parallel route. It sends "Reserve" in the parallel message into each node of the obvious route, except itself. When a node receives a message "Reserve", it checks whether of his predecessor in the explicit route provides a request. Then it sends back the message "Response", so that the source determined the success of the previous order. If the requested wave is not available in one or more nodes on the explicit route, the source will send removal request message to all units that have already reserved the wavelength from an explicit way.

2.4. MBR: A Markov-based Reservation Algorithm for Wavelength

Source node uses the shortest path of routing algorithm and uses reverse reservation protocol to create a connection. Data source node sends the message «PROB» to the destination node. After receiving the message "PROB", the intermediate node will update wave_map field by marking occupied wavelengths on the input fiber and mark output fibers as "busy". After receiving the message «PROB», destination node selects free wavelength based on information in wave_map field, and sends the message «RERV» up the appointment path. All nodes along the path block waves, indicated in the message «RESV».

2.5. Assignment in All-Optical Networks

When "PROB" message of connection request (A->E) arrives at intermediate node (C), the first node updates wave_map field in a message, marking occupied wavelength at the input and the output of links with such labels as "busy". When a request for another connection enters the node C, these probabilities also needed to be calculated. The calculation should be kept for possible assignment of wavelength based on information about earlier connection request. For more simple calculation heuristic method is used. After calculating the probability that the connection will use different wavelengths, we call the function wheel_of_fortune. Then node C keeps a record of the request in the current table settings wheel_game field in the result of the function wheel_of_fortune. Message «PROB» is sent to nodes that are below in the reservation algorithm. If the request comes node C and finds the intervention requests in the current table, it will call the solve_interference function.

2.6. Advance reservation-based co-allocation algorithm

The algorithm is implemented at each request reservation arrival. Stages of resource reservation planning and common distribution in GRC (Global Resource Coordinator) are the follows:

- GRC receives co-allocation request for cooperation from the user;
- GRC Planner creates several request reservation plans.

The scheduler selects N laddered terms from *[EST, LST + D]*. The scheduler receives the results of the available information resources on the N timeframe of RMs (Resource Managers). Using this available information of resources, the scheduler determines N' $(N' \leq N)$ reservations plans based on co-allocation distribution method. The scheduler sorts N' plans in any order, depending on co-allocation option in matters of the user and administrator. According to the reservation plans created by scheduler, GRC is trying to co-allocate selected resources in collaboration with minor RMs, that manage local information resources of a territory. GRC returns co-allocate distribution results to the user to determine whether the resource co-allocation procedure has succeeded or not. If it has failed, the user resubmit request with updated needs for resources.

The algorithms have their advantages and disadvantages in use. Requirements for each service about data transfer in network are different, so it should be used its network resource reservation algorithm for each service.

3. Load balancing

Load balancing – the ability of a router to distribute traffic over all network ports that are on the same distance from the recipient. In the load distribution algorithms is used information about channels capacity and reliability. Distribution load increases the intensity of network segments, and thus the effective network capacity in general. There are static and dynamic load balancing. In the case of static load balancing proportions of distribution does not change during the router operation. This approach is quite simple, but inefficient. It is advisable to use dynamic balancing, which involves load redistribution during operation.

The main difficulty in solving this problem is that under the condition of different routes cost is difficult to achieve the requirements concerning quality of service. Also, it should be remembered that the network is a complex distributed object. And it is impossible to anticipate its behavior in the next time. In most cases, guaranteed quality of service can be provided only in the allocation of virtual channel that implies the existence of one route with indicators of required performance. In such circumstances, there are situations when alternative routes are underused, and provide uniform loading of the network will be possible only with packets that are not sensitive to the QoS parameters. The main differences between this method and most existing one is that it is dynamic, and allows to distribute load depending on the channel conditions between alternative routes with different value. The routing process based on LB method for routes with different cost shown in figure 1.

For effective research and solution of the distribution (balancing) load task it is important adequately mathematically to describe the work of the router. This mathematical model should reflect the functional side of the router, and should be supported by information about network structure and operation to make management decision. In fact, the router is a storage device with a set of inputs through which traffic enters, and set of exits through which traffic is sent to the next network devices. Therefore, the model of the router will be considered as a dynamic system.

Consider the network load on the simple M/M/1 queuing model example. It receives heterogeneous requests flow with exponential intervals distribution between successive requests (elementary flow) and exponential duration of service requests in the device.

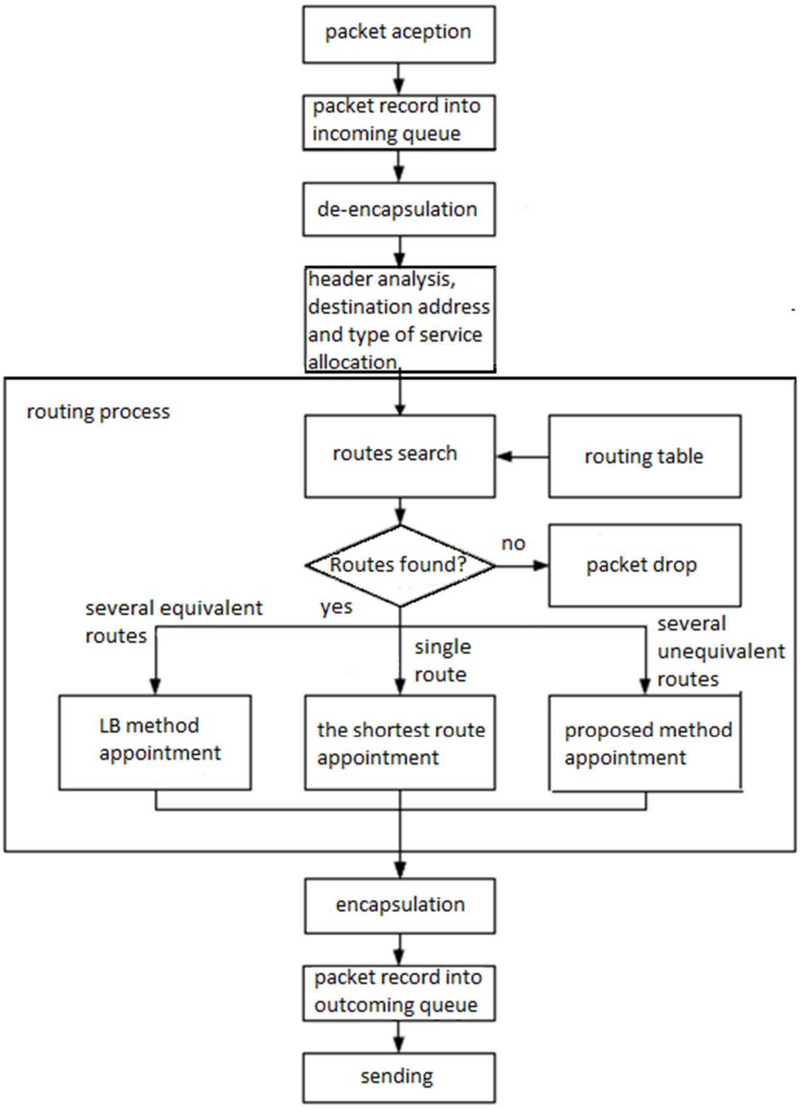

Figure 1. The routing process based on LB method

Construct a queuing system with heterogeneous requests flow, which received H request classes with intensities $\lambda_1, \ldots, \lambda_H$ (Fig. 2) and the average service length $b_1, \ldots, b_H$ including load that created by requests of class i (Fig. 3).

$$y_i = \frac{\lambda_i}{\mu_i} = \lambda_i b_i \tag{1}$$

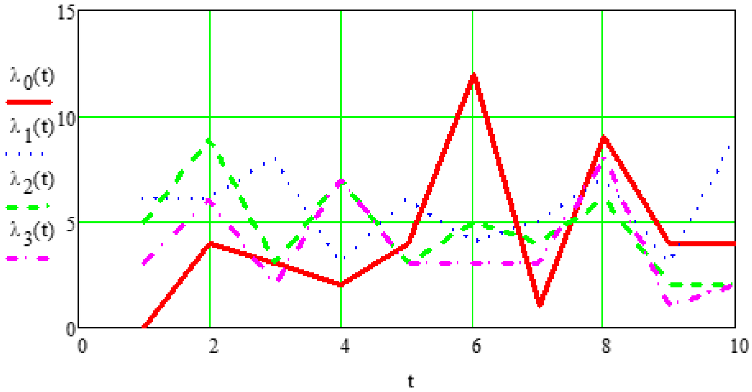

Figure 2. Requests intensity based on time

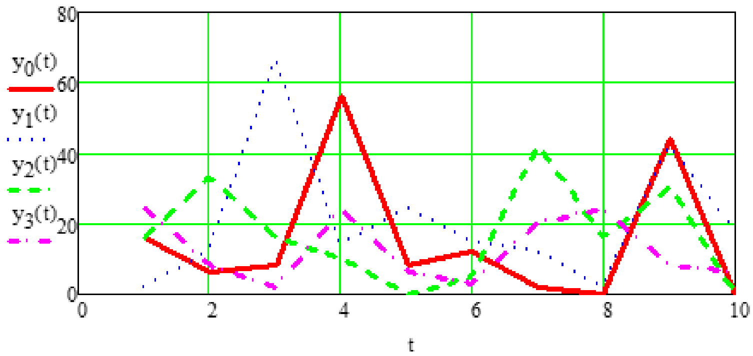

Figure 3. Length of service requests at different periods of time

Considering the probability of service requests $\pi_{0_i} = (1 - \pi_{n_i})$ expect the intensity of serviced requests flow:

$$\pi_{0_i} = (1 - \pi_{n_i}) \tag{2}$$

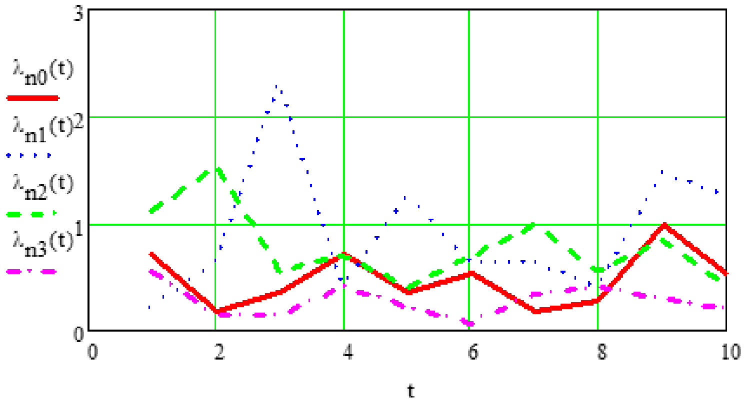

Figure 4. The intensity of serviced requests flow

The load of system, that created by class requests *i* is shown in Figure 5.

$$\rho_i = \min\left(\frac{(1-\pi_{n_i})y_i}{K}; 1\right) \tag{3}$$

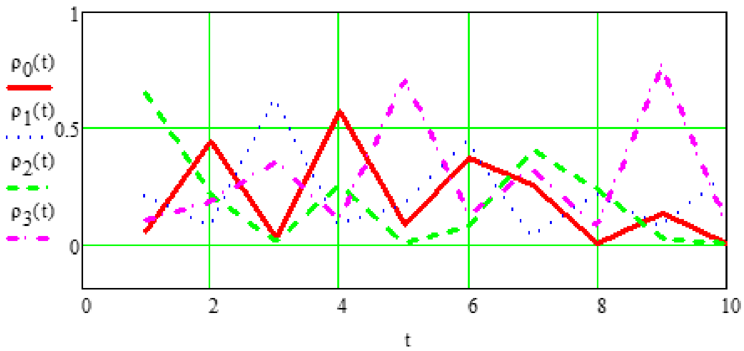

Figure 5. The load of system

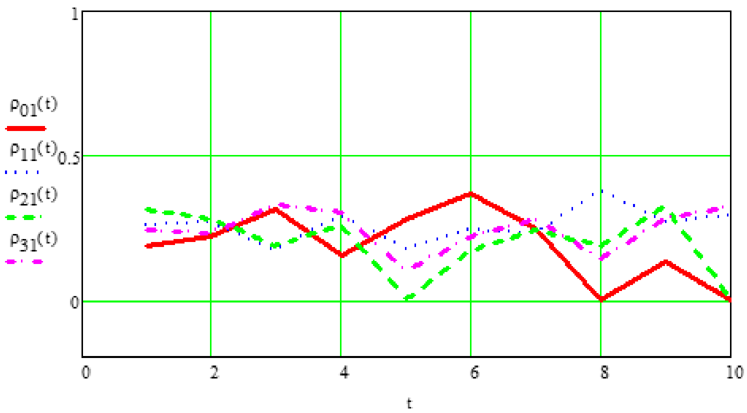

Figure 6. System load after optimization

Fig. 6 show a system load, that created by class request *i* after traffic flows redistribution optimization.

4. Conclusion

LTE network architecture is designed to provide packet traffic support with so-called „seamless" mobility, minimal packet delay and high QoS. Therefore, an important task was to investigate the resource reservation algorithms and traffic flows redistribution methods in the backbone mobile operator network.
As a result, it was proved that because discussed algorithms have their advantages and disadvantages in use and requirements of data transfer for each service in network are different, so it should be used its network resource reservation algorithm for each service.
It was also investigated the system load based on a simple M/M/1 queuing model. The results show that the use of dynamic load balancing models allows to achieve more balanced traffic distribution across the network and therefore higher performance.

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ON ALGORITHM OF SYSTEMS ANALYSIS FOR DECISION SUPPORT SYSTEM OF MEDICAL RESEARCH

Summary: The work is presents our results in field of application of system analysis methods to problem of medical research. We emphasize effects of uncertainty that should be taken into account in such complex processes. Medical system research requires information support system implementing data mining algorithms resulting in decision trees or IF-THEN rules. Besides that such system should be object-oriented and web-integrated.
The aim of this study was to develop information support system based on data mining algorithms applied to system analysis method for medical system research. System analysis methods were used for qualitative analysis of diseases mathematical models. Algorithms such as decision tree induction and sequential covering algorithm were applied for data mining from learning data set.
We observed the complex qualitative behavior of population and diseases models depending on parameters and controllers even without considering probabilistic nature of the most of quantities and parameters of information models

Keywords: system analysis, decision support systems, information system, simulation, optimization, dynamic system, qualitative analysis, decision tree, classification rule, health research systems

ALGORYTM ANALIZY SYSTEMOWEJ DLA SYSTEMU WSPOMAGANIA PODJĘCIA DECYZJI DLA MEDYCZNYCH BADAŃ NAUKOWYCH

Streszczenie: Artykuł przedstawia nasze wyniki dotyczące zastosowania metod analizy systemowej do problemu badania naukowego w medycynie. Zwrócono uwagę na znaczenie niepewności, które należy wziąć pod uwagę dla takich skomplikowanych procesów. Do medyczne systemowych badań wymagany jest system informacyjny wyposażony w moduł podejmowaniem decyzji. W wyniku działania takiego systemu, otrzymujemy drzewa decyzji lub reguły typu IF-THEN. Oprócz tego taki system powinien być obiektowo zorientowany oraz web-zintegrowany.

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Celem jest opracowanie systemu informacyjnego podejmowania decyzji opartego na algorytmach ‘data mining’ w zastosowaniu do badań medycznych naukowych. Zaproponowane metody analizy systemowej zostały wykorzystane dla jakościowej analizy modeli matematycznych chorób. Obserwowano skomplikowane jakościowe zachowanie modeli procesów medycznych i populacyjnych nawet bez rozpatrzenia prawdopodobieństwa większości parametrów.

Słowa kluczowe: systemy wsparcia podjęcia decyzji, system informacyjny, symulacja, system dynamiczny, analiza jakościowa, drzewo decyzji, reguła klasyfikacji, systemy badań zdrowia

1. Introduction

The forecast of unauthorized access to the State informational networks (SIN) must be undoubtedly based on tendencies researching, that are observed in changes of their current state under the influence of unauthorized access. In theory of automatic control is expected, that this state can be presented by the range of values of some controlled parameters. Then, obviously, the reason that causes changes of SIN state, must be changes of values of these parameters. Thus, the forecast of unauthorized access in SIN must be based on forecasting the values of controlled parameters state. This can be carried out on base of mathematical instrument of process extrapolation, that describes regularities of changes in parameters. In its turn the usage of extrapolation instrument needs certain processes formalization of changes in controlled parameters, i.e. it needs creating a certain mathematical model of SIN parameters measurements under the influence of unauthorized access.

Here we would like to present our results in field of application of system analysis methods to problem of clinical medicine. We emphasize effects of uncertainty that should be taken into account in such complex systems. It will be shown that even considering deterministic models of such nonlinear systems we see different qualitative behavior closely dealt with parameters values. Let’s start from origin of such a problem. Nowadays there are obtained a lot of models describing physiological indices of human body at different diseases and treatment schemes. Primarily they are based on regression analysis. More complex ones use neural networks and evolutionary programming. The most significant attempts to construct mathematical models at different levels of hierarchy of human organism were made by John Murray [3], Keener and Sneyd [2], G.I.Marchuk [1], Mackey and Glass (they investigated nonlinear phenomena applying dynamic systems and introduced notion of dynamic diseases). Without considering uncertainty all these models can be applied for patients from determined groups (primarily for given age and a lot of another restrictions).

As for projects stimulating given research we would like to note the following. During the last years Medical Informatics Department is fulfilling investigations initiated by Healthcare Ministry of the Ukraine in order to develop and use general system analysis algorithm to study different diseases [4] - [9]. Namely, in fields of oncology (melanoma, leukemia), infectious diseases (flue), therapy (bone tissue diseases). Naturally there arises a problem to develop a general model for disease. It is incorrect to state that we managed offering unique universal algorithm to construct disease general model at whole. More correct is to say this approach can be used for diseases of different nature. We believe this approach can be extended to processes

in sociology and demography as well as for economy and finance branches tasks. A lot of them have the same nature as human diseases. Let's pay attention on special medical terminology necessary (as small as possible). First of all, the most recognized definition of disease states that disease is a set of pathologic processes weakening vitality and activity of a human organism. Here pathologic process is a set of pathologic (that is not normal) and protectoral reactions within human organism. That is, the most significant is modeling pathologic process.
Based on this reasoning we offered general model for pathologic process including three counterparts
(i) the reason or cause of disease (it may be some external factor (like bacteria, chemicals) or own modified cells (tumor cells);
(ii) immune system supports organism with help of specific antibodies (sort of predators) and plasmatic cells (their ancastors);
(iii) normal cells, tissues and organs (it is necessary to consider them to satisfy to some constraints of toxicity).
For these researches we used our own software - Software Environment for Medical System Researches (SEMSR). There is developed conceptual model of software environment of system medical investigations support. Implementing it there is offered model of data structure in branch of system medical investigations and invented in terms of XML- technology. There is developed interface which is Web-integrated, user-oriented and adjustable. There are implemented mathematical methods of system analysis of pathologic processes in form of Java-classes hierarchy. There are developed software tools to execute system medical investigations, to prepare results obtained for presentation in Internet and visualization.

2. Main part

2.1. Uncertainties in medical system research

Uncertainties in such models may be parametric. Some of the parameters may be unknown functions. As for uncertainty in control it is necessary to take into account all possible scenarios. Note, the purpose of this article is not to present methods to identify these uncertainties. For these purpose we need to present powerful and deep mathematical apparatus of adjoint systems, sensitivity functions and minimax aposteriorial estimation. Here we would like to answer two questions
(i) why is it so important to take into account uncertainties?
(ii) the basic uncertainties in models of diseases.
When answering the first question we should say that as it was shown even mathematical solutions of equations have different qualitative behavior. In practice we can observe different forms of disease (subclinical, acute, chronic, lethal). Search of treatment scheme is dependent on such forms.
In our research we investigated uncertainties in the following issues: maturation time for plasmatic cells τ, influence of antigen on target-organ damage rate σ, relation between target-organ damage rate and immune response $\xi(m)$, therapy scheme (polychemiotherapy, radiotherapy), surgery interventions. Note, the three last ones are non- parametric. They depend on unknown function like controller.

2.2. Approach of Compartmental Systems

Problems of population dynamics, pharmacokinetics, mathematical epidemiology, and others are described by compartmental systems with time delay. Even in the linear case, the solution of such equations leads to approximate computation procedures, which makes it impossible to find solutions of the following problems in explicit form:
— determining the time instant at which the number of infected persons does not exceed some level i^* (mathematical epidemiology);
— estimating the time when no more than d^* medical product units (pharmacokinetics) remain in the organism of a patient, etc.
Explicit solutions of such problems can be obtained on the basis of exponential type estimates. A number of works are devoted to the construction of exponential estimates for systems with delay. In particular, in [1], an estimate for a linear system is obtained on the basis of the Cauchy formula. An approach based on Lyapunov functions with conditions of the Razumikhin type was developed in [2]. In [3], an estimate is found from the solution of a difference inequality for a Lyapunov–Krasovskii functional. In [4], a differential difference inequality is constructed for a Lyapunov–Krasovskii functional. For compartmental systems, a promising approach is proposed in [5] in which the method of construction of a class of exponential estimates is based on the Hale–Lunel inequality.

2.3. Software Development Based on Data Mining Technology

The objective is to develop and implement an algorithms of diagnostic classification applying decision tree induction and sequential covering methods and to study problem of their computational complexity.
The problem solved belongs to wide class of differential diagnostics problems. In medicine the notion of “differential diagnostics” means systemic approach based on evidence for determining causes of symptoms observed in case if there are few alternative explanations and also to reduce list of possible diagnoses.
One of approaches expressing natural process of thinking for differential diagnostics is data mining method. We are interested in the problem of computational complexity of the algorithms for real clinical data such as, for a example, for biochemical data in case of polytraumas.
Software implementation of decision tree induction. The methods are implemented within Netbeans developer system in Java language. The database of learning tuples is deployed on MySQL server. In fig.1 there is presented conceptual model of informational system. Class *DecisionTree* implements decision tree induction method. Class *DataManager* is processing calls from *DecisionTree* running queries to *mysql* database retrieving learning data.
Database *mysql* consists of two tables – table *attribute* for storage of information on attributes and table *categorized_data* – for learning tuples. The structure of tables in SQL syntax is shown below:

```
CREATE TABLE mysql.attribute (
id integer not null unique,
          attribute_name varchar(25),
          attribute_field_name varchar(25),
    primary key (id)
    ) ENGINE=InnoDB;
```

```
CREATE TABLE mysql.categorised_data (
id integer not null unique,
          A1 varchar(12),
          A2 varchar(8),
          A3 varchar(7),
                   ………………….. .
          A21 varchar(7),
          class varchar(28),
    primary key (id)
    ) ENGINE=InnoDB;
```

Classes of this project are included in package *decision_tree.model*. Here there are beans-classes *Attribute, Attribute_for_list* and *CategorisedData* for processing data of corresponding tables. SQL-queries for retrieving corresponding data including calculations of information indices are implemented in class AttributeListPeer.

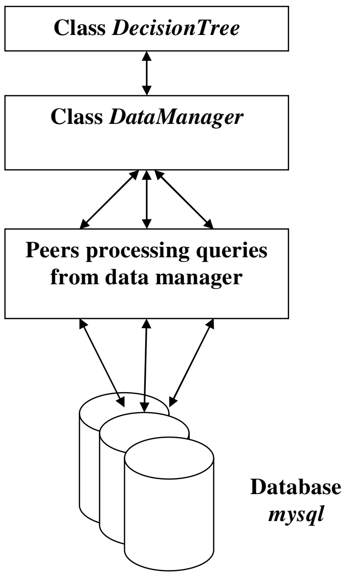

Figure 1. Conceptual model of informational system of decision tree induction

Problem of computational complexity of decision tree induction algorithm. As it was shown in the work [Han, 2001] time of decision tree induction algorithm running is estimated with value

$$O(p \times \#(D) \times \log(\#(D))) . \qquad (1)$$

Our goal was to check this result experimantally. Experiments were executed varying amount of attributes p. Decision trees were constructed for each value of p. In fig. 2 and 3 there are shown estimates of decision tree induction times due to (1).

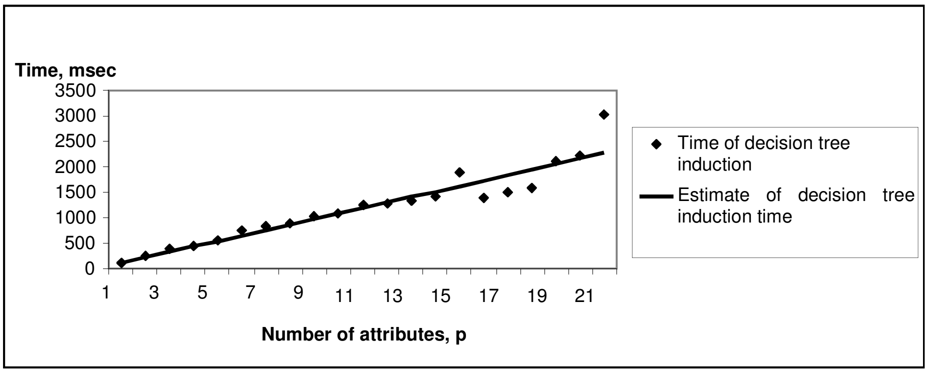

Figure 2. Estimate of algorithm complexity based on information gain

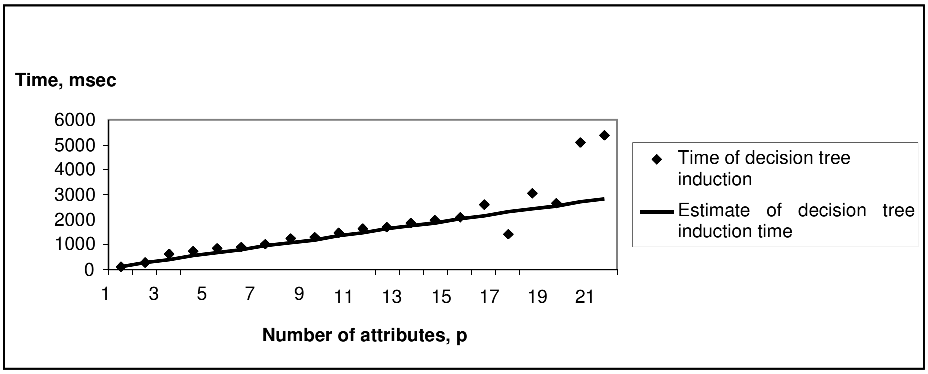

Figure 3. Estimate of complexity based on information gain ratio

Computational complexity of sequential covering algorithm. Due to analysis of sequential covering algorithm we conclude that computational complexity is determined by product of amount of possible values of class attribute K (quantity of external cycle iterations) and computational complexity of procedure *Mine_one_rule (D, Att_vals, c)* executed inside each cycle.

Procedure *Mine_one_rule (D, Att_vals, c)* includes execution of p iterations. For each iteration for a certain attribute A_i we calculate the measure $FOIL\_Gain$ for each of K_i values of attribute. That is internal body of cycle in procedure *Mine_one_rule (D, Att_vals, c)* is executed $\sum_{i=1}^{p} K_i$ times.

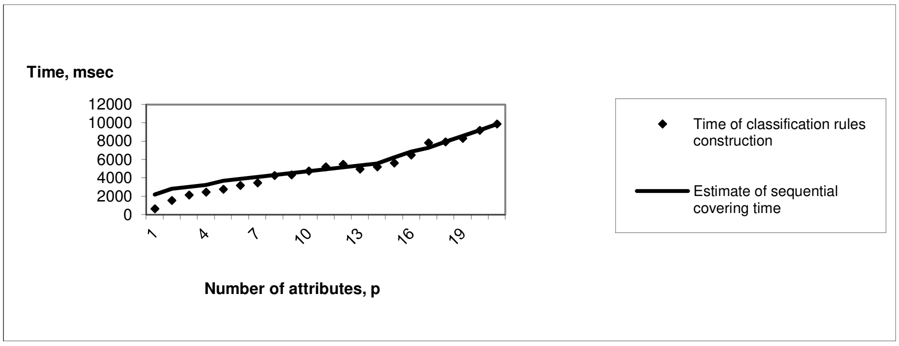

Figure 4. Estimate of complexity of sequential covering algorithm

The measure $FOIL\_Gain$ is executed as a result of 4 SQL-queries with complexity $O(\log(N))$ (according with MySQL 5.0 documentation). That is procedure *Mine_one_rule (D, Att_vals, c)* has computational complexity $O\left(\sum_{i=1}^{p} K_i \times \log(N)\right)$.

Summarizing we have sequential covering algorithm complexity of the order

$$O\left(K \times \sum_{i=1}^{p} K_i \times \log(N)\right). \qquad (2)$$

In fig. 4 there is shown estimates of sequential covering algorithm times due to (2).

3. Conclusions

So, even without considering probabilistic nature of the most of quantities and parameters we saw the complex qualitative behavior of diseases models depending on parameters and controllers. At different values of these quantities we observed subclinical, acute, chronic or lethal forms of pathologic processes.

Taking into account complexity of mathematical equations (nonlinear systems with delays) requires appearance of new powerfull methods of exact parameter identification and qualitative analysis.

From viewpoint of theoretical medicine uncertainties arising in models of diseases require to develop treatment schemes that are effective, take into account toxicity constraints, enable life quality, cost benefit.

In future works our idea is to compare behavior of pathologic processes using both deterministic and stochastic models and to extend such models to demographic processes.

In the work there is considered the problem of development and implementation of decision tree induction and sequential covering methods based on information indices for construction of diagnostic classification algorithm.

When investigating in this example the problem of computational complexity of decision tree induction algorithm it was observed that:

- decision tree induction time based on information indices is well approximated with estimate (1) at small number of attributes (in this case to 15-16);

- when increasing number of attributes (in this example over 15-16) the time of decision tree induction begins deviate essentially from estimate (1) independent on search of information measure;
- at small number of attributes decision trees induced constructed based on either information gain or information gain are identical; i.e., information measure determining splitting attribute doesn't affect on decision tree induced;
- computational complexity of sequential covering algorithm is well approximated by (2). Such estimate was checked changing an amount of attributes as well as number of learning tuples.

The perspective of this investigation is comparative performance analysis depending on volume of set of learning tuples.

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Artem AVRAMENKO[1], Sergey GOLUB [2]

CLASSIFICATION MODELS IN INFORMATION SYSTEMS FOR SOCIAL AND ENVIRONMENTAL CRISIS MONITORING

Abstract: New method for optimizing the structure of the crisis monitoring information systems is proposed. Reducing time of optimization achieved by classifying the input data arrays. Best algorithm of model synthesis is selected for each input data array. Effectiveness of the new method was experimentally confirmed. Time for restructuring of models reduced by 3-4 times. Errors of modelling is not significantly worse.

Keywords:crisis monitoring, multilevel modeling, system restructuring time,modelling error

MODELE KLASYFIKACJI SYSTEMÓW INFORMATYCZNYCH DO MONITORINGU KRYZYSÓW SPOŁECZNYCH I ŚRODOWISKA NATURALNEGO

Streszczenie: W pracy zaproponowano nowe metody optymalizacji struktury systemów informatycznych do monitoringu kryzysów. Osiągnięto redukcję czasu realizacji procesu optymalizacji poprzez zastosowania klasyfikacji wejściowych macierzy danych. Najlepszy algorytm syntezy został wybrany dla każdej z macierzy danych wejściowych. Efektywność nowej metody została potwierdzona eksperymentalnie. Czas restrukturyzacji modeli zmniejszono 3-4 razy. Błędy modelowania oceniono jako nie mające istotnego znaczenia.

Słowa kluczowe: monitoring kryzysów, modelowanie wielopoziomowe, czas restrukturyzacji systemu, błędy modelowania.

1. Setting the problem

Today, the use and development of monitoring systems is a crucial issue as research and practical application, because they can draw conclusions about certain events, while only based on previous data obtained by observation. Thus, such systems successfully used as diagnostic systems in various spheres of life.

The composition of the monitoring system is determined by the following factors: its functional purpose, scope and target set in the list of tasks, functions of information processing assigned for monitoring system and defined by user.

The main objective of the simulation monitoring systems is to provide information for decision-making. Information obtained by modeling the properties of an object based on monitoring data collected during the measurement numerical characteristics of the

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object. Decision-making in emergency situations imposes several restrictions on the technologies for information these processes.
Developments of emergencies usually are chain and dynamic process that causes sharp deterioration of an object that is catastrophic for this object and environment. The object usually is a set of areas and economic objects located there. All this means that decisions in these situations should be obtained as soon as possible. Also, poor predictability and dynamism of emergencies generates a large number of parameters for modeling, some of which may appear the first time that means greater possibility of error in pre-derived models.

2. Analysis of recent research and publications

There is a multi-data conversion technology that is implemented as an information system with hierarchical combination of multiparameter models [2]. These models can be implemented using inductive algorithms, neural networks, genetic algorithms and others.
In this system, the choice of best algorithm for synthesis of multiparameter model (ASM) implemented by successive trials and choice of the best by comparing their results [1].
Then the hierarchy constructs from synthesized models. Every level of the hierarchy is needed for solving the local problems of data conversion. In such hierarchical structures, large number of models can be combined, from fifty or more (Fig. 1).

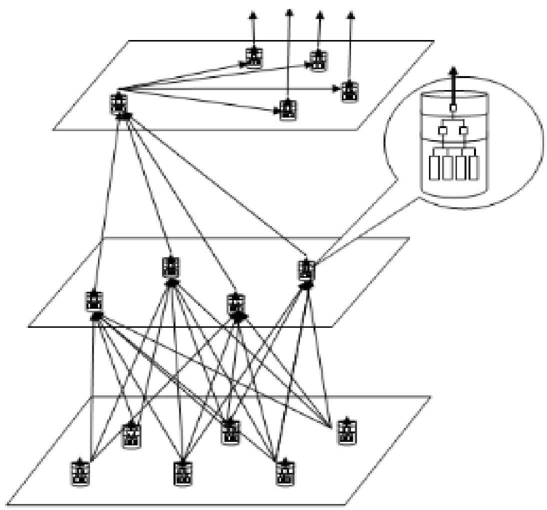

Figure 1. Structure of subsystem for information conversion

3. Pointing out the unsolved aspects of the problem

Since the object of our monitoring is emergencies then in the event when the properties of an IDA change and one of the models stops working, then "damaged" model and all models associated with it must be replaced by re-synthesized models. So, the whole system of fifty or more models need to re-learn.

This process takes a long time, about 40 minutes, depending on the number of models in the structure. In conditions of crisis monitoring where the justification for decision takes no more than 2-3 minutes and IDA properties change dynamically, therefore the situation of re-learning the whole system is pretty likely. This means there is a need to reduce the time of restructuring the hierarchy of models.

4. The aim of the article

As we concluded the main task is to ensure the reduction of time of re-learning the system while maintaining the quality parameters of the models.
In this paper is proposed to solve this problem by improving existing algorithm using classification of ASM to appropriate IDA instead of exhaustive search for ASM.

5. Results

To achieve this goal was formed the hypothesis that reducing the time of re-formation of the structure of the monitoring system can be achieved by solving the problem of recognition of best ASM from a predefined list for each IDA. Unlike sequential testing of each available ASM and selecting the best algorithm is proposed to construct a deciding rule to provide for each IDA the most suitable ASM.
Formulated hypothesis was tested experimentally. Solving rule was created by using multi GMDH algorithm [2]. Results of monitoring morbidity in Cherkasy region during 2000-2014 years [1] were used as IDA for synthesis of models. The process of model synthesis that contained morbidity dependent on the concentration of pollutants in water, air, food was studied in this work.
After analyzing modern methods of matrix and correlation analysis was formulated that the selection of algorithm for model synthesis is possible by pattern recognition technology based on the following table of informative parameters [3]:

- number of observations;
- number of independent variables;
- number of parameters that is strongly combined with the goal function;
- number of parameters not combined with the goal function;
- the average correlation coefficient of independent variables;
- the average correlation coefficient of independent variables and the goal function;
- the average determination coefficient of independent variables;
- the average determination coefficient of independent variables and the goal function;
- determinant of primary description table;
- determinant of the matrix normalized values of the independent variables;
- eigenvalue of the normalized table of primary description;
- eigenvalue of the matrix normalized values of the independent variables;
- maximum singular value of the normalized table of primary description;
- maximum singular value of the matrix normalized values of the independent variables.

A research tool was created based on this technology. It was used for a comparative analysis of the new method and the method of exhaustive search for ASM which is implemented in multi-level monitoring systems [2]. On fig. 2 shows the results of the analysis.

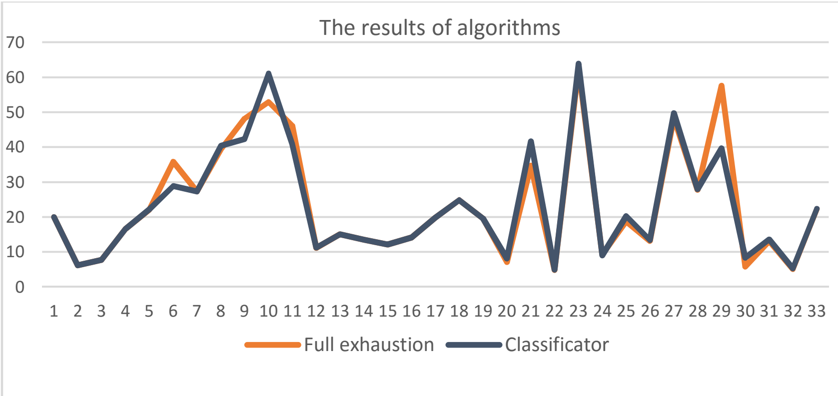

Figure 2. The results of comparing with classifier.

As a result of comparison of methods, synthesis time of model decreased by 3.5 times, with reducing errors of synthesis by an average of 1.37%.

6. Conclusions and suggestions

Growth modeling error is "payment" for reducing the time of model synthesis. Given the fact that the structure of the information system of multilevel data transformation contains 50 models and more, it is possible to achieve a significant reduction in the time structure by adapting to changes in the properties of IDA. In conditions of crisis monitoring these results give hope for the possibility of monitoring information systems with multi-data conversion technology for support decisions in emergencies localization.

Thus was proposed a new method of classifying arrays of input data in multi-level information systems for crisis monitoring. Reducing restructuring time of structure in multi-level information systems for problem solving of new problems in emergency situations is achieved by recognizing a better algorithm for synthesis of models with the rule that was created by the multi- GMDH algorithm.

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IDENTIFICATION OF VOTING ON THE PITCH FREQUENCY

Summary: Voice Recognition is an important advantage over many other methods of identification: it can be done remotely, by phone. In this article we were considered two methods: the method of acceleration based on the decomposition of the space of states and phonetic signs of a self-organizing map of Kohonen. Both algorithms are easy to implement, but have a number of features to speed up the method of calculation of a large order leads to a significant increase in the adoption of decisions, and Kohonen method solves the problem with the recognition speed as usual while the neural network is a few iterations. Even this parameter can be said that the method of Cohen better, since it solves the problem of speed.

Keywords: Steganography, voice, tone, modeling, methods.

IDENTYFIKACJA GŁOSOWA NA PODSTAWIE ANALIZY CZĘSTOTLIWOŚĆ

Streszczenie: Rozpoznawanie głosu posiada ważną zaletą w stosunku do wielu innych metod identyfikacji tzn. można jej dokonać zdalnie przez telefon. W niniejszym artykule rozpatrzono dwie metody: (i) przyspieszona metoda oparta na rozkładzie przestrzeni stanów oraz (ii) fonetycznych oznak z zastosowaniem samoorganizujących się map Kohonena. Oba algorytmy są łatwe do wykonania, mają wiele funkcji w celu przyspieszenia ich działania. Metoda pierwsza – obliczeniowej analizy dużego zbioru danych prowadzi do znacznego wzrostu czasu do momentu podejmowaniu decyzji, a metoda Kohonen rozwiązuje problem z szybkością rozpoznawania, gdyż gdy sieć neuronowa potrzebuje do tego tylko kilku iteracji. Na podstawie przeprowadzonych analiz można powiedzieć, że metoda Kohonena działa lepiej, ponieważ rozwiązuje problem prędkości.

Słowa kluczowe: steganografia, głos, ton, modelowanie, metody identyfikacji

1. Introduction

There are many methods of biometric identification of a person: the fingerprint, on the retina, DNA, blood, for heart palpitations, the structure of hair, etc. I would like

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to consider in more detail the identification of the person according to his voice. It is important that we use the method of identifying the voices did not depend on language, accent, dialect or content of speech of the speaker. Voice Recognition is an important advantage over many other methods of identification: it can be done remotely, by phone. This can be very important, for example, in the investigation of a crime when there is a guilty voice recording, which is then can be compared with the record of the suspect voice and on this basis, with high enough precision to draw a conclusion of guilt or, on the contrary, the suspect's innocence.

2. Features

The uniqueness of the human voice is due to a large number of physiological factors such as the structure of the vocal cords, the amount of light, the structure of the trachea, nasopharynx, dentition. However, at the moment it is impossible to exactly identify a person by his voice due to the imperfections of the sample itself voice recording system, the accuracy of which is adversely affected by many factors, such as:

- Recording medium (recording quality, resulting in a special room will be very different from the quality of entries received, for example, near the F / A relocation).
- Psycho-physiological state of the speaker (for example, we all know that in the event of severe nasal congestion with colds human voice is markedly different from the voice of a healthy person).
- Technical imperfection voice recording means (frequency filters installed in the microphone mute is too high or low frequency when encoding, which may lead to the fact that we hear in a completely different voice decoding).
- Interference in space also adversely affect the quality of the recording.
- To minimize the impact of the above factors, the following steps apply:
- Pre-recording processing (mute noise isolation announcers voice).
- Segmentation of Speakers.
- Allocation of biometric voice.
- Identification of speakers.

3. The recognition process

The recognition process is generally represented as a set of the following elements:

- sample preparation;
- feature extraction;
- creation of a model (template);
- comparison of the models;
- a decision.

It is known that the greatest value for recognition have voiced sounds. The sounds of this type are formed as follows: the flow of air from the lungs passes through the glottis, which periodically closes, producing sound pulses. Period at which pulses are produced is called the pitch period. Further spread of the pulse takes place through a series of cavities which have an impact on the frequency content of the resulting signal. The size and shape of the cavities of the vocal tract can be used as the individual characteristics of the human voice with the recognition.

4. The method of acceleration based on the decomposition of the space phonetic states

This method depends on the decision of the phonetic context, the transmission channel, and other factors. To overcome this shortcoming, it proposed a number of probability normalization methods.

The most widely used in recent years was a method called UBM (Universal Background Model), which is explained by his simplicity and the greatest accuracy in solving the problem of open speaker identification. The essence of this method lies in the introduction of another model of voice, which is trained using the speech of many speakers.

A Universal Background Model (UBM) is a model used in a biometric verification system to represent general, person independent feature characteristics to be compared against a model of person-specific feature characteristics when making an accept or reject decision. For example, in a speaker verification system , the UBM is a speaker-independent Gaussian Mixture Model (GMM) trained with speech samples from a large set of speakers to represent general speech characteristics. Using a speaker-specific GMM trained with speech samples from a particular enrolled speaker, a likelihood-ratio test for an unknown speech sample can be formed between the match score of the speaker-specific model and the UBM. The UBM may also be used when training the speaker-specific model by acting as a the prior model in MAP parameter estimation.

One disadvantage of this method is the fact that the calculation of high order result in a significant increase in the adoption of decisions.

Then, for each speaker, its Gaussian mixture is built in each subspace.

After each stage, the mixture is divided into the number of dependent sequences.

5. The self-organizing map of Kohonen signs

This algorithm has the ability to statistical averaging, ie, It solved the problem with the variability of speech. Like many other neural network algorithms, it provides parallel processing of information, ie, simultaneously work all the neurons. Thus, to solve the problem with the recognition speed - usually while the neural network is a few iterations.

Self-organizing maps can be used for tasks such as modeling, forecasting, search for patterns in large data sets, identifying sets of independent features and data compression.

The most common use of Kohonen networks - solution of the classification problem without a teacher, that is, clustering.

Recall that in this formulation of the problem we are given a set of objects, each of which is mapped to a table line (feature vector values). Requires initial set split into classes, ie, find for each object class to which it belongs.

As a result of new information about the classes, a correction of the existing rules of classification of objects.

Here are two of the most common applications of Kohonen maps: exploratory data analysis and discovery of new phenomena

The process consists of comparing samples of the following steps:
- Noise filtering;
- Spectral signal conversion;
- Postfiltration spectrum;
- Liftering;
- The imposition of the Kaiser window;
- Comparison.

The training algorithm adjusts network weights so as to produce consistent output vectors, t. E. To the presentation of sufficiently close input vectors produce the same outputs.

Perceptron trained, giving the set of images, one for input and adjusting his weight up until all the images are not the desired output is achieved. Assume that the input images are plotted on the map, display. Each map is divided into squares and each square on the perceptron supplied input. If there is a line in the box, then it is served by unit, otherwise zero. Many of the squares on the map sets, so the set of zeros and ones, which also served on the perceptron inputs. The goal is to teach perceptron include an indicator upon application of the plurality of inputs specifying an odd number and does not include the case of even.

For network training image of X is input and calculated output Y. If Y is correct, then nothing changes. However, if the output is wrong, the weight attached to the inputs of enhancing erroneous result, are modified to reduce the error.

6. Conclusions

Kohonen self-organizing map and signs of acceleration method based on the decomposition of the space phonetic states: In this paper, two methods have been considered.

Select these algorithms as they are both easy to implement, but different methods of application. Most modern speaker verification system use a UBM for modeling the alternative hypothesis in the likelihood ratio test. Type of learning, self-organizing map allows data to the training sample only hold values of the input variables. Kohonen network learns the data structure itself and solves the problem of clustering.

Both algorithms are easy to implement, but have a number of features to speed up the method of calculation of a large order leads to a significant increase in the adoption of decisions, and Kohonen method solves the problem with the recognition speed as usual while the neural network is a few iterations. Even this parameter can be said that the method of Cohen better, since it solves the problem of speed.

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USING RIVERBED MODELER FOR DDOS ATTACK SIMULATION

Summary: DDoS attacks are nothing new, they are still causing site outages to this day. In this paper, we address our approach to use Riverbed Modeler to simulate an FTP server's performance in a typical enterprise network under DDoS attack and provide some recent DDoS attack trends reports.

Keywords: DDoS attack, OPNET, discrete event system simulation

WYKORZYSTANIE PAKIETU RIVERBED DO SYMULACJI ATAKÓW DDOS

Streszczenie: Chociaż ataki typu DDoS nie są niczym nowym, mogą jednak spowodować odmowę usługi dla wielu stron internetowych. W artykule omówiono nowe podejście do zastosowania Riverbed Modeler pod kątem modelowania wydajności serwera FTP w typowej sieci firmowej pod atakiem DDoS. Zaprezentowano również informacje na temat wybranego symulatora sieci Riverbed Modeler.

Słowa kluczowe: atak DDoS, OPNET, system symulacji zdarzeń dyskretnych

1. Introduction

Distributed Denial of Service attacks are performed by attackers in different ways. The attack source can be a single host or advanced networked infrastructure (botnet). Botnet is a group of hijacked Internet-connected devices, each injected with malware used to control it from a remote location without the knowledge of the device's rightful owner.

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From the point of view of hackers, these botnet devices are computing resources that can be used for any type of malicious purposes—most commonly for spam or DDoS attacks [7]. Some latest research efforts on DDoS mitigation [2, 3, 5, 6].
DDoS attacks can be classified like that: Os level, Network device level, Application level, Protocol feature level, Data flood.
In above classification [4], Network Device Level attack is an exploit that takes advantage of a vulnerable device to gain access to a network or corrupt device functionality. OS Level attack uses OS vulnerability. Application Level attack finds application's vulnerability using port scanning. Data Flood attack overflows network or service with packets initiating incomplete connection requests that it can no longer process legitimate clients requests. The protocol feature attack uses some protocol's weak point such as the requirement of final acknowledgement from client by the server in TCP's three-way handshake. The remainder of this paper is organized as follows: Section 2 discusses the choice of network simulator used in this research. Section 3 presents the simulation analysis. Conclusion is made in the final section.

2. OPNET discreet network simulator

OPNET(Optimized Network Engineering Tool) is a sophisticated simulation tool with the specific purpose to construct, simulate, and evaluate communication network design (topologies with specific devices), configuration of network nodes, the transmission of packets through the network, and the use of different network protocols all from a performance point of view. In October 2012, OPNET became part of Riverbed. We use OPNET (Riverbed modeler academic edition 17.5) software for our simulation because this software has some advantages over similar software [8].
The general commercial simulators such as OPNET and Ns-2 are called hybrid simulators, since they combine both methodologies to provide a reasonable speed and, at the same time maintaining accuracy in the critical areas [1].
OPNET was developed by MIT. OPNET consists of four different editors:

- Network Editor: To Design Network Topology.
- Node Editor: Data Flow is defined here.
- Process Editor: Used for describing logic flows and behaviors.
- Parameter Editor: Seen as utility editor.

OPNET gives a graphical environment to the users for designing network topology which can simulate network authentically and then start collecting network information effectively and observe them. Another advantage of OPNET is the wide extent use of it and reliability of the output generated by it. OPNET software can inspect and process different intrusion techniques effectively. This software has been used in many research papers. One goal of our research is to find techniques that can be simulated in OPNET for large data files, including attacks and harassments in high speed.

3. Performance Evaluation

In this section, we simulate a common enterprise network setup under DDoS attack (network's FTP server is under application layer DDoS attack). The simulations are performed in OPNET. In our simulation we will simulate a Baseline scenario – a scenario of normal network functioning and a few attack scenarios.

3.1. Baseline Scenario

A baseline scenario is displayed in Fig. 1. In our network we have a FTP, Database and Web servers. We have a 100 Base-T LAN (Local Area Network) of 10 local users and they are all active. The LAN is connected to LAN router's Ethernet interface. Local users can use switch interface because the routing is not required to access the servers. LAN router is used to provide Ethernet interface to the local users LAN for connection purpose. In addition to this, we also have a 100 BaseT LAN of 5 remote users connected with the network through remote router „Router-1", the IP cloud (internet) and a firewall and they are all active.

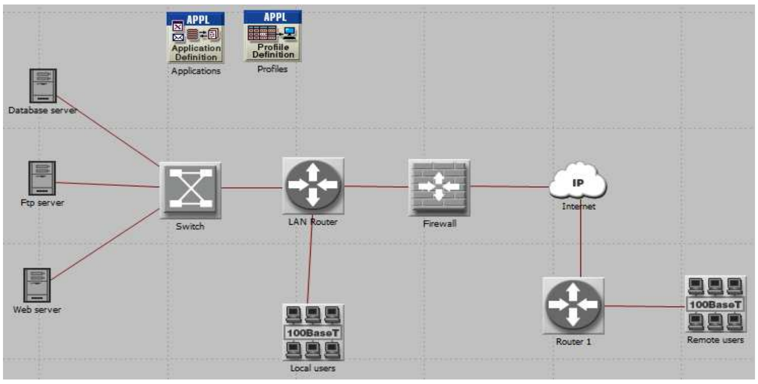

Figure 1. A baseline scenario of common enterprise network created in OPNET

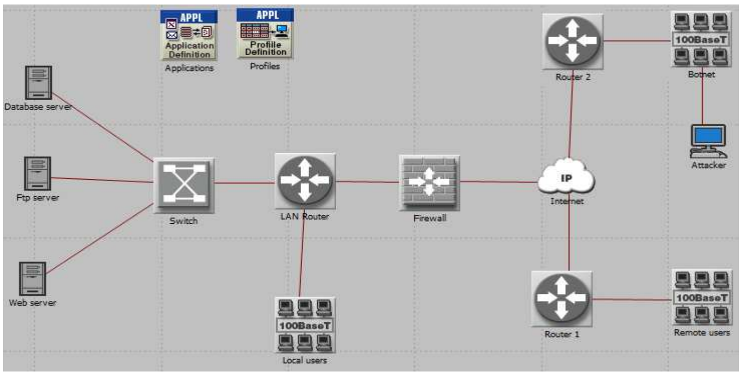

Figure 2. Attack scenario created in OPNET

3.2. Attack Scenario

In attack scenario, the network configuration stays the same as in baseline scenario. The difference is, we assume that an „Attacker" who controls a botnet succeeded to bypass the firewall of our network. It is out of the scope of this article how the attacker passed though the firewall. After that, the attacker launches DDoS attack on our FTP server. The attack scenario is shown in Fig. 2.

3.3. Simulation Results & Discussions

Usually the focus of network's behavior analyses under attack scenarios is on network traffic, its flow and aggregation. In our simulation, we decided to select a few additional performance metrics like some server side parameters to analyze the effect of DDoS attack on server performance and protocol delay (TCP delay). The following parameters are used:
1) CPU utilization and load (connection requests) on attacked FTP server.
2) Number of active TCP connections on the FTP server.
3) TCP delay on the FTP server.
4) Task processing time of FTP server.
5) Effect on all above parameters depending on the change of botnet size.
In our simulation we consider three botnet sizes with 50, 100 and 200 of "zombies" to observe how the botnet size change affects the other simulation parameters. The simulation time is set to one hour.

3.4. CPU Utilization (%)

We can see that CPU utilization on FTP server under baseline scenario is minimal, but it increases rapidly under attack scenario. Moreover, we have found that increasing botnet size has proportional effect on the CPU utilization. The reason is more traffic is sent by the attacker, more processing is required to process incoming requests by the server. As a result, server is unable to effectively respond the legitimate users requests. In our simulation, CPU utilization of FTP server has increased more than 300 times (percentage utilization) at peak value when the server is under DDoS attack with 200 zombies comparing to the baseline scenario.

3.5. Load on FTP Server (requests/sec)

From our simulation results we can see that load of FTP server is not highly loaded while being used by legitimate users during the baseline scenario. While under attack scenario, we observe a huge rise in FTP server load with increased connection requests. As we have concluded above that increased botnet size makes greater impact on server load. We observe that at peak value under attack scenario with 200 zombies the average load of 0.8 requests per second is received by the server comparing to 0.1 requests per second under baseline scenario, which is 8 times increase per second.

3.6. TCP Active Connection Counts & Delay (sec)

Similar to other parameters we can see that number of active connection under attack scenario increases greatly comparing to the baseline scenario. This parameter shows how the server is depleting it's resources in connection management of processing the attack traffic in result legitimate users will find a denial in connection establishment with the server. The peak value in our simulation results has 225 active connection counts on FTP server under DDoS attack with 200 zombies comparing to average value of 0.06 under baseline scenario. As with other parameters botnet size has it's influence on connection count load on the server. From Fig. 3, we can see TCP delay and find that the attack scenario causes additional transport layer delay at server's port which is about 25% more than the delay observed in baseline scenario. We observe that under attack scenario response of server becomes slow in its connection establishment & maintenance capacity. Moreover, increasing the botnet size has comparatively larger delay effect on the server in the simulated network.

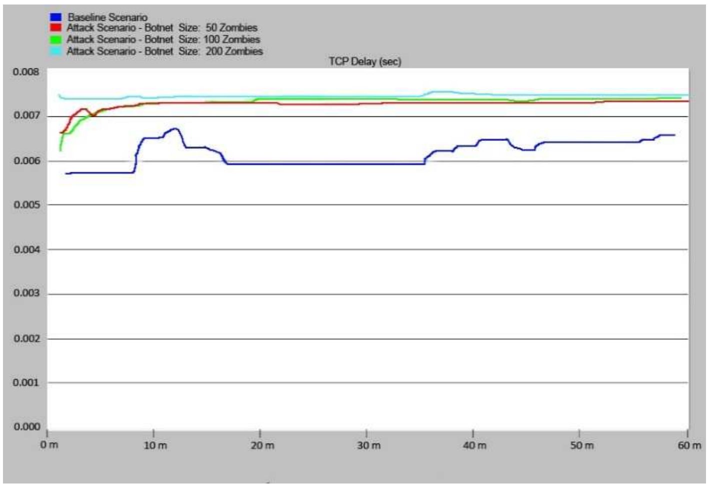

Figure 3. FTP Server – TCP Delay (sec)

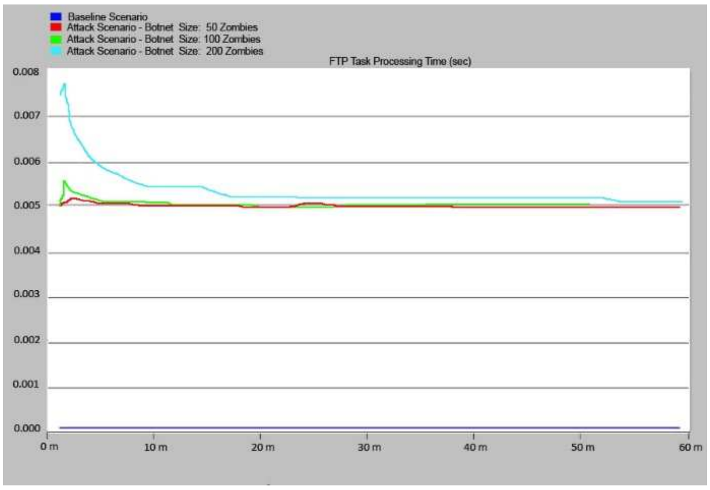

Figure 4. FTP Server – Task Processing Time (sec)

3.7. Task Processing Time (sec)

Task processing time of FTP server is displayed in Fig. 4. As with other parameters task processing time greatly increases under attack scenario comparing to baseline scenario. Average processing time (in seconds) per task is increased, degrading services for legitimate requests. Average task processing time increased 50 times under attack scenario comparing to baseline scenario.

4. Conclusion

In this paper, we provided a review on some common Distributed Denial of Service attacks classification. We also described some features of OPNET network simulator which was used for this research and introduced an approach to simulate performance analysis of an FTP server in scenario of an enterprise network under distributed denial of service attack. Simulations in OPNET showed noticeable variations in connection capacity, task processing and delay parameters of the attacked server as compared to the performance without attack. Our simulation results indicate that this approach is a feasible way to model DDoS attack given that it is hard to perform the same in a real network. We plan to continue our investigation of various DDoS attacks using Riverbed modeler to simulate more advanced attacks and defense techniques.

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WI-FI HONEYPOT JAKO SERWIS - KONCEPCJA MODELU BIZNESOWEGO

Streszczenie: Nowoczesne serwisy online dają swoim użytkownikom możliwość, aby zacząć ich użytkowanie bez żadnej dodatkowej wiedzy i dodatkowych wysiłków. W tym artykule przedstawiamy koncepcję serwisów, które mogą pomóc użytkownikom odkryć swój system WI-FI Honeypot oraz zarządzać jego elementami z dowolnego miejsca.

Słowa kluczowe: Wi-Fi, honeypot, serwis, chmura, infrastruktura

WI-FI HONEYPOT AS A SERVICE - CONCEPTION OF BUSINESS MODEL

Summary: Modern online services allows their users to start operate them without additional knowledge and extra efforts. In this article, we present conception of service that can help its user to deploy honeypot for Wi-Fi network and manage its elements from anywhere in the world.
Keywords: Wi-Fi, honeypot, service, sensor, cloud, infrastructure

1. Introduction

XaaS is a collective term said to stand for a number of things including "X as a service," "anything as a service" or "everything as a service." The acronym refers to an increasing number of services that are delivered over the Internet rather than provided locally or on-site. XaaS is the essence of cloud computing.
The most common examples of XaaS are Software as a Service (SaaS), Infrastructure as a Service (IaaS) and Platform as a Service (PaaS). Not so popular examples of XaaS include storage as a service (SaaS), communications as a service (CaaS), network as a service (NaaS) and monitoring as a service (MaaS), Security as a Service (SECaaS). SECaaS is a business model in which a large service provider integrates its security services into a corporate infrastructure on a subscription basis more cost effectively

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than most individuals or corporations can provide on their own, when total cost of ownership is considered. In this scenario, security is delivered as a service from the cloud, without requiring on-premises hardware avoiding substantial capital outlays. These security services often include authentication, antivirus, antimalware/spyware, intrusion detection, and security event management, among others [1-2].

In this article we are proposing new sub-conception of SECaaS which is called Wi-Fi Honeypot as a Service (WHaaS). WHaaS it an IoT based security service aimed at providing security of wireless range where defined wireless device works [3].

2. Elements of WHaaS

Minimal set of elements for WHaaS implementation includes:

- Wi-Fi Sensor,
- VPN Server,
- Database (DB),
- Command Node,
- Application Server.

Wi-Fi Sensor can be any computer that have integrated or supports external Wi-Fi card. In this research paper we decided to use single board computer such as Raspberry Pi. Single board computers have enough resources to install such operating systems as Windows or Linux and do not have redundant resources on board. 3th generation of Raspberry Pi has integrated Wi-Fi and Bluetooth modules and therefore there is no need in additional external devices [4].

Using VPN Server (bastion) we can provide communication between cloud infrastructure elements that are located in private subnet and sensors that have no public IP addresses. It might be free of charge software like OpenVPN. [6]

DB is deployed inside the cloud in private subnet. This approach helps to provide security to processed data.

Command Node is machine that can access sensors via SSH protocol. It provides possibility to install or update software on sensors automatically or execute command manually. There is a big number of configuration management software that can provide such service e.g. Ansible, Chef or Puppet [7-9]. Also, script might be generated accordingly to operation system that is installed on particular external element.

Application Service is environment with application which processes data from DB and transmits it to web UI where users can view them.

It is good to have possibility to analyze traffic from existing users. However, usually wireless routers do not fulfil any other role except providing access to a certain network resource. Installation of any additional software on wireless routers is often impossible due to architecture incompatibility or insufficient amount of memory. This issue might be solved by using any computer which has wireless adapter instead of Wi-Fi router. Such service can also be provided by separated machine which can gather and analyze input and output data from router. Besides, this element can register presence or absence of particular users in particular point of time and analyze their traffic [5].

But, using personal computers or servers is not efficient due to their large size, high price and computing resources redundancy. An exception to this case may be single-board computers, for example Raspberry Pi [10].
Single-board computers are well known for their cheapness and portability. They are not characterized by high resources capacity which quite often may be excessive.
Since single-board Raspberry Pi allows to deploy Windows or Linux on board what means that this type of device might run software developed on different programming languages. Integrated Ethernet and Wi-Fi adapters that are present in Raspberry Pi might be used as a set of instruments for routing or radio data collection.

3. Communication between sensors and database

In order to provide communication between sensors that might be connected to different physical network they should have some joint network resource. It is possible to create such resource using VPN technology.
After connection to VPN server sensors have possibility to connect to any element from cloud and vice versa.
Beign placed in the same network with DB sensors transmit gathered data about Wi-Fi devices to DB (Fig. 1).
Sensors provide continuous data gathering. When time defined by user is out sensor transmits data to database. Gathered data will be removed from sensors memory and process of discovering will start again. If data is already in database then insertion will be skipped.
There is a possibility that for some reason sensor can be disconnected from network or Internet connection can be lost. In this case sensor should write data to reserve DB. Example of such DB can be SQLite DB. SQLite provides similar syntax to MySQL but data is writen not to server but to *.sql file. Once connection is restored sensor will merge sql file with remote DB server.

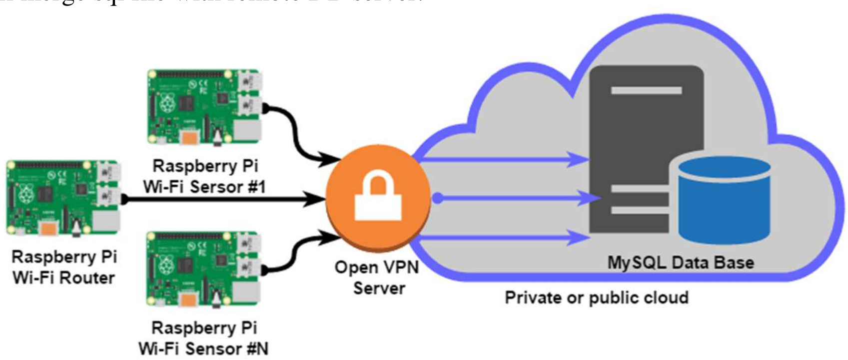

Figure 1. Data transitions from sensors to database

4. Interuction with user

Any XaaS must have user interface (UI) for data presenting and service management in general.

In order to get access to gathered and processed data from outside user should connect to web page which selects data from DB (Fig. 2). Based on data from DB that is continuously provided by sensors backend makes conclusions about attackers' presence or absence. Also, sensors provide information about attacks on determined client devices or access points.

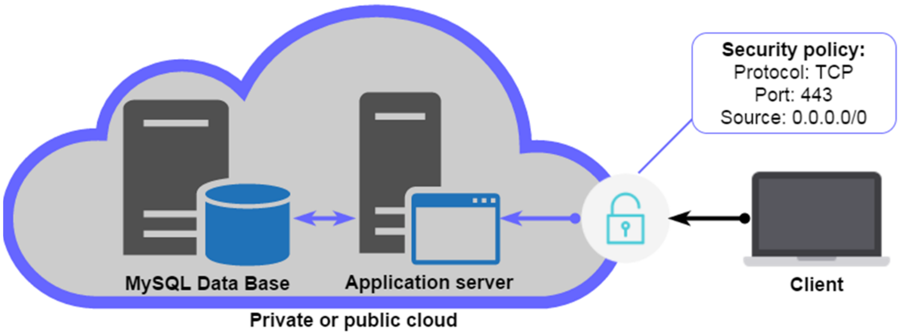

Figure 2. Access to data by user via web

Presentation of most important information on one page became a tendency of today's cloud providers. The most useful data for WHaaS's user can be (Fig. 3):
- Number of devices that were identified.
- Signal strength of monitored APs.
- Detected attacks.
- Result of external health checks.

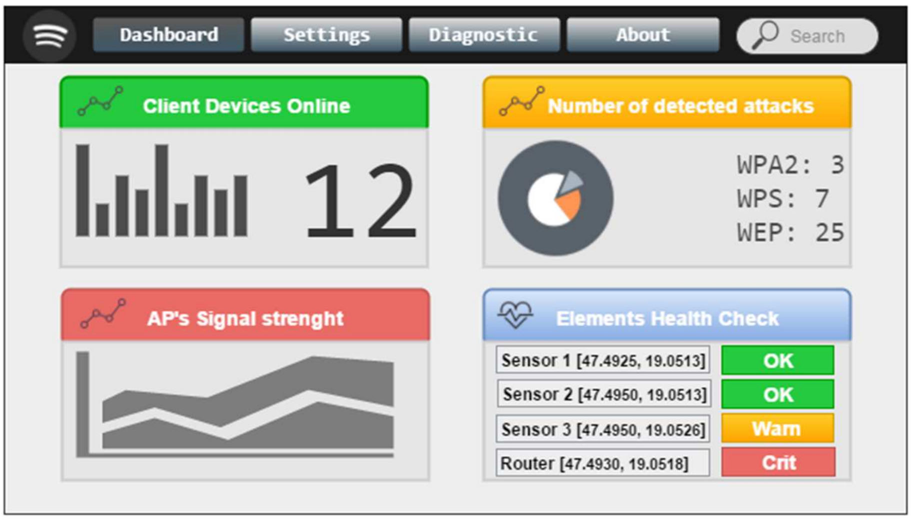

Figure 3. Web UI of WHaaS. Dashboard

Although external elements of honeypot are configured automatically user should have possibility to make their own adjustments. Furthermore there should be possibility to view detailed monitoring (Fig. 4).

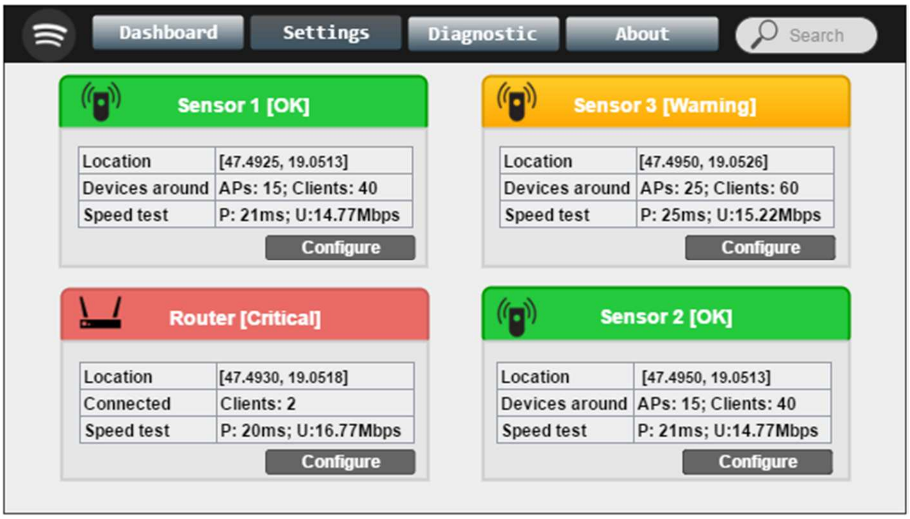

Figure 4. Web UI of WHaaS. Setting page

In order to apply settings manually user should connect to web UI and choose needed settings. After pressing configuration button list of changes will be delivered to command server where script with changes will be generated. Script is transmited to chosen external element (Fig. 5).

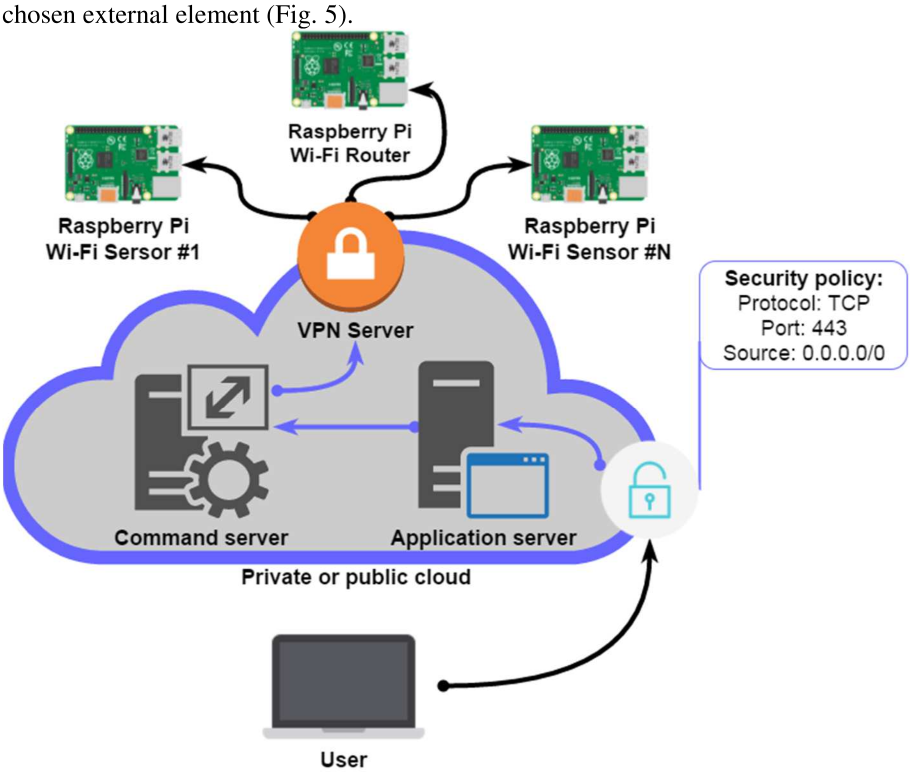

Figure 5. Process of settings applying

5. Conclusions

Currently cloud technologies are in continuous development. Many popular services are transferred from desktop to cloud.

Concept of WHaaS business model has been introduced in this article. This service can provide monitoring of one or more APs or Wi-Fi mobile devices that in their turn will take role of honeypots.

This approach provides up and running service, which can help users to activate and manage Wi-Fi honeypot without extra efforts.

Launching of honeypots especially for wireless networks is not so popular in today's realities, but implementation of such system probably will make them much more popular.

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OPRACOWANIE TECHNOLOGII DO ANALIZY SEMANTYKI TREŚCI

Streszczenie: Wykorzystanie elementu emocjonalnego poprawia efektywność wpływu na podświadomość. Obecnie, zmiana kierunku sugestywnej informacji stała powszechnie stosowana w konfrontacji informacyjno-psychologicznej. W tym celu, przez autorów opracowano technologię analizy semantycznej tekstowego komponentu. Technologia ta bazowana jest na kombinacji statystycznego i fonetycznego podejść do analizy treści danych. Istniejący system elektroniczny daje możliwość implementacji opracowanej technologii.

Słowa kluczowe: analiza dokumentów, analiza informacyjno-psychologiczna, analiza treści.

DEVELOPMENT OF TECHNOLOGY ANALYSIS FOR THE CONTENT SEMANTICS

Summary: Using emotional component improves the efficiency of influence on the human subconscious. So now change the direction of suggestive information gained a wide application in the information-psychological confrontation. For this purpose, authors developed the technology of semantic analysis of the text component. The technology is based on a combination of statistical and phonetic approach to the data contents analysis. The existing electronic system allows implementing the developed technology.

Keywords: document analysis, information-psychological analysis, analysis of content.

1. Formulation of the problem

Search methods, analysis, drafting and formation of texts (information) are presented very widely. However, the system that implements these methods are not always suitable for conducting information-psychological confrontation.

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A lot of implemented systems used to analyze the formation and texts from specified parameters impact which oriented on Russian texts are narrow. Another drawback of most of these systems is the lack of descriptions of their mathematical basis and the governments of most states ban on the export of the products in full.
That is why it is necessary to create their own information and analysis systems. Any system is good only when they have good mathematics and software and hardware from which it is composed, and the staff that it serves.

2. Analysis of recent research and publications

There are several approaches to the analysis of the text in a document or document library [1-4]. They discussed approaches to the implementation of an automated process of quasi-referencing of electronic documents and forming a plurality of keywords in information-search systems based on using analysis of the text semantic structure and its logical segmentation.
Software catalog and resource analysis and linguistic word processing on the Internet are presented in [5]. The most common system VAAL [6] and TextAnalyst.
The system VAAL (http://www.vaal.ru) allows predicting the effect of unconscious influence of texts to a mass audience, analyzing texts from the point of view of the impact, to make the text with a given vector of influence and identify individual psychological qualities lyricist.
The TextAnalyst system (http://www.analyst.ru) allows us to build a semantic network of concepts selected in the treated text with links to context. Present function of semantic search text fragments based on latent semantic relationships in the text of your search terms. It allows us to analyze the text by constructing a hierarchical tree of topics/subtopics, which affect the text. Also, there is an abstracting the text.

3. Problem definition

Suggest an integrated document analysis method, which allows selecting in text documents complete sections of text which correspond determined topics and select key components allocation suggestive of directional text.

4. Statement of the main material

The document as a whole is seen as a sequence of words that can be grouped into sentences, paragraphs and sections. Sometimes it is possible to identify the main parts: the header (title), annotation, analysis of literature's office, the purpose, the majority (consisting of sections), references and others.
There are several approaches to the analysis of text documents.
The using only a statistical approach to analyze the contents of the document allows you to create information about the structure of the text only by analyzing the frequency of words occurrence in the text. The "central" word domain, which is

found in the text at least a specified number of times, will be referred to the set of keywords.

In contrast, the methods of semantic orientations convertible at identifying the content (subject matter) of the text, its thematic focus and the determination of relationships between the individual elements of the text and the text as a whole. In this case, if the structure of two sentences (paragraphs) have the same keywords or words with the same meaning then these sentences (paragraphs) will be considered semantically coherent.

Linguistic approaches (based on the syntactic and morphological methods) allow bringing the text document to word forms dictionary.

Phonetic analysis methods allow you defined orientation suggestive lyrics.

Content analysis reveals the frequency of text occurrence specified characteristics which interest the researcher and allow him to make some conclusions about the intentions of the creator of the text or the possible reactions of the recipient.

Using a set of these methods allow selecting in text document completed sections of text that meet certain topics and to provide them with the release of the key components of the orientation of suggestive text as a whole and its main part.

Algorithm for complex document analysis is shown in figure 1. Consider its common stages.

First, selection of document analysis and open it. The document is converted into a convenient form. At first the document choice for the analysis and opening. The document is converted into a convenient form.

The statistical analysis of the document - a quantitative count of words, letters, sentences, lines, paragraphs, pages, sections, figures, tables, list of references, and so on.

After a preliminary analysis of documents are conducted downloading dictionaries.

For the analysis of texts is desirable (and in some cases also necessary) using a set of specially trained dictionaries. To ensure the best quality of analysis should provide an opportunity for self-adjustment of the subject area. Setting dictionaries allow filtered layered not the interesting information in the text and opposite, to provide an important part of it.

Each dictionary should contain three main sections:

-deleted words - contains words that are simply removed from the text in the analysis. In most words that are removed include prepositions, adverbs, numerals, and some adjectives that generally do not carry useful information. In addition, their removal does not affect the grammatical structure of sentences;

- wide-used words - contains words that are not removed in the analysis as separate concepts. Basically these are the words of a total value not represent self-interest for the analysis of the material text, the low-informative;

- special words - words containing the domain. In this section, it is desirable to identify words that are of greatest interest to the user.

During using vocabulary from the analysis of text documents filters deleted and wide-used words, and all other special finds words researched text, which is formed on the basis of key concepts.

Figure 1. Algorithm for complex document analysis

As key concepts selects:
- domain-specific words and their ratios ended, including wide-used words encountered in the text at least a given number of times;
- word-benefits that met in the text at least once and their completed connections, including special and wide-used words that met in the text at least a given number of times.

Limit of the occurrences frequency that used for the selection of concepts is determined by the amount of the processed text.

To bring the various forms to the total (normalization) can be used in two ways: automatic allocation root base and full transfer of word forms. In the first, simpler case, rather present in the dictionary one (arbitrary) form of words. In an analysis of all the other forms that have the same root are considered equivalent. In the second, more difficult, but sometimes necessary case if all word forms are given in the form of a list, which shall be deemed equivalent to the analysis of the text.

Then calculates the weighted coefficients of keywords. Weighting factor ϖ_t of keyword $t \in S$ is calculated as the ratio of sentences of text documents in which the word (concept) occurs, to the total number of text sentences:

$$\varpi_t = \frac{N_t}{c}, \tag{1}$$

where N_t – number of sentences of the text document, which meets keyword (term) t;

c – the total number of text sentences.

Determination of orientation phonetic keyword conducted to determine the load keywords suggestive on human`s perceptions.

Defining the subject of the text. The subject text of the document can be determined by comparing the keywords $t \in S$ of text document (including their weights ϖ_t) with the keywords that can be assigned to one of the subjects.

After selecting a topic it may specify by determining the semantic relation keywords of this subject, keywords of text document and name of the document (if available).

Determination of compatible components adjacent sentences in the text. Common elements of two adjacent sets of sentences are defined as follows:

$$S_{ij} = P_i \cap P_j, \ j = i+1, \ i = \overline{1,c}, \tag{2}$$

where P_i, P_j – set of special words of sentences i, j -accordingly,

c - total number of text sentences,

S_{ij} – set consisting of the same elements P_i and P_j of the set.

Definition of semantic connections between sentences. The degree of semantic relation sentence with the following sentence j equals the number of elements of the set S_{ij}.

Logical segmentation of text. When the text refers to logically segment without crossing segments of text (sentences, paragraphs or plural), each of which it goes about any characteristic of that information.

To determine the degree of "saturation" of logical segments of text information, which is typical for them, we introduce a linear coefficient U_i - parameter that characterizes the average degree of semantic coherence of i -sentence with n sentences that lie ahead:

$$U_i = \frac{1}{n}\sum_{w=1}^{n} | S_{i-w,j-w} |,\ j = i+1,\ i = \overline{1,c}, \tag{3}$$

where n – number of sentences of the text segment preceding i -th sentence;

$|S_{i-w,j-w}|$ – the degree of semantic connection $(i-w)$ sentence between $(j-w)$ sentence.

The beginning of a new segment $f_k \in F$ in the text, and subsequently the boundary between segments, we assume a reduction of linear factor of the current sentence, compared with a linear coefficient U_i of the preceding sentence i, provided that between the current sentence i and the following sentence j is no semantic relationship:

$$f_k : U_i < U_{i-1},\ | S_{ij} | = 0. \tag{4}$$

Otherwise, the segment continues to sentences in which semantic link with the previous sentence is missing.

Definition connectivity keywords with segments of text in which they fall is determined to calculate the semantic weight L_t of word $t \in S_k$ that describes the number of segments sentences semantically related word t:

$$L_t = \sum_{i=1}^{t} P_i \cap t - 1,\ t \in S_k, \tag{5}$$

where t – element of the set S_k of keywords text document.

Definition connectivity segment text from a single keyword. Degree of semantic communication segments of text with a keyword-level equals number of elements of the set S_k of common components (words) sets specific segments $F_k \in F$ of words with one keyword, which is defined by the following way:

$$S_k = F_i \cap ... \cap F_j,\ i \neq j,\ k = \overline{1,l}, \tag{6}$$

where F_i, F_j – set of special words segments i, j respectively, which contain the same keyword,

l – number of proposals for all segments of a keyword,

S_k – set consisting of the same elements F_i and F_j of the set.

Downloading table with "positive-negative" words. Tables "positive-negative" words are using to identify areas of the text with the same set of words belonging to the same group of terms. Name the tables are provisional and subject to change.

The definition set of words that got in the "negative" and "positive" group. Determine the set Y consisting of words, what are caught in a "positive" group and set Z - with words, what are caught in the "negative" group.
Evaluation content of the text is defined as the ratio of sentences of text documents in which there are the words from "negative" ("positive") sets the total number of sentences of text

$$v = \frac{H}{c}, \tag{7}$$

where H – number of sentences of text documents in which the word is found with a "positive" Y ("negative" Z) sets;

c – the total number of text sentences.

Creating abstracts of keywords. Performed for each keyword (concept) by selecting all the text of the document sentences in which it occurs.
In some cases, the abstract may be included and whole paragraphs (segments) of the text, if this keyword is connected.
Creation of reports with "positive-negative" words. Is based on the selection of sentences (paragraphs segments) of text documents, which contain the same key components of the sets of "positive" ("negative") words corresponding tables (dictionaries).
Analysis of phonetic meaning of the text document. Phonetic analysis of texts based on the analysis of alphabetic writing based on soft consonants. The text as it is presented in the voice-letter form.
Definition phonetic value of the text segments is carried out to tracing the dynamics of change of loading suggestive on the human perception and definition of phonetic stress on different parts of the text.
It is held at logic with obtained by logical segmenting of text segments or by splitting the text into document-level segments (usually at least 10).
Definition phonetic orientated abstracts keyword conducted to tracing suggestive loading on the human perception text segments with similar keywords.
Definition phonetic orientated reports with "positive-negative" words is held to tracing suggestive loading on the human perception of text segments into pieces that are constructed with the use of the words "positive" and "negative" groups.
Definition sound-color matching text. A peculiar aspect of the symbolism of speech sounds is the sound color matching. They have the purely synesthetic basis and apply only to certain sounds.
The clearest sound color matching can be traced mainly to Russian vowels: e, o, yi, u, i, a.
We see that most clearly in solid colors painted three sounds: a - bright red, i - blue, o - light yellow. These three colors in the spectrum are essential in the sense that by mixing them in different proportions you can get all the other colors and shades.
Definition sound color matching text document is conducted by counting the vowel letters. The text of the document takes coloring dominant vowel letters. Dominance is determined by the excess number of vowel letters above the threshold. Typically, the threshold is defined as 80-90% of maximum.
Definition sound color matching segments text document is held to tracing the dynamics of change in coloring of the text and identify sound-color stress on different

parts of the text. It is held at logic obtained by segmenting of text segments or by splitting the text into document-level segments (usually at least 10).
Download dictionaries with neuron-linguistic programming (NLP). To determine the orientation of NLP (load) of text designed (or developed) dictionary words, which are typical for people with a variety developed perception. As such dictionaries are the words to the dictionaries audial, visual, kinesthetics.
Definition NLP load on the text of the document is made by counting the number of words that fall into different groups. View NLP loading is matched group which hit the maximum number of words.
In addition for visual determination of loading carried counting the number of graphics (pictures). Their quality is measured visually or by using special techniques. Other analysis. For example, conducting the motivational analysis "Aspiration K" - "Getting away from."
Definition of topics intersection in the text of the document is made possible by identifying additional subjects excluding keywords that relate only to the main topic of the document that has been defined before.
After completing the analysis of the document text is made to bring it in its original form or closing.
The analysis results are entered into a database and can be used for further work and/or corrections medium (normal) estimates attribute scales and dictionaries for all types of analysis.
The report is created for all types of analysis in graphical and text form.

5. Conclusions

The methods of complex analysis document, which allows us to select text in a document completed sections of text that meet certain topics and to provide them with the release of the orientations key components for suggestive text is offered. In terms of features meet modern requirements of the corporate electronic document and can be widely used in various fields.

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MEDODY KOMPRESJI DANYCH W ZARZĄDZANIU SYTUACJAMI KRYZYSOWYMI W AWIACJI

Streszczenie: W niniejszej pracy opisano metody kompresji oraz dekompresji danych video. Dyskutowane metody zapewniają maksymalną kompresję krytycznych danych video (we wierszach) na określonych poziomach jakości w odniesieniu do cyfrowych obrazów video. Praca opisuje rozwój metod ulepszenia technologii kompresji obrazów video w oparciu o redukcję poszczególnych struktur cyfrowych w warunkach ograniczonego pogorszenia jakości wizualizacji.

Słowa kluczowe: sytuacje kryzysowe, dron, dane video, kompresja obrazu, redundancja strukturalna, redundancja psycho-wizualna sytuacje kryzysowe, dron, dane video, kompresja obrazu, redundancja strukturalna, redundancja psycho-wizualna

VIDEO DATA COMPRESSION METHODS IN THE AVIATION CRISIS MANAGEMENT

Streszczenie: The methods of compression and decompression of video data was described. These methods ensure the maximum compression of critical video data rows at specified levels of the digital video image quality. Method of improved of video compression technology based on the reduction of a particular digital structure under the conditions of a limited decrease in the quality of visualization was developed.

Słowa kluczowe: crisis situations, drone, video data, image compression, structural redundancy, psycho-visual redundancy

1. Introduction

The global aviation security system is associated with the growing significance of modern information technologies and system of information support and decision

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making in crisis situations. The development of aviation security centers is based on the implementation of video data received in standard and crisis situations (O'Regan, 2011).

It is clear that the volumes of video data significantly increase at present. That is why an effective scientific method is demanded regarding the management of aviation security centers. This method can ensure effective collection, processing, transmitting, and recognition of critical data in the form adapted (simplified) for managers performing their functions in the area of aviation.

To achieve these goals, it is necessary to carry out the communication between aviation security centers and satellites located over a particular area, and to process the information obtained with the help of aerospace monitoring systems in order to ensure security and effective functioning of aviation in crisis situation. To effectively operate, modern aviation security centers should include subsystems of storage, transmitting, processing, and analysis of video data of different types.

The main purpose of these centers is to monitor the current state of an object on the basis of the analysis of data which verify depending on external and internal factors; to support effective information exchange and data visualization; to analyze perspectives for the development of the objects under observation depending on external and internal hazards; to determine the possibility of crisis situations, destabilizing factors, and quick response to incidents.

Therefore, the objective is to organize appropriate video data support in order to obtain clarified data in the form acceptable for efficient analysis and decision making.

To reduce the time of receiving and analysis of data, it is necessary to ensure the required quality of visualization.

Nowadays, the modern data compression methods are used to reduce the volumes of video data. The characteristics of data compression methods are not sufficient for the video data analysis which is performed in real time in compliance with the appropriate quality (Blelloch, 2013).

The objective of research is to develop video data compression methods at the required level of visualization.

2. Theoretical research

In the modern conditions, the character of data is not permanent and the rows of data verify in crisis situations. The requirements become stricter pertaining to the acceptance of decision made on the basis of video data of high quality.

When analyzing the dynamics of the process, it is clear that the decisions in crisis situations connected with risks of unlawful interference with civil aviation should be accurate.

Ignoring this approach can lead to the consequences of insufficient decisions made by managers and cause global human casualties and expenses in civil aviation.

Analytical aviation security centers for crisis management ought to have communication with the groups of satellites located over a particular area and to process data received from means of aerospace monitoring in order to ensure effective functioning of crisis management personnel. Figure 1 shows the process of providing analytical crisis centers with video data.

According to Figure 1, wire and wireless communication channels are used to provide interconnection. If video data consisting of images of high resolution are transmitted, the period of data delivering is multiplied by several times due to the fact that existing rates of data transmitting are at least ten times lower than the required rates of video traffic transmission. It is recommended to decrease the volumes of images which are transmitted to crisis management centers, using the improved methods of data compression.

While developing video data compression methods, it is necessary to exclude uncontrollable decrease in the quality of restored images. This decrease is caused by both the reduction of psycho-visual redundancy and insufficient professional data selection to characterize structural components at the phases of data transformation. It should be noted that the time of data analysis ought to be reduced during the processes of forward and inverse transformation at the phases of preliminary data analysis and coding which are performed to reduce the spatial redundancy.

It is appropriate to reduce psycho-visual redundancy at the initial stage of video data compression. At this stage, transformed images are obtained taking into account the following features of human visual perception: high sensitivity to bright images, low sensitivity to color components, extremely high sensitivity to objects located in the area of low frequency, and extremely low sensitivity to the distortion of objects operating in the high frequency range.

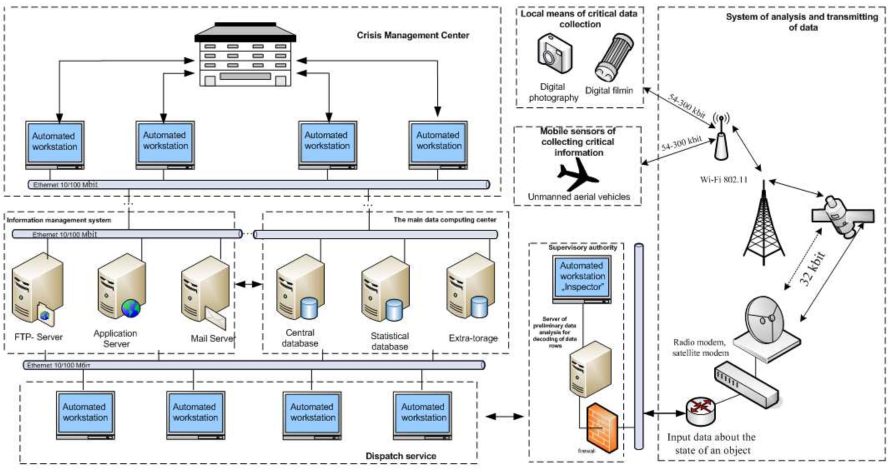

Figure 1. Structural scheme of information received by analytical crisis management centers

Psycho-visual redundancy has two features, in particular transformation of triple-colored images into the signal used in video systems to convey the color information of the picture, and two-dimensional discrete cosine transformation (DCT). As a result, three components are formed. The main one of them is brightness which is considered to have the greatest significance for visualization. The rest are additional monochrome components. The initial RGB image is transformed into a YUV color space. This transformation results in the appearance of three components with identical sizes in vertical and horizontal areas.

Owing to the ability of the basic function core to divide, the discrete cosine transformation is carried out in two phases. At phase 1, one-dimensional DCT is conducted for the matrix columns of obtained images. As a result, the formation of one-dimensional DCT transforms is constructed (Yudin, 2014).

DCT allows to achieve the re-transformation of output signal energy and to obtain the areas which are filled with compressed data on transformed images depending on the quality of visualization. This fact makes it possible to eliminate psycho-visual redundancy.

The proposed data compression method consists of six phases which are as follows:

Phase 1. Transformation of RGB image into a YUV color space.

Phase 2. Discrete cosine transformation (DCT) is performed in two stages. At the first stage the one-dimensional DCT column array of source image. Resulting in a one-dimensional array $Z'(\xi,\chi)$ of DCT transformant $Z'(\xi,\chi) = F(\xi)\ X(i,j)_{\xi,\chi}$, where $X(i,j)_{\xi,\chi}$ - array of video output image; ξ, χ - index row and column array element $X(i,j)_{\xi,\chi}$, $\xi = \overline{1,m}$; $\chi = \overline{1,n}$.

$$Z'(\xi,\chi) = \sqrt{\frac{2}{m}} \sum_{\xi=1}^{m} X_{\xi,\chi}^{(i,j)} \cos\frac{(2m+1)\xi\pi}{2m}, \quad \xi = \overline{2,m} \tag{1}$$

The second stage is performed for DCT-dimensional array of rows $Z'(\xi,\chi)$. Resulting in a transformant $Z''(\xi,\chi)$ two-dimensional DCT, that is $Z''(\xi,\chi) = Z'(\xi,\chi)\,F(\chi)^{(-1)}$, where $F(\chi)^{(-1)}$ - transposed vector of discrete values of DCT basis functions.

Phase 3. Implementation of binary form. Owing to the binary form of quantum transform elements, the features of zero areas location is considered, in particular the sizes of zero element areas for different positions of transforms in the binary form.

Phase 4. Formation of series of binary elements. This process is carried out to obtain bit areas. This process allows to construct series of zero elements.

$$A_\nu = \begin{cases} A_{\nu,k} = \{\nu_{1,k},\dots,\nu_{S,k}\}, \rightarrow k \le K-1 \\ A_{\nu,K} = \{\nu_{1,K},\dots,\nu_{S_K,K}\}, \rightarrow k = K \end{cases} \tag{2}$$

Phase 5. Adaptive coding of positional numbers formed for the columns of segments of binary elements. These columns are described as follows: $A_\nu^{(k)} = \{\nu_{s+(k-1)S,k}\}$

$$C(p)_k = \sum_{s=1}^{S'} \nu_{s+(k-1)S,k}\ p^{S'-s}, \text{ where } p = \max_{1\le s\le S}\{p_s\} \tag{3}$$

Adaptive coding ensures the simultaneous reduction of additional data and the exclusion of uncontrollable information loss at the transformation phases of the binary form and the formation of a compressed transform expressed with the help of code words. Besides, the size of a code word can be determined only once for the first column of the formation of binary element segments after the calculation of the code of after positional number, using one multiplying operation only.

Phase 6. Construction of a compressed transform pattern on the basis of the sequence of code words containing data on the code of positional numbers.

To ensure the specified quality of image the visualization of images obtained as the outcome of decompression, it is necessary to exclude the following:

Uncontrollable information loss as the outcome of both the inaccurate determination of the endings of code words containing the values of positional number codes, and inaccurate positioning of patterns of adjacent transforms;

Errors in calculating of binary element series which contain the main data on transform components, including low frequency components of the spectral form.

The developed decompression method consists of the following phases:

Phase 1. Determination of the characteristics of compressed form patterns of data series. This phase includes the process of coding renewable transforms in compressed images and constructing the series of code words V_c to calculate codes $C(p)_k$ of adaptive one-based numbers.

Phase 2. Restoration of elements $A_\nu = \{A_\nu^{(k)}\}$ and the series of binary elements by means of adaptive coding.

Phase 3. Formation of the absolute values of DCT transform components, using the polynomial value.

$$z_{\xi,\chi} = w(d-1)_{\xi,\chi}\, 2^{d-1} + \ldots + \; w(0)_{\xi,\chi} \tag{4}$$

Phase 4. Two-dimensional inverse DCT. Taking into consideration that $z'''_{\xi,\chi} \neq z''_{\xi,\chi}$, the restoration of values $x'_{i,j}$ can differ from the obtained value $x_{i,j}$ of video data series $X(i,j)$. This leads us to conclude that $x'_{i,j} \neq x_{i,j}$.

Phase 5. Obtaining a fragment of a RGB image. On the basis of the developed methods of adaptive coding and decoding, it is possible to improve the compression of ITS (information telecommunication systems) digital image, which helps to reduce redundancy under the limited decrease in the quality of visualization as well as to reduce delays in data processing (Figure 2).

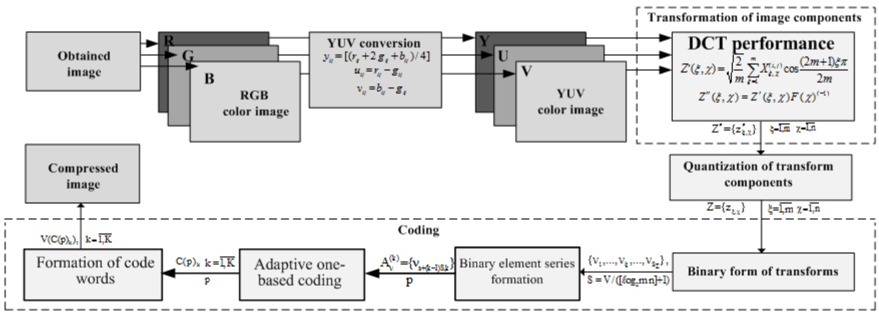

Figure 2. The improved technique of image compression

3. Experimental research

The method of video data compression can be assessed when reducing data volumes taking into account that the exclusion of uncontrolled loss of quality is ensured without using data on the vector of binary element series in the columns.

Average volume $\overline{V}_{ci}$ of video data having the compressed form depends on loss of quality. The level of image visualization under limited quality loss corresponds to the ratio 'signal/noise' and equals $\sigma = 50$ dB. The normal level of image visualization equals $\sigma = 30$ dB. The largest reduction in the volume of video data is achieved with increasing loss of quality. Average volume $\overline{V}_{ca}$ of video data for one series is equal to $\overline{V}_{ca} = \overline{V}_{mz} + \overline{V}_{mo}$, consequently average volume $\overline{V}_{\Sigma}$ of compressed video data for one series is equal to

$$\overline{V}_{\Sigma} = \frac{mn(([S_{\Sigma}([\ell og_2 mn]+1)]+1)V_c / V_{mc} + \overline{V}_{mz} + \overline{V}_{mo})}{M\,N} \tag{5}$$

Fig. 3 shows the comparative assessment regarding average quality losses in compressed video data for imbalance positional coding (IPC) and adaptive coding (AC).

The level of quality losses corresponds to the maximum signal/noise ratio $\sigma = 27$ dB, and processed images are selected in three types, depending on their degree of correlation. When selecting the images, only the errors made at the stage of quantization of transform components are taken into account.

Upon analyzing the diagrams in Fig.3, the following conclusions can be made:

- If limited quality loss takes place under $\sigma = 27$ dB, average loss of bits for one series varies from 20 to 50 bits, depending on the degree of image coherence;
- Adaptive coding allows to decrease average volumes of compressed video data by 12% for low- correlated images and 7% for highly correlated images.

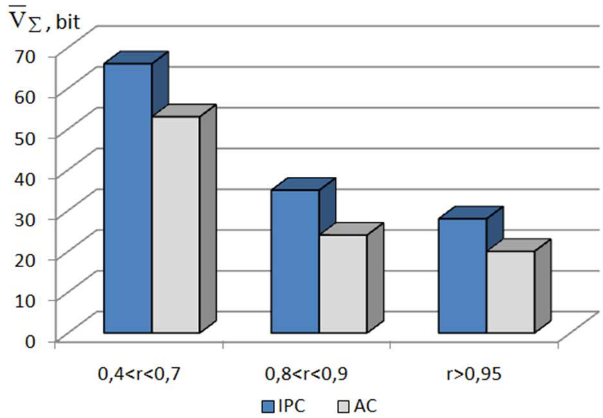

Figure 3. The value of volume $\overline{V}_{\Sigma}$ for imbalance positional coding (IPC) and adaptive coding (AC) with the maximum signal/noise ratio $\sigma = 27$ dB, depending on the degree of image correlation

According to the developed method, for specified volume $\overline{V}_{\Sigma}$, compression degree η is calculated on the basis of the following ratio:

$$\eta = \frac{d\,M\,N}{([S_{\Sigma}([\ell og_2 mn]+1)]+1)V_c / V_{mc} + \overline{V}_{mz} + \overline{V}_{mo}} \tag{6}$$

Taking into consideration the data in fig. 3, obtained for the average volume of compressed images, a compressed fragment can be estimated using compression coefficient η, while the parameters of block coding (Farrelle, 2011) are as follows: $m \times n = 64$ and $d = 8$ bits. Then, depending on the degree of correlation, the average compression coefficient for "signal/noise ratio" equals as follows: for low-correlated images - 12 times; for medium-correlated images - 28 times; for highly correlated images - 35 times.

Figures 4 and 5 show the comparative analysis regarding the level of image compression is carried out in accordance with the developed method which allows to apply different techniques of coding positional numbers obtained for the columns of binary elements and JPEG images.

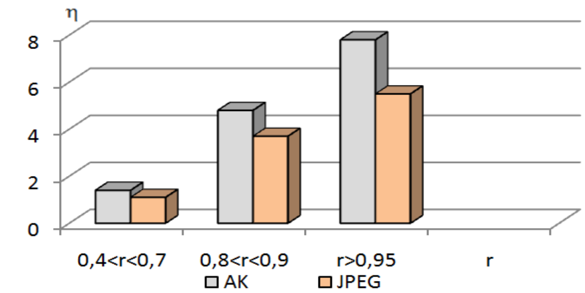

Figure 4. Dependence of compression coefficient η on the image correlation under $\sigma = 27\ dB$

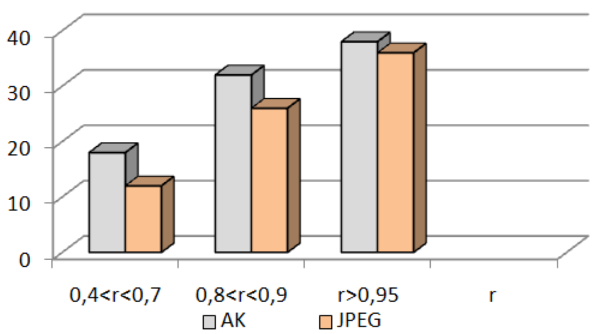

Figure 5. Dependence of compression coefficient η on the image correlation under $\sigma = 50\ dB$

Upon analyzing the diagrams in Fig.4 and 5, the following conclusions can be made:

1) Using the proposed method, under reduced loss of quality in a renewable image that corresponds to 'signal/noise ratio' 50dB, it is possible to achieve a decrease in the compressed volume of video data as follows: 15% for low and medium correlated images; 20% for highly correlated images;
2) In comparison with the methods applied for JPEG images, the proposed method helps to achieve a decrease in the volume of compressed images under loss of quality that corresponds 'signal/noise ratio' 27db, when low-correlated image are processed for 20%, and medium-correlated images for 18% respectively. At the same time, the compression of highly correlated images can be carried out according to both the proposed method and methods applied for JPEG images.

4. Conclusions

The method of video data compression includes the previous quantization of DCT transform components and implementation of adaptive coding. This method allows researchers to increase the level of compression; to exclude an uncontrolled decrease in the quality of renewable images, which is caused by both the elimination of psycho-visual redundancy and insufficient selection of data to describe the structural components of the stages of data conversion; to reduce processing time at the pre-selection stage and at the stage of coding to reduce redundancy.
To provide a specified quality of visualization of images derived as a result of image restoration, the method of image decompression has been proposed. This method is intended to restore images with the limited decrease in the quality of visualization and to exclude uncontrolled loss of data.
The developed methods allow to improve adaptive coding and decoding, compression of digital video images, which, in turn, allows to reduce compressed volumes of data as follows: 15% for low-correlated and medium-correlated images; 20% for highly correlated images at a signal/noise ratio equal to 50dB, and to minimize delays in data processing.
The proposed method allows to increase the efficiency of communication channels and video data processing performed by aviation security centers, and provides information support and quality of decision making in crisis situations.

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WYKORZYSTANIE PODPISU CYFROWEGO ORAZ ZNAKU WODNEGO DO ZABEZPIECZENIA DOKUMENTÓW ELEKTRONICZNYCH

Streszczenie: Cyfrowy podpis oraz cyfrowy znak wodny są dwiema znanymi technikami używanymi do ochrony praw autorskich. Używanie cyfrowego podpisu oraz cyfrowego znaku wodnego do ochrony dokumentów elektronicznych oraz ich istotne wady opisano w niniejszej pracy. Ponadto, przeanalizowano także zalety schematów kombinacji podpisu elektronicznego oraz elektronicznego znaku wodnego.

Słowa kluczowe: podpis cyfrowy, cyfrowy znak wodny, bezpieczeństwo danych, dokumenty elektroniczne

COMBINING OF DIGITAL SIGNATURE AND DIGITAL WATERMARKING TO IMPROVE THE SECURITY OF ELECTRONIC DOCUMENTS

Summary: Digital signature and digital watermark are two techniques used for copyright protection. The use of digital signature and digital watermark to protect electronic documents and their significant disadvantages had been described. The advantages of combination digital signature and digital watermarking scheme were analyzed.

Keywords: digital signature, digital watermarking, data security, electronic documents

1. Digital signature and watermarking: definitions and uses

The problem of determining the authenticity of documents (money, securities and confidential documents, photos) is now raised more and more often. This is due to the increase in the volume of documents between organizations as well as the development of document exchange technologies. In this regard, there are many

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different methods of document’s protection against forgery such as digital signature, digital watermarking.
A digital signature is a mathematical scheme used to validate the authenticity and integrity of a message, software or digital document [1, 2]. Digital signatures use a standard, accepted format, called Public Key Infrastructure (PKI), to provide the highest levels of security and universal acceptance [3]. They are a specific signature technology implementation of electronic signature.
To determine the authenticity of an electronic document signed with electronic signature, it is necessary to resort to the (services of certification centers) third party services, which can be costly and time consuming, in addition, the user cannot trust a third party.
Digital signatures are based on public key cryptography, also known as asymmetric cryptography [1, 3]. Using a public key algorithm such as RSA, one can generate two keys that are mathematically linked: one private and one public. To create a digital signature, signing software (such as an email program) creates a one-way hash of the electronic data to be signed. The private key is then used to encrypt the hash. The encrypted hash – along with other information, such as the hashing algorithm – is the digital signature (Figure 1).

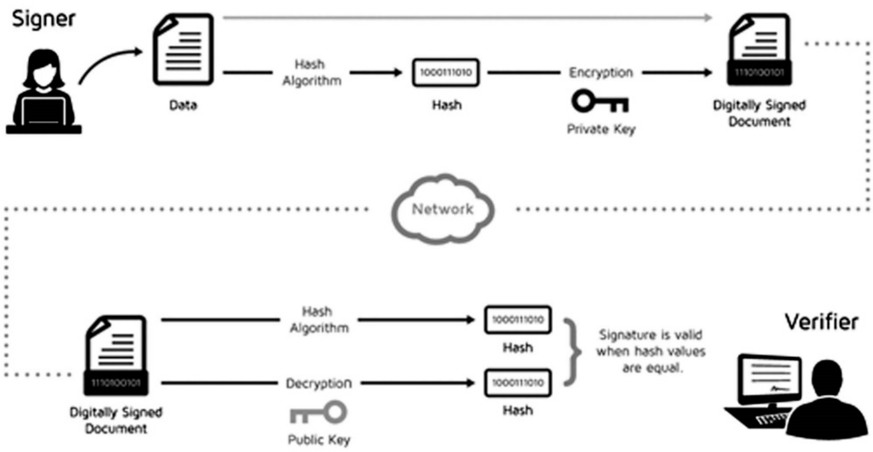

Figure 1. Definition Digital signature

A digital signature can be used with any kind of message whether it is encrypted or not simply so the receiver can be sure of the sender's identity and that the message arrived intact. Digital signatures make it difficult for the signer to deny having signed something (non-repudiation) assuming their private key has not been compromised as the digital signature is unique to both the document and the signer, and it binds them together.
Digital signatures have some disadvantages that go with them, which were described in [4]:

- Expiry: digital signatures are highly dependent on the technology it is based on, so that many of these tech products have a short shelf life.

- Certificates: in order to effectively use digital signatures, both senders and recipients may have to buy digital certificates at a cost from trusted certification authorities.
- Software: to work with digital certificates, senders and recipients have to buy verification software at a cost.
- Law: in some states and countries, laws regarding cyber and technology-based issues are weak or even non-existent.
- Compatibility: there are many different digital signature standards and most of them are incompatible with each other.

Digital watermarking algorithms were developed to solve the problem illegal copying of documents [5]. Watermarking algorithms embed digital signatures or digital data to prove the owner's identity and stop copyright infringement. Several commercial companies around the world offer copyright protection services to their customers. The watermark can be visible [6], where it is easily seen by the observer and owner or invisible where it can be detected by the originator by certain decoding algorithms. For this application the watermark needs to be robust so that it cannot be destroyed by modifying the digital media. Another requirement for watermarking for copyright protection is the algorithm needs to be blind. In blind techniques the original media is not required to extract the watermarking information. Security is an important issue which requires the watermark to be modified only by the owner.
There are several ways in which we can model a watermarking process [5, 6]. These can be broadly classified in one of two groups. The first group contains models which are based on a communication-based view of watermarking and the second group contains models based on a geometric view of watermarking.
Figure 2 shows typical digital watermark schemes.

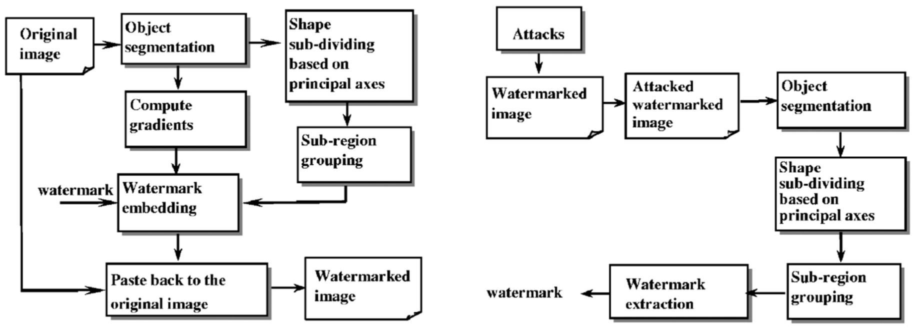

Figure 2. Typical digital watermark scheme

The watermark can be attacked using different techniques [6].
- filtering and noise removal attacks,
- JPEG compression attack,
- additive noise,
- cropping attack,
- rotation attack.

Watermarks are typically used to try and reduce the possibility of thievery [7]. With the availability of affordable or free photo editing programs such as Photoshop and Gimp, this may prove to be a wasted effort. Using the clone or trimming tools, even a novice can remove your watermark in one of these editing programs. A thief may place his own watermark on the image after removing yours. Watermarks do not offer foolproof protection against theft.
Watermarking doesn’t prevent image copying but we can track down and detect ownership of copied images.
Watermarks vanish if someone manipulates the image. Resizing, compressing images from one file type to another may diminish the watermark and it becomes unreadable.

2. Combining of digital signature and digital watermarking

Digital signature and digital watermark are two techniques used for copyright protection and authentication, respectively. It is well known, a digital signature when using it as the sole protection level does not always provide a 100% guarantee of security [8]. It is proposed to combine the use of electronic digital signature (DS), and a digital watermark (DW): signing the entire container with embedded DW to private key of an authorized officer. The resulting signature is transmitted to the storage of certification center, is also stored and public keys with certificates of employees.
The protected file can be additionally integrated digital mark the signing of the file. This will provide intra-use control document management system. Each legitimate user may be using the public key of the Certification authority (CA) to verify the authenticity and immutability of the electronic document.
A DW is hidden in the file serves as a guarantee that even if the attacker to sign the file on its own behalf, the results of verification of the signature and DW will not match and it will be possible to establish a violation. DW acts as an additional level of protection, which is sometimes difficult to even detect, let alone to get around. The certificate confirms that the public key really belongs to a certain person.
Simultaneous using of several technical protection measures – DW, DS and timestamp – much more difficult and raise the price of the implementation of malicious acts, such as container modification, the substitution of authorship, etc. Since the remedies are used independently, overcoming one of them does not allow an attacker to silently and with impunity change the file for their own purposes.

The proposed scheme extracts signature from the original image and embeds them back into the image as watermark, avoiding additional signature file. It can also locate the illegal modifications. Experiments show the scheme is robust to reasonable compression rate while preserving good image quality, and capable to authentication. Studying of possible attacks on the proposed protection scheme can be the following research stages.

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AUTHENTICATION WHEN ACCESSING CLOUD SERVICES BY MEANS OF LANGUAGE PYTHON

Summary: The most pressing issue "cloud computing" is the issue of information security, as data is stored and processed on the remote, not user-controlled information resources. The majority of users are connecting to the cloud using a web browser. The most common attack is an attack on the client, and in this way are considered attacks such as Cross Site Scripting, «hijacking» passwords, intercepts web sessions, "the man in the middle" and many others. The only defense against this type of attack is the correct authentication and the use of an encrypted connection (SSL) with mutual authentication. However, these remedies are not very comfortable and very wasteful for cloud creators. This information security industry there are still many unsolved problems.

Keywords: authentication, authorization, secure connection, information security, cloud computing.

UWIERZYTELNIANIE PRZY DOSTĘPIE DO USŁUG W CHMURZE ZA POMOCĄ JĘZYKA PYTHON

Streszczenie: Największym problemem w "chmurze obliczeniowej", a zarazem najważniejsze, jest zapewnienie bezpieczeństwa informacji, ponieważ dane są przechowywane i przetwarzane na zdalnych zasobach informacyjnych niekontrolowanych przez użytkownika. Większość użytkowników jest podłączona do chmury przy użyciu przeglądarki internetowej. Najczęstszymi atakami są ataki na klienta, do których zaliczmy ataki, takie jak Cross Site Scripting, "porwanie" haseł, przechwytywanie sesji internetowych, "człowiek w środku" i wielu innych. Jedyną obroną przed tego typu atakami jest poprawna autoryzacja i wykorzystanie połączenia szyfrowanego (SSL) ze wspólnym uwierzytelnianiem. Jednak te narzędzia nie są bardzo wygodne i bardzo rozrzutni dla twórców chmury. W dziedzinie bezpieczeństwa informatycznego nadal istnieje wiele nierozwiązanych problemów.

Słowa kluczowe: uwierzytelnianie, autoryzacja, bezpieczne połączenie, bezpieczeństwo informatyczne, usługi w chmurze

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1. Introduction

Cloud technology - a convenient medium for storing and processing information, which combines hardware, licensed software, communication channels, as well as technical support to users. Working in the "cloud" is aimed at reducing costs and improving the efficiency of enterprises.
Protecting the cloud is not much different from the protection of a traditional data center - approaches are the same. Sometimes I even get to use the security tools already familiar. This provider is doing everything he can to ensure data integrity and high availability:

- Network access to the virtual server to the client is usually limited to the external firewall protection function of a variety of attacks including DDoS-attacks.
- The virtual client environments is isolated at the level of the control software. In other words, apply the policy of differentiation of access rights to employees of the data center and customer specialists.
- As for the information on the disk, it can be encrypted both on the provider level (repository virtual disks), and at the client level (logical drives, user folders).

Clouds allow to realize the same level of confidentiality of a local data center. Add to that a powerful infrastructure provider of professional data center, security and the ability to comply with corporate policies system, you'll have a good platform for storing important information.
If the data for whatever reasons, will be damaged or lost, then this case providers offer a backup service. The client is able to quickly restore the data and settings in the event of unforeseen problems. Backup-function and provides 1cloud company: the client automatically adjusts all of the options with the help of the configurator in the control panel.
Backup is performed automatically once per day. Copies are stored in the user selected for the duration of 7, 14, 21 or 28 days. For example, if you connect a backup storage in the depth of 7 days, you have the ability to "roll back" the server to the state of any of the 7 copies created.
Copying is performed on a remote disk array, which allows access to data for recovery even at full unavailability of the server file system, including as a result of irreversible acts.

2. Threats to the security of cloud services

Security requirements to cloud computing do not differ from the safety requirements for the data center. However, new threats do not cease to appear.
Different access control and ensuring transparency of system-level change is one of the main criteria for protection.
The classification of attacks on the "cloud":

1. Traditional attacks on software.
2. Functional elements of the attack on the cloud.
3. Attacks on the client.

4. Attacks on the hypervisor.
5. Attack on the control system.

Like any other system, cloud servers also creates journal entries (Log Data), which can serve as an important source of information during the engineering and technical expertise (especially for dynamically started and stopped cloud servers).

If we approach the issue of the risk classification of classical positions, for the main actors in the transition to cloud computing (users, service providers, service providers) should be considered, at least three risk categories: organizational, legal, technical.

The greatest risks are expected by users. They are the most vulnerable during the transition to cloud computing.

Each user must have a unique login. There should be no association with existing accounts. So how do OAuth providers encrypt only the login process, and all the cookies that are used for authentication, authorization, after going in the clear, so the possible interception of data and access to the "cloud" user.

Processes and authentication protocols are widely used in practice.

The main attack on the authentication protocols:

- impersonation. User impersonating someone else in order to obtain the powers and possibilities of action on behalf of another user;
- interleaving attack. The attacker in the course of this attack is involved in the authentication exchange between the two sides in order to modify the traffic passing through it;
- replai attack consists in retransmitting the data authentication by any user;
- forced delay. The attacker intercepts some of the information and transmits it after a while;
- chosen-text attack. The attacker captures the authentication traffic and trying to get information about the long-term cryptographic keys.

3. Methods of protection

In accordance with the interests of business, automated systems, in addition to direct automation features - faster and more efficient business processes, must fulfill the necessary requirements for information security, ensuring the reliability of the automated systems, as well as the reliability, availability and confidentiality of the data circulating in it.

From the point of view of cloud security are only one of the types of infrastructure platforms, even with a high degree of automation. Such basic functions such as firewall, IDS / IPS, virtual closure of vulnerabilities (Virtual Patching) and anti-virus software, is an indispensable element of any security concept, whether physical, virtual or cloud systems.

The authentication process - the process of confirming the authenticity of the subject. Produced with the help of a secret confirmation of ownership issued and granted subject to the registration process, after complete identification, consisting scrutiny presented entity identifiers.

The process of identification - a comparison of the presented entity identifier to the reference listed in the database when you assign a unique label to the subject.

To ensure higher reliability, often resort to such means as tokens (electronic key for access to anything) and certificates. The most simple and fairly reliable method of authentication - a technology OTP (One Time password, OTP). These passwords can be generated by any special programs or additional devices or services with shipment to the user by SMS. The main difference between cloud infrastructure is high scalability and a wider geographical distribution. In the foreground there is the use of one-time passwords for mobile gadgets that today have virtually everyone. In the simplest case of a one-time password is generated by a special authentication server and sent in an SMS to the user's mobile phone after entering the correct password on the static page access to the cloud service. For transparent interaction with the provider identification system for logging, it is also recommended to use the LDAP protocol (Lightweight Directory Access Protocol).

To prevent such attacks in the construction of authentication protocols are used:

- the use of mechanisms such as "challenge-response", "timestamp", random numbers, IDs, digital signatures;
- you Set the authentication result to the subsequent user actions within the system. An example of this approach is the implementation of the authentication process the exchange secret session keys that are used to further user interaction;
- periodically perform authentication procedures within the already established communication session, and so on.

3.1. Security authorization by means python 3.0

With python language you can write a program that will ensure the security authorization as python provides multithreading, versatility, generation of passwords using different alphabets.

An example of such a program might be:

```
def Main():
    try:
        # Getting users and separate password's list.
        print('%s  -  Getting  list  of  users  ...'  %
datetime.now().strftime('%H:%M:%S %d.%m.%Y'))
        usersList = GetListFromFile(config.usersFile)
        print('%s  -  Getting  list  of  passwords  ...'  %
datetime.now().strftime('%H:%M:%S %d.%m.%Y'))
        passwordsList                                      =
[GetListFromFile(config.passwordsFile)]
        if len(passwordsList[0]) / config.brutThreads <= 1:
            config.brutThreads = 1
        if config.brutThreads > 1:
            print('%s - Separate passwords list by threads
...' % datetime.now().strftime('%H:%M:%S %d.%m.%Y'))
            passwordsList                                  =
SeparateListByPieces(passwordsList[0], config.brutThreads)
        print('%s  -  Bruter  initialize,  status:  oK'  %
datetime.now().strftime('%H:%M:%S %d.%m.%Y'))
        # Open new browser's instance, going to form-based
auth page and start brute.
        for i in range(config.brutThreads):
            OpenBrowser(i,                    config.timeout,
config.selBrowserString, config.selFFProfile)
            GoingToTarget(i, config.timeout, config.target,
```

```
                          config.xPathLogin,
config.xPathPassword, config.xPathAcceptButton)
            threads.append(threading.Thread(
                target=Bruter,
                args=(i,  config.timeout,  config.xPathLogin,
config.xPathPassword, config.xPathAcceptButton,
                      config.xPathSuccessAuth,
config.xPathFailAuth, usersList, passwordsList[i],
                      config.randomCredentials,
config.resultFile)))
            et        =        EstimateTime(len(usersList),
len(passwordsList[i]), config.timeout,
                            round(config.rumpUpPeriod    /
config.brutThreads))
            print('%s     -     Thread     #%d,     %s'     %
(datetime.now().strftime('%H:%M:%S %d.%m.%Y'), i, et))
            threads[i].start()
            if     (config.brutThreads     >     1)     and
(config.rumpUpPeriod > 0) and (i != config.brutThreads - 1):
                time.sleep(config.rumpUpPeriod             /
config.brutThreads)
        # Waiting until all threads done.
        threadsAreInProgress = True
        while threadsAreInProgress:
            for t in threads:
                if t != None:
                    threadsAreInProgress = True
                    break
                else:
                    threadsAreInProgress = False
    except BaseException:
        print('%s  -  Bruter  initialize,  status:  error'  %
datetime.now().strftime('%H:%M:%S %d.%m.%Y'))
        traceback.print_exc()
    finally:
        status = Cleaner()
        sys.exit(status)
```

Each of the authorization file contains some randomly generated string of characters for which the database server has a hash tied to a particular user ID. Thus, the time required to input minimal: after the user drags an authorization file on the page, the JS checks the file size, inserts the contents into a special text field and then submits the form - no additional action to login is not required, even the button " Login "do not need to press.

4. Conclusions

Providing reliable secure cloud server for processing - is only the first step in using cloud services. The second and third stages required to move the data to a secure cloud server and make sure that they are in the remained safe.

To date, the most popular are four methods to protect the information in the "cloud":

1) Encryption;

2) Data protection in the transmission;
3) Authentication;
4) Isolation of users.

Confidentiality of information is the principle of the audit, which consists in the fact that auditors are required to ensure the preservation of documents received or drawn up by them in the course of auditing activities, and may not transfer these documents or copies of any whatsoever to third parties or disclose orally contained in them information without consent of the owner of the economic entity. Except as otherwise provided by legislative acts.

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THE OPEN-SOURCE SOFTWARE-BASED SOLUTION FOR DEVEOPMENT OF INFORMATION INFRASTRUCTURE OF MEDICAL UNIVERSITIES

Summary: The role of the information technologies in the education process of the medical universitieis signed. A solution to the development of the information infrastructure based on the maximal open source software usage for the medical (pharmaceutical) universities is proposed. Examples of the system and application and specialized open source software are presented. The capabilities of the open source software usage in the healthcare and medical education fields are demonstrated. The advantages of the hardware virtualization and platform-independent web-applications usage are presented. The complex process of the web applications deployment in a new network cluster in the I.Ya. Gorbachevsky Ternopil State Medical University is given as example.

Keywords: medical education; open-source software; application software; information system; content-management system; learning management system; virtualization.

ZASTOSOWANIE OPROGRAMOWANIA 'OPEN SOURCE' W CELU OPRACOWANIA INFRASTRUKTURY INFORMATYCZNEJ UNIWERSYTETU MEDYCZNEGO

Streszczenie: W pracy omówiono rolę technologii informatycznych w procesie edukacyjnym uniwersytetu medycznego. Zaproponowano rozwiązanie dotyczące opracowania infrastruktury informatycznej uczelni medycznej (farmaceutycznej) w oparciu o maksymalne wykorzystanie oprogramowania typu open source. Przedstawiono systemowe, stosowane oraz specjalizowane oprogramowanie open source w branży zdrowia i edukacji medycznej. Zwracamy uwagę na zalety korzystania z technologii wirtualizacji sprzętu oraz stosowania aplikacji webowych niezależnych od platformy. Jako przykład przedstawiono proces rozwijania zestawu aplikacji webowych w tworzonym klastrze Uniwersytetu Medycznego w mieście Tarnopil.

Słowa kluczowe: edukacja medyczna, oprogramowanie open source, system informacyjny, system zarządzania treścią, system kształcenia zdalnego, wirtualizacja.

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1. Introduction

In the field of higher medical (pharmaceutical) education Ukraine the formation of information infrastructure in recent years has acquired great importance due to the active implementation of various information technology in the educational environment. One of the problems of medical education is to provide training, can effectively harness the power of modern medical information systems, to participate in the development and support them

1.1. Main part

Modern trends in development of information infrastructure of any organization oriented tovard the transition to web-oriented technologies and corresponding server software applications [1]. Major benefits of this approach include:

1. Eliminate binding of application software to a specific hardware and software platform, simplify installation, configuration and administration of application software, minimize the list of required software for workstations (OS + web browser only in an ideal case)
2. An efficient usage of diversed set of workstations, including outdated as far as mobile devices (eg, tablets), which are owned by the university staff and students.

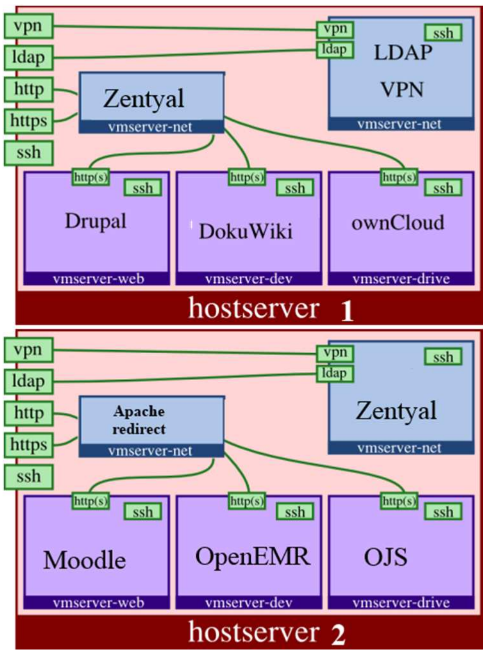

Figure 1. Two-nodes network cluster design

The main difficulty of this approach lies in the laborious process of setting up a server that will provide access to software applications. Virtualization technology usage and network clusters deployement are helpful methodologies to solve hardnes which shown above. The open source Proxmox VE platform provide excelent capabilities to implement both those technicues. This way system administrator got tools to create high-available, managable, scalable and effective network infrastructure environment of the organization (fig. 1). [2]

High availability network cluster of Ternopil State Medical University was established in early 2013, as an initiative of both, author and supervisor. , as one of the stages of implementing a set of measures to reorganize the information infrastructure of the University [3].

At the end of 2016 cluster includes 4 physical servers and 24 virtual machines (virtual servers). Some servers are act as test platforms for the analysis and evaluetion of capabilities of application software. Results is used to establish new information technologies in educational process TSMU (fig. 2).

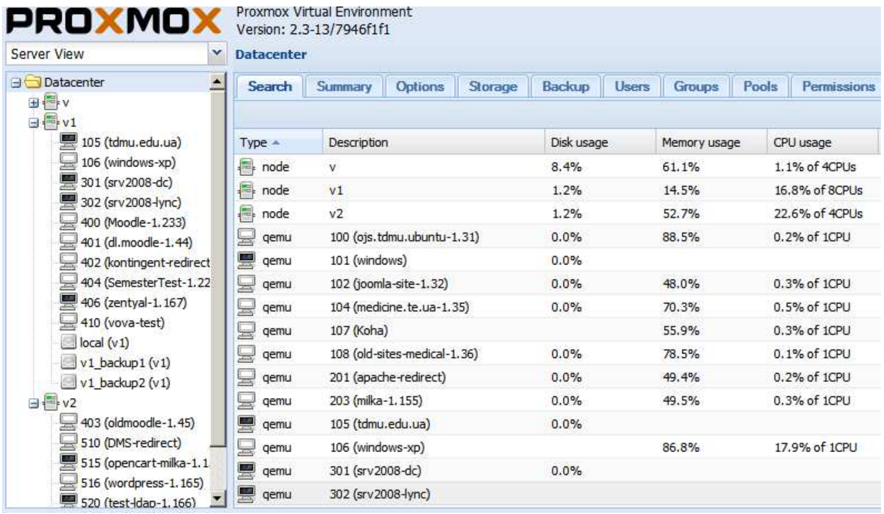

Figure 2. The TSMU network cluster based on the open-source virtualization platform Proxmox VE

The main group of virtual servers provide a number of key services of information infrastructure TSMU. Among them [4, 5]:

1. Web-server which host the TSMU main web-site (http://tdmu.edu.ua) with separate deicated redirect and cache server. Proposed approach increase erformance and securtiy. The TSMU main site is runned by the WordPress CMS.
2. Servers LMS Moodle (http://moodle.org), with electronic versions of courses (http://moodle.tdmu.edu.ua) and Learning Centre Ternopil State Medical University (http://dl.tdmu.edu.te.ua);
3. The site of scientific journals Ternopil State Medical University (http://ojs.tdmu.edu.ua/), running special CMS open source Open Journal Systems (http://pkp.sfu.ca/?q=ojs);
4. Server Hosting sites individual units TSMU. Hosted sites operate on the basis of CMS open source WordPress or Jomla. To manage web hosting is also used open source software - ISPConfig (http://www.ispconfig.org).
5. The servers of the CSE information system which is used to support examination process in TSMU. CSE system consist of Windows cient-server application which is used to prepare wtitten exams and web-application which support oral part of exams and used to create reports (http://cse.tdmu.edu.ua).
6. The server, which run an infromation system, written in TSMU, which perform integration of the Google Apps for Education cloud services with

the existing informational infrastructure of the TSMU. Main task of this system is to sync user account data.

7. Server training videos (http://videotube.tdmu.edu.ua/) is running a special CMS open source ClipBucket (http://clip-bucket.com/).
8. Experimantal and scientific servers, especially: EMS servers of the Ternopil State Medical University - OpenEMR (http://openemr.tdmu.edu.ua) and Doctor Elex (http://doctor.eleks.com/en/).

2. Conclusions

The solution for development of the information infrastructure of medical (pharmaceutical) universities based on maximum usage of freely distributed, open source software suggested by authors. The advantages that it makes use of hardware virtualization and platform-independent Web-applications software solutions usage are provided. The exemple of mentioned above solution usage in the I.Ya. Gorbachevsky Ternopil State Medical University for the information infrastructure re-organization and re-novation is presented.

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UDOSKONALENIE KOMPLEKSOWEJ METODY MIGRACJI DANYCH I ZASOBÓW OBLICZENIOWYCH NA PODSTAWIE ALGORYTMÓW WIELOMIANOWYCH W SKALOWALNYCH REPOZYTORIACH ROZPROSZONYCH

Streszczenie: Zdefiniowano ogólne zagadnienie migracji danych w skalowalnych repozytoriach rozproszonych. Przedstawiono problem określenia metody rozwiązania ogólnego problemu skalowania rozproszonego repozytorium, z uwzględnieniem zdefiniowania zagadnienia migracji, opracowania ogólnej metody migracji danych oraz udowodnienia tezy o celowości zastosowania algorytmu wielomianowego migracji danych.

Słowa kluczowe: system ochrony informacji, technologie informatyczne, technologia SDN, bezpieczeństwo danych, repozytoria rozproszone, migracja danych

THE COMPLEX DATA MIGRATION METHOD AND COMPUTING RESOURCES IMPROVEMENT ON THE BASIS OF POLYNOMIAL ALGORITHMS IN THE SCALABLE DISTRIBUTED STORAGES

Summary: Definition of data migration general problem in the scalable distributed storages is given. The question of method scaling solution finding of the distributed storage problem, concerning definition of migration problem, development of the general data migration method and the proof of the thesis about expediency of data migration polynomial algorithm use are considered

Keywords: information security systems, information technologies, SDN, data security, distrib-uted storages, data migration

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1. Introduction

The priority directions of state policy in the sphere of information are development and deployment of functioning providing of the information security systems (ISS) perspective methods by creation of new models, methods, means and transmission modes, storages and uses of information taking into account need of development of confidentiality infrastructure support, integrity and data accessability. The network industry which was earlier based on hardware solutions concerning architecture of networks creation and similar solutions concerning management of them and their safety ensuring, moves towards software platforms today. It provides failure from static character of networks and transition to dynamic management of their resources and information security systems. In view of this, and also considering experience of the information technologies (IT) application in the military sphere, today scientists and developers of IT systems work on creation of the integrated platform structures which are capable to support large number of unique safe connections to the government distributed institutions with SDN-Technologies (Software Defined Networks) use.

Development of SDN-Technologies allows to consider dynamic component concerning the ISS organization and data security providing by the way of their moving to non identify or previously set safe segments of the general national infrastructure (NI) in the specified network technologies. Definition of NI safe segments and moving data and computing resources inside them will allow to raise considerably information security level in any accessory structures. Thus topical issue is distributed infocommunication resources scaling for the purpose of the most optimum placement of data in final segments. Proceeding from this, the improvement of data migration complex method and computing resources on the basis of polynomial algorithms in the scalable distributed storages is the purpose of the article. It is supposed that considering the principles of migration of data in the scalable distributed storages, specifically, the procedure of final segment assets configuration is given in [1] the question of the general problem of searching the solution of distributed storage scaling method is necessary to investigate. In particular, questions concerning data migration problem definition in the scalable distributed storages, the data migration general method development and the proof of the thesis about expediency of polynomial data migration algorithm use is necessary to solve.

2. Definition of data migration general problem in the scalable distributed storages

Let's formulate in the form of data migration problem definition in the scalable distributed storages, using concepts and terms entered into [1-4].

Definition 1. The multicriteria problem of time optimization of data migration and computing resources is problem of data migration in the scalable distributed storage $GRAF$.

According to Definition 1, criterion of task which we will consider as the basic, time of migration of data to subgraph is $GRAF_{SCALE}$. The second, auxiliary criterion, we will select time of data migration to subgraph $GRAF_{END}$.

3. Development of general problem solution of data migration method in the scalable distributed storages.

Supposing that the solution method of general problem of data migration in the scalable distributed storages, contains achievement of optimum result on the main criterion stated above, that is optimality concerning scaling time achievement in the basis. For the purpose of its solution we will prove that the scaling subgraph $GRAF_{SCALE}$, is bichromatic multigraph. As it has been shown [1] earlier, number of optimum polynomial algorithms of arcs coloring is developed for it.
Lemma 1. The scaling subgraph $GRAF_{SCALE}$, is bichromatic.
For the proof of lemma 1 and improvements of visual explanation, we will bring, according to [1] description of model of the scalable distributed storage. Basis of model is the hypothetical distributed storage which has no restrictions concerning storage space of program and technical assets,

$$\left.\begin{array}{l}\left.\begin{array}{l}GRAF=\left(CAP,MOVING,WEIGHT\right);\\ MOVING\subseteq CAP\times CAP;\\ WEIGHT:MOVING\rightarrow DEPLOYMENT;\end{array}\right\}\\ \forall dat,res\in CAP\Rightarrow WEIGHT\left(dat,res\right)=WEIGHT\left(dat,res\right).\end{array}\right\}\tag{1}$$

where the data involved in migration process is stored. The accent is explicit selection of storage assets subset which are subject to exception or inclusion in structure of the general set of program and technical assets of final segment, in case of change of its configuration. It gives the chance of accounting of distributed storage features which can be scaled. We use from [5] definition about the scaling subset: the subset $SCALE$ which keeps the column to scale change, is scaling. It contains subset of graph tops which as a result of configuration change of the distributed storage needs to be excluded from it or to add to it.
It is obvious that among operations set of data transfer transmission operations between program and technical assets which are scaled are inadmissible, that is:

$$\forall dat,res\in SCALE\subseteq CAP\Rightarrow WEIGHT\left(dat,res\right)=0\,.\tag{2}$$

According to [5], the distributed storage $GRAF$ which can be scaled (the scalable distributed storage) is such storage which comprises explicitly the selected scaling subset $SCALE$:

$$GRAF=\left(CAP,MOVING,WEIGHT,SCALE\right),\tag{3}$$

where $\forall dat,res\in SCALE\subseteq CAP\Rightarrow WEIGHT\left(dat,res\right)=0$.

Let's show process of division of the scalable distributed storage into program and technical sets [5] which are called by us assets. It is obvious that process of final segment scaling demands execution of procedure of migration on all scaling program and technical assets $SCALE$. After its termination there is possibility of release and carrying out migration of data on storage assets which remained unused. Procedure of migration can be separated into two stages: 1) scaling; 2) residual migration.

According to [6, 7], basis problems solution of division are theoretical provisions from the graph theory which describe division of graphs into subgraphs. According to it, possible division of the graph of the scalable distributed storage $GRAF$, on two subgraphs: 1) the scaling subgraph $GRAF_{SCALE}$; 2) residual subgraph $GRAF_{END}$. The scaling subgraph $GRAF_{SCALE}$ is the subgraph of the scalable distributed storage $GRAF$ formed by set of tops $SCALE$ and set of tops $SCALE_{adject}$, which adjoining with $SCALE$, and also those arcs which connect tops $SCALE$ with $SCALE_{adject}$ that is:

$$\left.\begin{array}{l}\left.\left.\begin{array}{l}\left.\begin{array}{l}GRAF_{SCALE}=\left(CAP_{SCALE},MOVING_{SCALE},WEIGHT\right);\\ CAP_{SCALE}\subseteq CAP;\\ MOVING_{SCALE}\subseteq MOVING;\end{array}\right\}\\ dat\in SCALE_{adject}\subseteq CAP\Leftrightarrow\exists res\in SCALE,WEIGHT\left(dat,res\right)>0;\end{array}\right\}\right.\\ CAP_{SCALE}=SCALE\bigcup SCALE_{adject};\left(dat,res\right)\in MOVING_{SCALE}\Leftrightarrow dat\in SCALE,\\ res\in SCALE_{adject},WEIGHT\left(dat,res\right)>0.\end{array}\right\} \tag{4}$$

Expression $dat \in SCALE, res \in SCALE_{adject}, WEIGHT\left(dat, res\right) > 0$
is equivalent to expression

$$\left.\begin{array}{l}dat\in SCALE_{adject}\\ res\in SCALE\end{array}\right\}WEIGHT\left(dat,res\right)>0 .$$

That is connected with that, that [1], the graph $GRAF$ is the nondirectional that illustrates picturre 1 where the graph $GRAF$, on which in the form of black tops − subset $SCALE$, and gray tops − $SCALE_{adject}$.

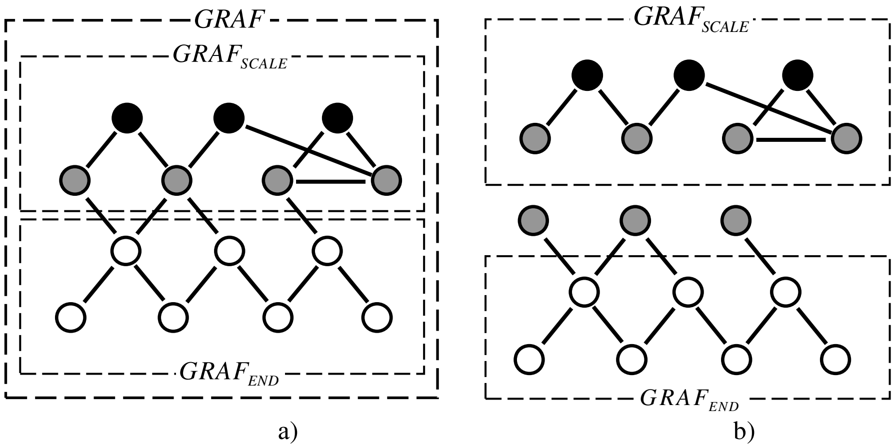

Figure 1. Division of the graph of the scalable distributed storage $GRAF$, on subgraphs $GRAF_{SCALE} = (CAP_{SCALE}, MOVING_{SCALE}, WEIGHT)$ and $GRAF_{END}$, where: a – the graph $GRAF$, that contains subset $SCALE$ (black tops), and subset $SCALE_{adject}$ (gray tops)

Proof of lemma 1. The scaling subgraph $GRAF_{SCALE}$ contains set of tops $SCALE$ and set of tops in the basis $SCALE_{adject}$. As it follows from (4), these tops are nearby to $SCALE$. Besides sets of tops $SCALE$ and set of tops $SCALE_{adject}$ divide the graph $GRAF_{SCALE}$ into two parts. It will mean that in the graph there are no arcs which leave set of tops $SCALE$ and sets of tops enter to the same $SCALE$, and also that there are no arcs which leave set of tops $SCALE_{adject}$ and enter the same set of tops $SCALE_{adject}$. Tops of set $SCALE_{adject}$ have no general arcs which connect them. In that case, this status would contradict definition of subset (2) which scales the distributed storage which is part of scalable storage (3). Expression (4) testifies that any arc entering it integrates set tops $SCALE$ only with tops of set $SCALE_{adject}$ and, as a result, set tops $SCALE_{adject}$ have also no general arcs that testifies that sets of tops $SCALE$ and $SCALE_{adject}$ are independent parts of bichromatic multigraph $GRAF_{SCALE}$.

Let's develop the general algorithm of data migration. We will apply concessions method to solution of this task and we use two earlier brought optimization criterion. The algorithm of data migration is optimized by the first criterion, conceding to efficiency on the second.

Let's set the first partial criterion. Scaling time, that is data migration in the scaling subgraph will be $GRAF_{SCALE}$. Migration time in other assets that is equivalent to data migration on subgraph will be the second partial criterion $GRAF_{END}$. Given we will show on picture 2 in the form of linear algorithm.

Let's develop *algorithm of polynomial data migration.* Its development consists in that on step 7 general algorithms of migration of these (picture 2), instead of reboric algorithm we will apply algorithm "Polynomial coloring of edges".

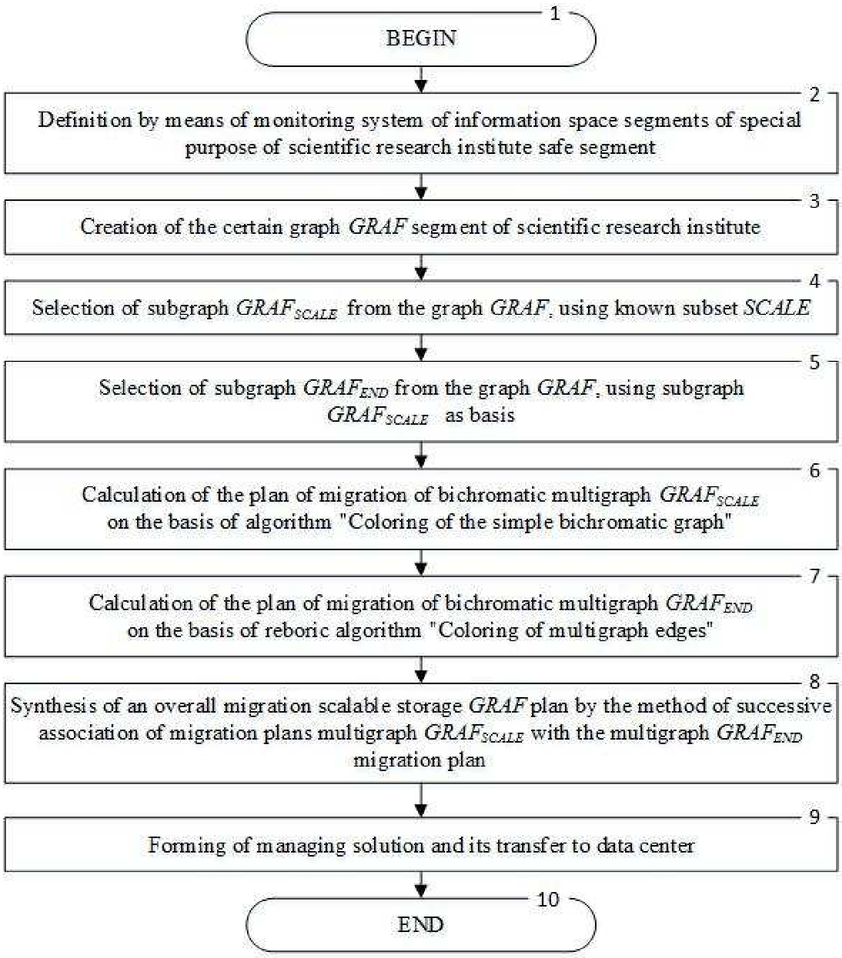

Figure 2. The generalized algorithm of data migration

Theorem of data migration algorithms optimality: The general and polynomial algorithms of data migration are optimum on scaling time in the scalable distributed storage, that is optimum on time of data migration to the scaling subgraph $GRAF_{SCALE}$ the concept about which is formulated in Definition 1.

Proof. Let's consider the entered concept about the general algorithm of data migration. According to lemma 1, the subgraph $GRAF_{SCALE}$ – is bichromatic multigraph. To find method of optimum coloring of arcs $GRAF_{SCALE}$, in it is possible to apply algorithm "Coloring of the simple bichromatic graph". It gives the chance to find optimum time of subgraph migration $GRAF_{SCALE}$. The analysis of problem definition (it is made in definition 1) shows that the optimality of data algorithm

migration according to the first criterion is based on optimality of subgraph time migration $GRAF_{SCALE}$. It is provided on step of the 6th algorithm given on pictuure 2. From that follows that the data migration general algorithm is optimum by the first criterion.
The proof concerning algorithm of polynomial data migration differs from mentioned about only in that on step 7 (picture 2) the algorithm "Polynomial coloring of edges" is used. The optimality, similarly shown above, is provided on step 6. As a result, the data migration polynomial algorithm also is optimum by the first criterion.

Theorem of data migration polynomiality algorithm: The offered algorithm of data polynomial migration has polynomial computing complexity.
Proof. We remember that the algorithm of data polynomial migration matches the generalized algorithm of data migration which is given on picture 2 except that on step 7 the algorithm "Polynomial coloring of edges" is applied. Then, analyzing the mentioned picture, we see that steps 4 and 5 are polynomial. It follows from that finding of values of tops of set $SCALE_{adject}$ which are adjacent with set tops $SCALE$, is task trivial, and procedure of selection of subgraph $GRAF_{SCALE}$ and subgraph $GRAF_{END}$ which are formed from the set tops, has linear complexity which is defined by quantity of tops, that is $OC \equiv |CAP|$. Steps 6 and 7 are also polynomial with computing complexity $OC = |ARRIS| \log \delta$ and $OC = |ARRIS|(|CAP| + WFunc)$ according to algorithm "Polynomial coloring of edges" and algorithm "Coloring of the simple bichromatic graph", where $ARRIS$ − set of the graph target segment edges, CAP − set of its tops, δ − the maximum degree of its tops, $WFunc$ − weight constant.
Two plans of movement (that is − migrations) will be result of work of steps 6 and the 7th algorithm (picture 2). In their basis there will be descriptions of operations execution sequences of data movement (arc of subgraphs). The step 8 corresponds to simple operation of consecutive combination of the specified two plans. It is obvious that this step has linear runtime $-OC \equiv |ARRIS|$ which depends and is defined by number of edges to the graph $GRAF$.
As the algorithm of polynomial migration of data is consecutive association of steps 4-8 (picture 2; condition − on step 7 the algorithm "Polynomial coloring of edges" is applied), its computing complexity will be defined by computing complexity of the most costly step:

$$\max\{OC = |CAP|; OC = |ARRIS| \log \delta; OC = |ARRIS| \log \delta, OC \equiv |ARRIS|\} =$$
$$= \max\{OC = |ARRIS| \log \delta; OC = |ARRIS|(|CAP| + WFunc)\}.$$

The given testifies that the polynomial data migration algorithm has polynomial complexity and testifies to achievement of goal.

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MODEL MATEMATYCZNY DO EWALUACJI SKUTECZNOŚCI FIZYCZNEGO SYSTEMU OCHRONY

Streszczenie: Przedstawiane model sprawcy oraz strategię jego działania w systemie ochrony fizycznej obiektów z ograniczonym dostępem. Opracowany model może być stosowany do oceny skuteczności technicznych systemów ochrony dla obiektów z ograniczonym dostępem.

Słowa kluczowe: system fizycznego zabezpieczenia, przestępca, wskaźnik efektywności

MATHEMATICAL MODEL FOR DETERMINING THE INDICATOR OF EFFICIENCY OF PHYSICAL PROTECTION SYSTEM

Summary: A model of the offender and the strategies of his actions in the system of physical security of objects with limited access is presented. The developed model can be used to assess the efficiency of technical means of protection of objects with restricted access.

Keywords: physical protection system, offender, the indicator of efficiency

1. Introduction

The result of the operation of physical protection systems (PPS) is to prevent causing any harm from offenders, who entered the controlled area under any external conditions, to the objects with limited access. Under damage in relation to the object is understood: malfunction isolation mode; penetration to the object of outside intruders; moving things, violation of conservation of material resources the institution. A key aspect of building a PPS of object is to simulate potential threats. In most cases, the actions of people are the main danger to the objects with limited access, in connection with the analysis of threats there is an objective need to create a model of a potential offender and strategies of his actions.

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There are different approaches to the construction of the model of offender. For example, model which represents offender, as a set of its characteristics (parameters) and a description of the values that take these characteristics [1]. In [2] it is proposed to form a "set of models offenders", including technological, operational and project models. The process model is developed as a set of potential violators characteristics that allow you to implement the relevant threats to the object. Operational model actualizes the intended range of potential offenders' characteristics on the current time. The project model is a set of characteristics of potential offenders, who must successfully confront the system of physical protection of the object.

In general, when constructing a model of the potential intruder of PPS object and scripting his behavior, it is advisable to take into account: the threats and sources for protected sites, the ways of their realization, especially the protection of the object, a set of characteristics (parameters) of the offender, the degree of training and equipment, the degree of completeness of the engineering and technical means of protection and surveillance of possible ways and means to overcome the boundaries of the protection elements.

2. Threats to the objects with limited access

Under the threat of immediate danger to the object is understood the damage or potential implementation risks arising as a result of certain factors, or their combination [3].

The set of threats may be represented as a set $X = \{x_i: i = \overline{1,q}\}$. It contains all possible types of threats (q elements) to be considered when designing on the object PPS. For each type of threat, you can prioritize this threat at the current level of the operational situation. The set of priorities threats can be denoted as $R = \{r_i: i = \overline{1,q}\}$. The correspondence between the set of threats and a set of priorities threats is assigned each threat r_i factor. The resulting compliance rate will tell how likely the realization of the *i*-threat under the existing operational environment in comparison with other types of threats [4].

The mathematical model of the object of protection can be represented as a vector [5]:

$$V = \{v_k: v_k \geq 0, k = \overline{1,k}\}, \tag{1}$$

where k - the number of characteristics of the object, $k = 9$;

v_1 - the type of object (W);

v_2 - the category of equipment by ITSO complex (CE);

$$CE = \begin{cases} \mathit{1 - 1\ category;} \\ \mathit{2 - 2\ category;} \\ \mathit{3 - 3\ category;} \\ \mathit{4 - absent.} \end{cases}$$

v_3 – the index of term operation of the facility (CO);

$$CO = \begin{cases} 1 - \ constant; \\ 2 - temporary; \\ 3 - momentary. \end{cases}$$

v_4 - the indicator of the level of thermal radiation (L_{tr});

v_5 - the indicator of the level of electromagnetic radiation (L_{er});

v_6 - the indicator of the level of seismic noise (L_{sn});
v_7 - the number of inputs - outputs of acquisition and processing system of information (N_{in});
v_8 - a sign of the possibility of installing technical means (TM) on the object and external fencing (S_{oo});

$$S_{oo} = \begin{cases} 0 - \ if \ the \ installation \ of \ TM \ is \ not \ possible; \\ 1 - \ if \ the \ installation \ of \ TMis \ possible. \end{cases}$$

v_9 - a sign of outside fencing (S_{of});

$$S_{of} = \begin{cases} \textit{0 – absent;} \\ \textit{1 – brick, ferroconcrete;} \\ \textit{2 – metal;} \\ \textit{3 – wood;} \\ \textit{4 – grid, wire, reinforced barbed tape.} \end{cases}$$

Since several receivers and transmitters' electromagnetic radiation may be in the object with limited access, they can be characterized by the average frequency (*FR*) and frequency range (*DFR*), it is convenient to consider these characteristics as the individual vectors [5]:

$$FR = \{f_i : i = \overline{1, l}\}, DFR = \{f_i : i = \overline{1, l}\}, \quad (2)$$

where *l* – the sum of the number of transmitters and receivers in the facility.

3. The model of offender and strategies of his actions

The next strategies of offender actions are expected: an open attack on the object; hidden penetration on the object; overcome the major barriers, disabling engineering and technical means of protection; SAPs; overcoming the line of protection of the facility; ambushes on the route of special transport.
These strategies can be implemented in various ways. The most likely strategies and actions of offenders are listed in Table 1, in which the plus is the applicability of this strategy or method against this type of object, and negative - are not applicable.

Table 1. The strategies of offender actions

The nuber of strategies	The strategies of offender actions	The type of object		
		Points of permanent bases, warehouses of territorial agencies	Manufacturing, construction and repair facilities	Communication networks and electricity
		1	2	3
1	An open attack on object	+	+	+
2	Hidden penetration on the object	+	+	+
3	Ambushes on the route of special transport	-	+	-

Strategies matrix A is associated as [5]:

$$A = \{a_{ij}\}(i = \overline{1,n}; j = \overline{1,m}), \tag{3}$$

where a_{ij} - binary function;
n - number of strategies;
m - number of object types.

$$a_{ij} = \begin{cases} 1 - if\ the\ strategy\ is\ applicable\ on\ the\ facility; \\ 0 - \ if\ the\ strategy\ isn't\ applicable\ on\ the\ facility. \end{cases}$$

The probability of the use of strategies on the *j*-facility is represented like [5]

$$b_{ij} = \begin{cases} H_{ij} - if\ a_{ij} = 1; \\ 0 - if\ a_{ij} = 0, \end{cases} \tag{4}$$

then a matrix of application of strategies can be shown like [5]:

$$B = H\{\psi(A)\}. \tag{5}$$

Table 2. The methods of offender actions

The nuber of method	The method of offender actions	The type of object		
		1	2	3
1	Through a major barrier (via up, break)	+	+	-
2	Through the checkpoint for transit transport (using vehicle or by the passage)	+	+	-
3	Through the checkpoint for the transit of people	+	+	-
4	With the use of communications (air, ground, underground)	+	+	+
5	Digging under	+	+	+
6	Hacking designs	+	-	+
7	Opening doors and windows	+	-	+

A complete group of events is constituted for each type of object of possible strategies, so condition of normalization must be performed for each column of the matrix [5]:

$$\sum_{i=1}^{n} B_{ij} = 1. \tag{6}$$

In compliance with the methods of offender actions at the *i*-strategy for *j*-type objects matrix C_{ij} is presented [5]

$$C_{ij} = \{C_{ijr}\}\left(r = \overline{1, k_{ij}}; i \in n, j \in m\right), \tag{7}$$

where C_{ijr} - binary function:

$$C_{ijr} = \begin{cases} 1 - if\ the\ method\ is\ applicable\ on\ the\ facility; \\ 0 - \ if\ the\ method\ isn't\ applicable\ on\ the\ facility; \end{cases}$$

k_{ij} - the number of modes of action in the *i*-strategy for the *j*-type objects.
The probability of the use of the *r*-method on the *j*-object can be presented as [5]

$$d_{ijr} = \begin{cases} h_{ijr} - if\ C_{ijr} = 1; \\ 0 - if\ C_{ijr} = 0, \end{cases} \tag{8}$$

the matrix of probabilities of the method is [5]

$$D_{ij} = \{d_{ijr}\}\left(r = \overline{1, k_{ij}}; i \in n, j \in m\right), \quad (9)$$

For each strategy, action methods constitute a complete group of events so for each cross-section of the matrix *D* must be satisfied the normalization condition [5]

$$\sum_{r=1}^{k_{ij}} d_{ijr} = 1. \quad (10)$$

Probabilities of strategies and methods of actions of infringers against of each type objects can be determined by expert assessments.

Accounting for the effects of strategies and methods of offender actions on the main indicator of the efficiency of physical protection system (probability of detection) should be carried out at the average criterion, as in emergency situations, offenders can affect the protection of objects without using stereotype, and taking into account the specific circumstances with using that or these strategy. Thus, the probability of detection of the offender when trying to penetrate to the *j*-object is given by [5]

$$P_j = \sum_{i=1}^{n} (\sum_{r=1}^{k_{ij}} (d_{ijr} \cdot P_{or}))\, b_{ij}, \quad (11)$$

where P_{or} - the probability of intruder detection by the *r*-method of penetration, which is determined experimentally [6].

The violator may affect, for example, on the elements of the protection system the purpose of bringing them down. Resistance of technical means to the effects of violators accounted for in the index of survivability P_s that is defined by the organization of developers for the case of the application by the violator the most effective means of influence.

$$P_j = b_{ij} P_{01} P_s + \sum_{i=1}^{n} (\sum_{r=1}^{k_{ij}} (d_{ijr} \cdot P_{or}))\, b_{ij}, \quad (12)$$

where P_{01}- the probability of finding the technical means in the case of disabling it by infringer.

For funds in which the derivation of them out of action automatically generates an alarm, the index P_{01} is appropriate to be taken equal to unity.

4. Conclusions

In the process of improving the presented model it is necessary to carry out a formal description of methods of actions of offenders when implementing the entire set of possible strategies, which will fully take into account the characteristics of objects with limited access during the construction of PPS. In the future, the developed model can be used to assess the efficiency of technical means of protection of objects with limited access.

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RESEARCH OF SOCIAL NETWORKS AS A SOURCE OF INFORMATION IN WARFARE

Summary: Social networks are increasingly being used as an information source, including information related to global world events. The current study examines social networks Twitter and Facebook by using the programming language R for getting and analyzing information about different events.

Keywords: Big Data, social networks, warfare, users` reaction, R language

BADANIA SIECI SPOŁECZNOŚCIOWYCH JAKO ŹRÓDŁA INFORMACJI DO WOJNY INFORMACYJNEJ

Streszczenie: Sieci społecznościowe są coraz częściej wykorzystywane jako źródło informacji, w tym także informacji związanych z wydarzeniami czy tendencjami ogólnoświatowymi. W niniejszym artykule omówiono badania sieci społecznościowych Twitter oraz Facebook przeprowadzone używając języka programowania R. Celem badań było for pozyskanie oraz analiza informacji o różnych wydarzeniach

Słowa kluczowe: Big Data, sieci społecznościowe, wojna informacyjna, reakcje użytkowników, język programowania R

INTRODUCTION

Nowadays, at the time of constant improvement of information and communication technologies, any conflict is reflected on the Internet. Oftentimes, such a reflection on social networks influences the result of a competition. Active involvement of the multimillion audience in virtual network allows to manipulate public opinion and to significantly affect the processes between opposing sides.

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Understanding of the importance of the Internet and social networks leads the advanced countries to invest heavily in social networks which now become not only a medium but also an efficient political weapon [1].
Modern social networks significantly changed the task – today researches have free research resource and fast-moving spreading of social online-services and evolution of Big Data technologies initiated the interest in using information from social networks in different branches. Cooperative using structural and content information potentially allows to use social networks to decide different tasks such as people`s opinion manipulation and researching especially during information warfare.
Active using of social networks allows to quickly influence public opinion and human behavior, turning them into a battlefield of groups with various interests. The scope of influence on people and event management the social networks provide offers many opportunities for tasks to be solved. The lack of censorship and other sorts of obstacles allows the networks users to be on the front line in creating a favorable basis for successful action, both in the virtual and the real space. All of this indicates that social networks become an arena for information warfare. Social networks serve as a source of information about users around the world. It isn`t easy to use this source and appearing issues require special technologies and tools.

1. Social networks as Big Data

Nowadays modern information technologies reached that level when information in any sphere of people activity is huge. A source of this information can be data from measuring devices and scanners, streams of messages from social networks, streams of data about mobile networks users, audio- and videofixation. This information has such a large amount that was created special term – Big Data. Big Data is not amount of information but methods of data gathering, processing and analyzing. Such information is different types and dynamic.
Currently there are following tasks connected with Big Data: saving and managing Big Data because sizes of information hundreds terabytes or petabytes more do not allow saving and managing it easy; structuring gathered information.
The data in distributed systems is stored and indexed on multiple hard drives and servers. Also the so-called «map» is created, which contains informaation about location of a particular piece of information [2].
Main adventages of using Big Data technologies are: getting qualitatively new knowledges by complex analyzing information in social networks; extending the functionality of existing support information systems; increasing the efficient use of server hardware.
Analytics of Big Data helps to improve information security. Analytics of Big Data can be used to analyze network traffic, log files and finance operations; to correlate the multiple sources of information in coherent form; to detect anomalies and suspicious activity. Combine of security intelligence and Big Data analytics allows to expand possibilities for outside threats of cyber-security and for inside rysc by analysis enriched security data (structured and unstructured) and reveling harmful activity hided in raw data masses [3].

Today social network are one of the biggest source of information in the world. Social networks are huge stream of different-type information, so it needed to use Dig Data technologies for gathering, structure and processing data.

Analysis of social networks is reflection and calculation of relationships and streams between people, groups, organizations, computers, URL-adresses and other connected information or knowledges. People and groups are as a nodes of networks, in that time links show relationships or streams between nodes. Analysis of social networks provides mathematics analysis of people`s relationships.

Big Data can reduce processing time of big size information in distributed calculating environment. It also can predict potency abuse of cyber security and help to stop cyber-attacks.

Big Data transfer technologies such as Hadoop, databases NoSQL, getting information stream and complex actions processor allow to analyze great and heterogeneous arrays with high speed [2, 4]. They can convert analytics of security by improving technical service, saving and analysis information about security.

Social networks form a huge database of streaming information, which consists of private and public messages, information about users, comments on a particular message and so on.

Social networks like Facebook and Twitter have more than 2.0 billions registered users, including actors, singers, politicians and even presidents of different countries [5]. That is why social netwoks are not just a way to relax and chat with friends, but also the raw material for the analysis of the events, comments of celebrities and audience reaction to them. As for the world’s leading countries, such as USA, a number of institutions are engaged in research on public reactions to what the politicians are saying during their speeches. This could be achieved through analyzing the so-called «tweets» and «posts» by breaking them into lexical components, getting certain keywords and producing statistics of their appearance as a reaction to the politician’s statement. According the estimates Twitter is one of the top-10 visited internet sites in the world (table 1) [6]. Quantity of Twitter users is more than 310 million people. Every second in average is published about 6000 «tweets», every day – over 600 million, every year – more than 2 billion and this number is increasing from year to year [7]. People send tweets on very various themes such as reaction on an event of spam (see Figure 1).

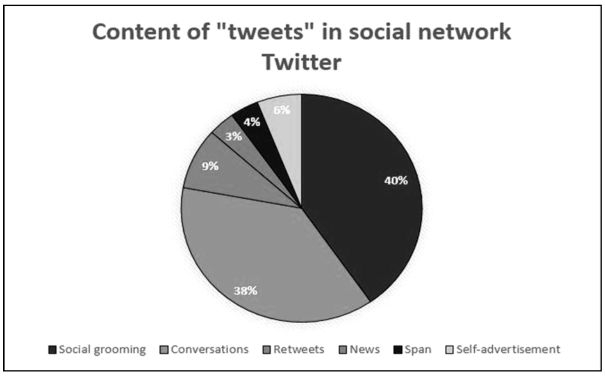

Figure 1. Content of tweets in social network Twitter

Today quantity of users in the most popular social network in the world Facebook is more than 1.1 billion people (table 1) and amount of information that Facebook store is about 300 petabytes. Every day Facebook users make more than 4.75 billion publications and it is very good basis for researching of social statement of population of any country [8].

Table 1. Top-10 the most popular social networks in the world

№	Social network	Quantity of users
1	Facebook	1,700,000,000
2	YouTube	1,000,000,000
3	Twitter	310,000,000
4	LinkedIn	255,000,000
5	Pinterest	250,000,000
6	Google Plus +	120,000,000
7	Tumblr	110,000,000
8	Instagram	100,000,000
9	Reddit	85,000,000
10	VK	80,000,000

Therefore, given these statistics, we can conclude that social networks are beautiful basis to analyze people`s reaction on different events. So, methods for readout, structuring, processing and analysis data from social networks must be developed for researching manipulating of people opinion during information warfare.

2. Gathering and analyzing of information from social networks by using R language

Research was conducted on a computer with a quad-core processor Intel core i7-6700HQ CPU @ 2.60GHz and DDR4 memory type and capacity 16 GB and Internet-speed 100 Mbit/s. Operation system – 64-bit Windows 10 Home. As an instrument of researching programming language R and libraries for working with social networks Facebook and Twitter are chosen. R is a programming language for statistical data processing and work with graphic. To work with R appropriate free programming environment Rstudio was used.

2.1. Developed functions to research social networks

This article introduce a way of obtaining data from social networks Twitter and Facebook using R language functions [9]. For research purposes, some special functions were developed that allow to get certain information from the social networks:

- NumberOfRewievsDates function which allows to get a number of keywords to a given number of «tweets» matching a given tag in social network Twitter and to build a chart reflecting the general statistic result;
- NumberOfRetweets function, which allows to get a number of «retweets» to a certain number of «tweets» matching a given tag in social network Twitter;

- FacebookLSC function, which allows to get a number of likes, reposts and comments on the latest posts on the public pages for a given key tag in social network Facebook;
- FacebookReactions function, which allows to get a number of responses to a particular post in the form of «good», «bad», «normal» and alike for a given key tag in social network Facebook and to build a chart reflecting the general statistic result.

For the research of social network Twitter a special API key (api_key) and an API-secret (api_secret) had to be set that was available on the Twitter site in the «Developer» section. To set these values, the following function has to be used:

```
setup_twitter_oauth(api_key, api_secret, access_token = NULL,
access_secret = NULL)
```

This function is needed to connect programming environment Rstudio and package of functions «twitteR» with an account in Twitter [10]. Before that it was created needed account in Twitter because there isn`t access to data for unauthorized users.
For the research of social network Facebook a similar action was taken, but far more complex in structure. First, it was necessary to register and log on the official Facebook website to get an ID of the application which is being developed (app_id) and a secret (app_secret). This could be done in the «Facebook for developers» section. After that, the following function has to be used to connect to the social network and to the corresponding features pack «Rfacebook» [11]:

```
fbOAuth(app_id, app_secret, extended_permissions = TRUE)
```

In the same section a so-called token had to be gotten. Token is a kind of code that consists of a set of characters that enables to work with functions for receiving data from Facebook social network. To obtain the token it is necessary to find «Graph API Explorer» subsection in the «Facebook for developers» section and to click «Get token». A special window (Figure 2) appears, where there is a list of options.

Figure 2. Parameters window to receive a token

After the necessary parameters are set, the choice must be confirmed and the token is obtained by copying it from an edit box.
Token is temporary that is uncomfortable for developer because it can be active only two hours and after it`s activity ending to continue work with functions new token must be got for the previous algorithm (shown Figure 2) and set it in program.

2.2. Research of social network Twitter

For researching as a basis an event was chosen – the second tour of debates between USA presidential candidates Donald Trump and Hillary Clinton that was on 10^{th} of October in 2016. This event is one of the best for researching because these debates became the most popular for all history. Debate was being watching by more than 84 million people around the world. It became the best basis for researching people`s reaction and their support to every of candidates. For that have been chosen tags «Clinton» and «Trump»; have been chosen dates before and after second tours of debates – since 2016-10-04 to 2016-10-09 and since 2016-10-10 to 2016-10-15; sample of 10000 «tweets» for each preset tag. As keywords next list with appropriate to each keyword number that means people`s reaction on performances presidential candidates was chosen: 1 – good; 2 – bad; 3 – terrible; 4 – beautiful; 5 – worst; 6 – best; 7 – normal.
At the beginning, function NubmerOfReviewsDates was chosen and results have been written in appropriate varieties:

```
TrumpBeforeDebats  <-  NumberOfReviewsDates(10000,  "Trump",
'2016-10-04', '2016-10-09')
TrumpAfterDebats  <-  NumberOfReviewsDates(10000,  "Trump",
'2016-10-10', '2016-10-15')
ClintonBeforeDebats <-NumberOfReviewsDates(10000, "Clinton",
'2016-10-04', '2016-10-09')
ClintonAfterDebats  <-NumberOfReviewsDates(10000,  "Clinton",
'2016-10-10', '2016-10-15')
```

Next empty graph with coordinates system was built by using function plot() [12] and filled appropriate varieties to draw lines that mean every of event and candidate and get a result:

```
plot(reactListNumb, xlab = "Word", ylab = "Quantity", main =
"Users reactions")
lines(TrumpBeforeDebats, type = "o", col = "black", lty=2)
lines(TrumpAfterDebats, type = "o", col = "black")
lines(ClintonBeforeDebats, type = "o", col = "grey", lty=2)
lines(ClintonAfterDebats, type = "o", col = "grey")
```

For easement for each variety and appropriate line on graph is set a color: dark shades for Donald Trump and light shades for Hillary Clinton. Dotted line means result before debates, common line means result after debates. A graph of quantity keywords (Quantity) and the keywords (Word) was got (Figure 3).
The result of graph (see Figure 3) shows that after debates people`s attitude to Hillary Clinton changed to better but people`s attitude to Donald Trump changed to worse.

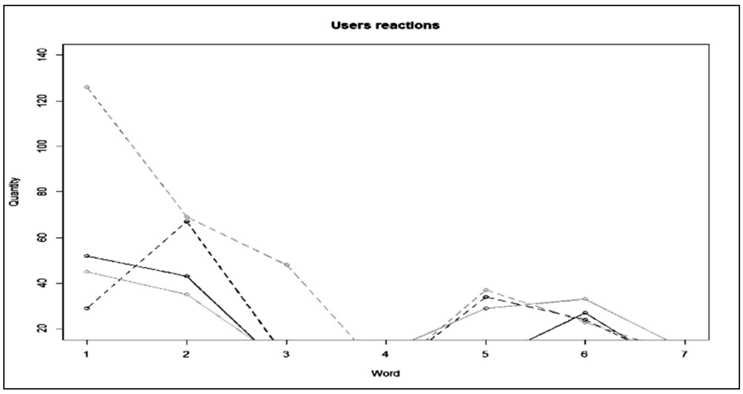

Figure 3. Graph of people`s reaction on USA presidential candidates before and after debates

Every request in social network Twitter took about one hour because for work with huge content of data must be appropriate equipment with high computing possibility. All research took about four hours.

2.3. Research of social network Facebook

To research two USA presidential candidates Hillary Clinton and Donald Trump were chosen. In the research is work with quantity of «likes» that were got by requests «Clinton» and «Trump» and sample 1000 «posts».
For that created function FacebookLSC that allows getting quantity of «likes», «reposts» and comments and result is written in appropriate varieties was used:

```
Trump<-FacebookLSC("Trump", 1000)
Clinton<-FacebookLSC("Clinton", 1000)
```

As a result it was got vectors where quantity of «likes» from every of 1000 «posts» in appropriate requests are. After that, graph of analysis of quantity «likes» (Likes) and «posts» (Posts) was built. As a result, the graph was received (Figure 4) that shows light line that means Hillary Clinton and dark line that means Donald Trump.

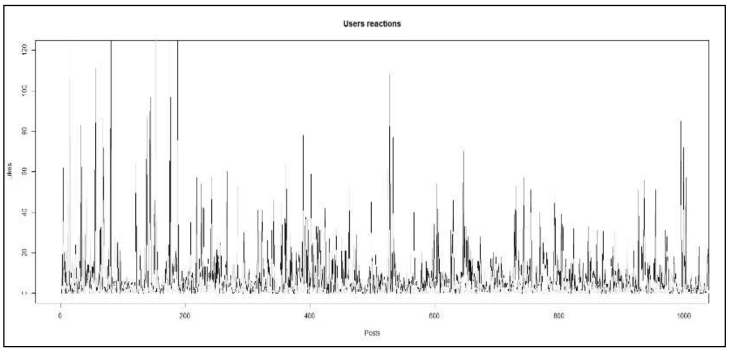

Figure 4. Graph of likes in posts about USA presidential candidates

Figure 4 shows that quantity of «likes» in «posts» about Donald Trump much more than in «posts» about Hillary Clinton, so people supports Donald Trump more.
Received conclusions are the same as results of analytics of The Telegram [13] that said people`s reaction and support D. Trump and H. Clinton changed after debates.

3. Conclusions

In this article famous social networks Facebook and Twitter as source of Big Data were analyzed. Social networks can be used for different researches and even during information warfare.
For gathering and analyzing information of social networks using R language that proves to be good in statistic researching was offered.
Researching of people`s reaction in social networks Facebook and Twitter on USA presidential candidates debates Hillary Clinton and Donald Trump was made. The result of the investigation is the same as analytics of The Telegram.
But the researching took a lot of time and resources because of different factors such as different information access, different server power, and different storing Big Data systems.
It is planned to research with different programming languages and other methods of readout and processing information from social networks to increase the performance and quantity of searched data sample.

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KLASYFIKACJA TEKSTÓW W MONITOROWANIU WIELU TECHNOLOGII INFORMATYCZNYCH

Streszczenie: W pracy zamieszczono wyniki dotyczące rozwiązania problemu klasyfikacji tekstów. Zastosowano technologie: text mining (eksploracji tekstu) oraz monitorowania wielu informacji. Opisano nową metodę eksploracji tekstu. Różni się ona od innych metod, które wykorzystują wielopoziomowe modelowanie. W proponowanej metodzie stosuje się nowe procedury informacyjne dla opcji wyszukiwania oraz tworzy się specjalną tablicę wejścia. Skuteczność nowego sposobu zostało potwierdzone eksperymentalnie uzyskując poprawne wyniki klasyfikacji.

Słowa kluczowe: eksploracja tekstu, monitorowanie informacji, dane klasyfikacyjne

CLASSIFICATION OF TEXTS IN THE TECHNOLOGY MULTILEVEL INFORMATION MONITORING

Summary: Results of solving of text classification tasks by Text mining which is based on the technology of multilevel information monitoring are given. A new method of intellectual text analysis is described. It differs from other methods by using the technology of multilevel modelling, selecting a base view of a model, a new means of survey of information text parameters and formation of inlet file data. The number of correctly classified texts reaches 100% after parametric process optimization of intellectual analysis.

Keywords: Text mining, information monitoring, classification data

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1. Foreword

Text classification is one of the tasks which are implemented by the technology of intellectual text analysis (text mining) [1]. Despite the formulation of the task in author profiling of text message, the task of text qualification is facilitated by the possibility to work out sorting in the amount of 1000 signs and more. This enables to increase informational content of traditional frequent characteristics of the text. [2] Their usage simplifies the automatization of text message decomposition and its transformation into the array of numerous characteristics.

2. Task formulation

Process of Text mining that aims at grouping texts with similar message content is searched in this work. For achieving the aim the following tasks were solved 1) transformation of information from typed text message format into the format of numerous characteristics of informative text features; 2) the construction of classification model that has the main role, that enables to form new texts. Such rules can have limiting meanings of classification features or analytical expression that transforms meanings of numerous features into the classification result that is the conclusion of text appliance to a certain class; 3) to develop the methodology of classificatory appliance in the technology of information monitoring.

The solution of tasks were based on the proof of some hypotheses.

Hypothesis 1. The application of methods and means of multilevel modelling [3] will enable to successfully solve the task of text classification by content on condition of enough information content inlet data (ICND) – numerous characteristics of text features.

Hypothesis 2. Information content features that form ICND are provided with deep text decomposition to the level of separate features and sign combination. The profoundness of decomposition is individual for every class of tasks.

Hypothesis 3. Text classification must be viewed as a process of reflection of numerous text classes on numerous task classes of algorithm formation of synthesis of classificatory models (ASCM). Researches demonstrated that it is not possible to reveal either the list of classification features or a determining rule that is built on the base of these features. So a peculiar set of features is formed for every class and on their base a certain determining rule is built that enables to identify a text which belongs to a given content class.

Rules were synthesized as multilevel functional dependences that include in their structure inductive models [4] neuronetwork, genetic algorithm, hybrid models which were received by complete algorithms. In order to solve the task of coordinate interaction of this models, the method of ascending element synthesis is used [3]. Steps that produce transformation process of a typed text in ICND, the formation of a determining rule, the developing methods of its application for revealing a certain message content in one of given classes are combined in a new method of text classification in Text mining. The content of these steps is shown in table 1.

A text is analysed by means of singling out separate parts with successively located sentences in the text [5]. Transformation of text message is done with the help of calculation of frequent characteristics of text features which are given preliminary that

is frequency of applying of every feature in a separate text window. As a result of calculation we get the set of features – the start of surveys in multilevel scope of features of initial description of the modelling object.
After estimation of information content some features of texts that have unsatisfactory frequent characteristics are removed from the original text. Points of observation that are built by the vector of information content features form ICND . The appliance of the part of the text to the given content class was reflected by means of marking the observation point as “Not strange”.

So the succession of observation points is formed that reflect in their structure the content of the message that belong to a given class.

Table 1. Method of text classification

№	Step content	Result
1	Determination of the common features set that can contain information about text content	General vocabulary of text features
2	Determination of list of text message classes and the list which is known to belong to a separate class	Formalized task of text classification. Class list. Text lists that are related to each of classes for model training
3	Research of feature information content out of general vocabulary for each of the text message class	Preliminary estimation of information content feature
4	Selection of text features of preliminary estimated information content. Formation of dictionaries of information content features for every class of text messages	List of information content features for every text class
5	Identifying the list of numerous characteristics of each of features that belongs to a dictionary	List of frequent and other characteristics which are used for estimation of every informative feature.
6	Identifying the size of the window for a text decomposition	Results of optimisation of number of signs in the window for every text class
7	Decomposition of the text	Set of text section that is suitable for formation of informative points of observation
8	Formation of information content inlet data (ICND)	Array of numerous characteristics of informative parameters which are ready for studying of a classificatory model
9	Synthesis of classificatory model	Determining rules that are available to solve weakly formalized tasks of text classification
10	Test of CM	Numerous characteristics of separating surface for class features. Characteristics of model quality.
11	Use of CM	Identification of text belonging to one of required texts.

For other observation points a status “Strange” was given. They reflect the content of messages that belong to other classes.

Solving of tasks of text grouping is done by model synthesis. Each model is used as a classificator that allows to refer every group of observation points (text) to one of the given classes. To form this rule the hierarchy combination of multilevel models according to inductive method must be used [4].

A limiting meaning of modelling results was defined on the result of model testing and if the meaning was higher it was marked as “Not strange”. After this the model is referred to the database of model knowledge.

2. Text classification. The analyzed text is sent to the input of SCM. The decision about the correctness of a researched text fragment of a given content is according to the results of transformation of ICND which are parallel to some “determining rules” of database knowledge. The number of correctly identified fragments of the text in accordance to a preliminarily given content and dependence of results of content survey of a base model were defined during the testing of a described technology. The number of correctly classified observation points reached 100% after adaptation of base model view in accordance with class qualities.

3. Summary

A new method of intellectual text analysis was offered and it enables to automate the process of text message survey accordingly to the content. So the possibility to organize the intellectual system of multilevel informational monitoring is provided.

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HIGH-PRODUCTIVITY METHODS OF FINDING RESIDUES MULTIDIGIT NUMBERS BY MODULO

Summary: The tasks associated with finding residues of multidigit numbers by module, are extremely actual in different fields of modern science. The effective methods for finding quadratic residues and residues of multidigit numbers by module with using the system the remaining classes and binary number system that will reduce the time complexity of processing information flows in computer systems are described in this article. These methods are iterative and do not contain transactions complicated for implementation by hardware. These can be used in asymmetric cryptography, systems coding and transmission of information, other areas of discrete and computational mathematics.

Keywords: residue, module, iteration, multidigit numbers, system of residual classes, quadratic residue

WYSOKOWYDAJNE METODY POSZUKIWANIA RESZT LICZB KILKUCYFROWYCH

Streszczenie: Zadania związane z poszukiwaniem reszt kilkucyfrowych liczb z dzielenia tychże liczb przez pewną liczbę (np. modulo 2 – reszta z dzielenia przez 2), są niezwykle aktualne w różnych dziedzinach współczesnej nauki. W pracy opisano efektywne metody znajdowania residuum kwadratowego oraz obliczania reszt liczb kilkucyfrowych (modulo wybrana liczba) z użyciem systemu klas reszt oraz dwójkowego systemu zapisu. Metody te pozwalają zmniejszyć czasochłonność przesyłu informacji (potoków danych) w systemach i sieciach komputerowych. Dyskutowane metody są interaktywne i nie zawierają skomplikowanych operacji (możliwe do dla wykonania przez hardware). Można je wykorzystywać w asymetrycznej kryptografii, systemach przekazania i kodowania informacji, a także w innych problemach matematyki dyskretnej oraz innych problemach obliczeniowych (numerycznych).

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Kluczowe słowa: pozostałość, moduł, iteracja, wielogatunkowe liczby, system pozostałych klas, kwadratowy nadmiar

1. Introduction

Finding the square root by modulo (quadratic residue by modulo) is in the tasks of asymmetric cryptography, particular in Schoof's algorithm in order to calculate the elliptic curve (EC), generating parameters and data points EC [1, 2], the Rabin cryptosystem [3], systems for transmission and coding information [4], data protection from errors of the most labor-intensive operations [5] and for finding residues of multidigital numbers (MDN). Methods of varying difficulty were proposed by many scientists to solve tasks of this class [6-11].

Their analysis indicates that methods for solving such problems are far from perfect, because requirements to ensure the required level of cryptographic protection of computer flows and speed of data transmission increase in connection with the intensive development of information technologies. In the majority of cases, these problems are solved by increasing the dimension of the input parameters of encryption algorithms, which leads to study MDN. The algorithms built in the system of residual classes (SRC) [12, 13], which allows to paralel computational processes and operate with numbers of much less bit capacity, which reduces the time complexity.

Also search of remnants is an important task in number theory, results for which are widely used in improving the algorithms for choice of the system of modules for improved and modified perfect forms of SRC and processing MDN regarding conditions for the implementation of modular operations [14-16].

Development of relevant theoretical foundations and software computing tools can increase productivity, speed, reduce the computational complexity of processing methods of MDN.

1.1. Literature review

It is necessary to find value of residual and square roots by modulo in the Rabin cryptosystem. The methods are considered for finding the quadratic residues $x^2 = a \ (mod\ p)$ on the bases of the use of Jacobi ($J(a,p)$) and Legendre ($L(a,p)$) symbols that are determined as follow: if a – is any integer, and p – is a prime number greater than 2. The value $J(a,p)=0$, $L(a,p)= 0$, means that a is divided by p. If a – a quadratic residue by modulo p, then $J(a,p)=1$, $L(a,p)= 1$. The disadvantages of this is the fact that when the module p is a composite number, then the value of $J(a,p)$ and $L(a,p)$ is equal to 1 will not always be true, i.e. indicate on the existence of root by modulo.

Optimal schemes of the tabular approach for determining residues for numbers represented in binary form are considered in the work [6]. This approach requires additional memory resources for data storage. The efficient algorithm is also known and its implementation for finding residues in the binary number system is parallel [7]. The hardware implementation of a new RNS-converter with using a limited set of modules is described in [9].

High time complexity, which limits the functionality in determining residues, is the disadvantage of these methods.

1.2. The purpose of the article

Thus, the aim of this work is to develop an effective method of finding the square root by modulo, finding remnants of MDN with using SRC and the binary system of calculation that will reduce the time complexity of processing information flows in cryptoalgorithms and for data transmission in computer networks.

1.3. The method of finding the residue in MDN in the Rademacher's Basis

Presentation of MDN P and module b as binary numbers was laid in the basis of the proposed method, i.e.:

$$P \bmod b = K, \tag{1}$$

where $P = \sum_{i=0}^{n-1} p_i 2^i,\ p_i = 0{,}1$; $b = \sum_{i=0}^{k-1} b_i 2^i,\ b_i = 0{,}1.$

k-1 of senior order bit P is allocated at the first stage, resulting we received the vector $K = (P_{n-1}, P_{n-2}, ..., P_{n-k-1})$. If $K \geq B$, then it is calculated $K \bmod b = 0, K - b = S$ and recorded as $S = \sum_{i=1}^{k-2} S_i 2^i, S_i = 0{,}1$. Then $S = (S_{k-2}, S_{k-3}, ..., S_1, S_0)$ and the vector

$$S_1 = (S^1{}_{k-2}, S^1{}_{k-3}, ..., S^1{}_1, S^1{}_0, p_{n-k-3}) \tag{2}$$

is formed by appending in lower order bit p_{n-k-3}. Then inequality $S_1 > B$ is checked. If it is true, the value $S_1 \bmod b = S_1 - b$ is sought, otherwise it is appended in lower order bit p_{n-k-4} and received:

$$S_2 = (S^2{}_{k-2}, S^2{}_{k-3}, ..., S^2{}_1, S^2{}_0, p_{n-k-3}, p_{n-k-4}). \tag{3}$$

Then the value $S_2 \bmod b$ is calculated. This procedure continues until p_0 will not receive in lower order bit, i.e. vector

$$S_n = (S^n{}_{k-2}, S^n{}_{k-3}, ..., S^n{}_1, S^n{}_0, p_0). \tag{4}$$

As a result, it is necessary to find value for finding a residue in the binary number system:

$$P \bmod b = S_n \bmod b = K. \tag{5}$$

Figure 1 presents the developed block diagram of the algorithm for finding residues of MDN by common modules.

The main advantages of this algorithm are to reduce the excessive usage of memory and the number of comparisons. In addition, its feature is the use of binary number system and reducing the number of operations of addition, which is proportional to the digit capacity of numbers that is demonstrated on the example:

$10989_{10} \bmod 7_{10} = 2_{10}$

$10101011101101_2 \bmod 111_2 = 10_2$

$10101011101101_2 - 11100000000000_2 = 111011101101_2$

$111011101101_2 - 111000000000_2 = 11101101_2$

$11101101_2 - 11100000_2 = 1101_2$

$1101_2 - 111_2 = 110_2$
$110_2 < 111_2$.

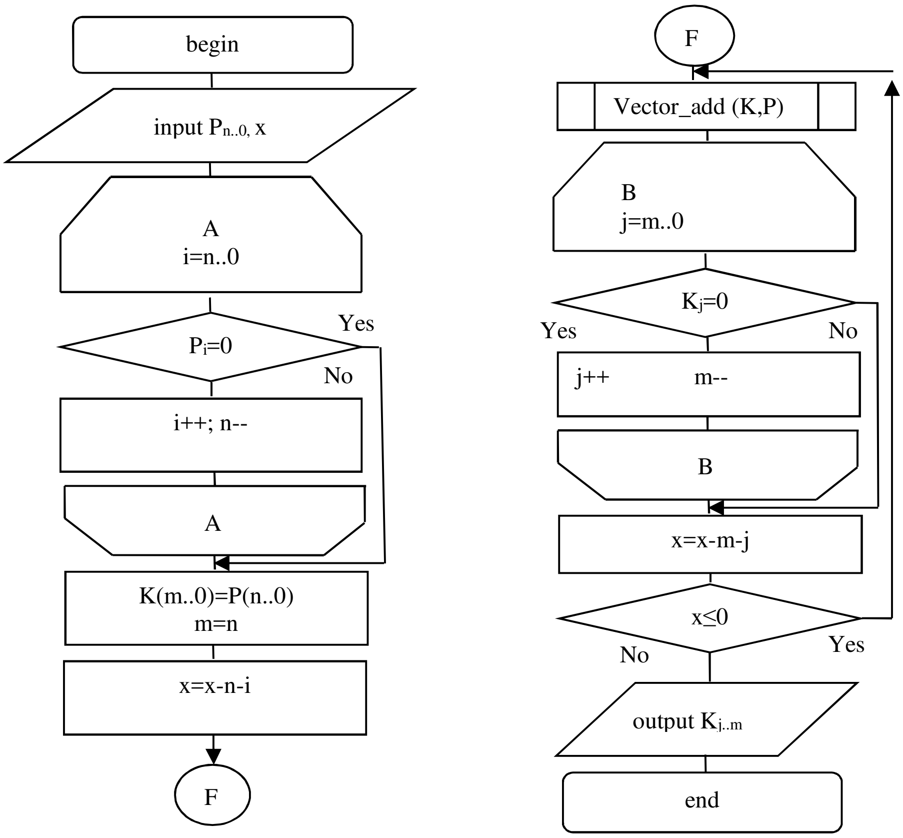

Figure 1. Block diagram of the algorithm for finding residues of MDN

Computational complexity of the algorithm is $O(n) = \dfrac{n \cdot \log_2 n}{\log_2 p}$.

1.4. Search method of quadratic residues of multidigital numbers

Let us consider remains of squares of integer numbers by a few simple modules p_j, that is $a_1(p_1, p_2, ..., p_m) = b_1^1, b_2^1, \ldots, b_m^1$, $a_2(p_1, p_2, ..., p_m) = b_1^2, b_2^2, \ldots, b_m^2$, $a_n(p_1, p_2, ..., p_m) = b_1^n, b_2^n, \ldots, b_m^n$, where $a_i = i^2$, $b_j^i = a_i (mod\ p_j), 1 \le i \le n$, $1 \le j \le m$, m – the number of modules.

Squares of integer numbers can be represented as the sum of odd numbers, whose number is equal to this number:

$$n^2 = \sum_{i=1}^{n} (2i - 1). \tag{6}$$

Using the property (6), the unknown remains can be obtained by using the recurrent formula:

$$b_j^i = \left(b_j^{i-1} + z_i^j\right) mod\ p_j, \tag{7}$$

where $z_j^i = z_i\ mod\ p_j$, z_i=2i-1.

The corresponding results by modules 3, 5, 7, 11 are presented in the table 1.

Table 1 – Finding residues of squares by common modules

N	z_i	a_n	p_1=3		p_2=5		p_3=7		p_4=11	
			z_1^i	b_1^i	z_2^i	b_2^i	z_3^i	b_3^i	z_4^i	b_4^i
1	1	1	1	1	1	1	1	1	1	1
2	3	4	0	1	3	4	3	4	3	4
3	5	9	2	0	0	4	5	2	5	9
4	7	16	1	1	2	1	0	2	7	5
5	9	25	0	1	4	0	2	4	9	3
6	11	36	2	0	1	1	4	1	0	3
7	13	49	1	1	3	4	6	0	2	5
8	15	64	0	1	0	4	1	1	4	9
9	17	81	2	0	2	1	3	4	6	4
10	19	100	1	1	4	0	5	2	8	1
11	21	121	0	1	1	1	0	2	10	0

Table 1 reflect the cyclical properties of quadratic residues by simple modules. They allow to reduce the process of iterative enumeration by half, because $n^2\ mod\ p_j = (-n^2)\ mod\ p_j = (p_j-n)^2\ mod\ p_j$ (the number of quadratic residues for each module is $(p_j+1)/2$, including 0), and is performed for all modules.

Figure 2 shows the developed block diagram of the algorithm for determination of quadratic residue, where addition by modulo is the most complex operation, and the number of iterations will be equal to $(m-1)/2$.

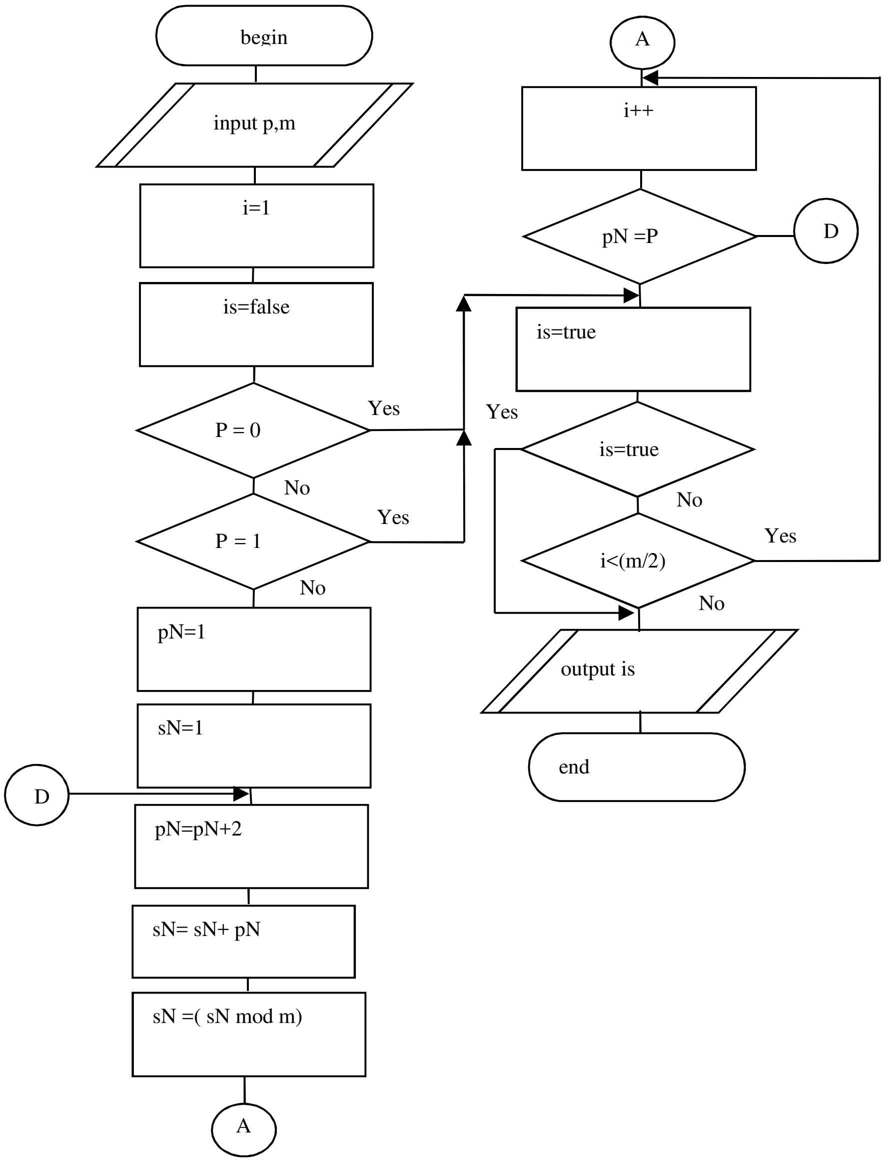

Figure 2. Block diagram for determination of the quadratic residue

The algorithm for determination of quadratic residue of number by a particular module consists of the following steps:

1) the number *a* is stored (the residue for checking on quadratic) and simple module of the number *p*;
2) the counter *i*=1 is initialized;
3) binary features *is=false* is set;
4) if *a* =0, then a property *is* = *true* is set and a transition to step 12 is occur, because

the residue 0 is always a residue of the square;

5) if a =1, then a property *is = true* is set and a transition to step 12 is occur, because the residue 0 is always a residue of the square;
6) the counter $pN=1$ and the counter $sN=1$ is initialized;
7) as each square is changed to step with the difference 2, respectively, $pN=pN+2$ та $sN= sN+ pN$ is increased;
8) restrictions by the module p are imposed on the counter, i.e. there is reassignment $pN=(pN \bmod p)$; $sN =(sN \bmod p)$;
9) the value of the counter i is increased on 1;
10) if $pN = a$, then a property *is=true* is set and a transition to step 11 is occur;
11) if the counter i<(p /2), a transition to step 7 is occur;
12) the algorithm returns the property *is*, which can acquire only two different values: 1 or 0, as in Jacobi symbol, is an indicator of belonging of the residue number to the quadratic residue by a particular module.

This algorithm allows reducing time complexity by replacing operation of multiplication by adding.

The result of the algorithm can be only two values 1, 0 that indicate on a possible quadratic or guaranteed non-quadratic residue. You can use several modules in order to increase probability for determination of the quadratic residue.

The proposed method has effective application and high practical value when implementing methods of processing multidigital prime numbers in problems of the number theory and modern computational technology, because it is iterative and does not contain transactions that are difficult for performance by hardware means.

2. Conclusions

The method of finding residues of MDN, which feature is the use of binary number system and reducing the number of operations regarding addition of proportional digit capacity of numbers, which reduces the time complexity, is developed in this article. The proposed high performance method fo finding quadratic residues by modulo with using SRC has effective use and high practical value when implementing methods for processing of multidigit prime numbers in problems of the number theory and modern computational technology, which is characterized by a lower time complexity relatively well-known methods.

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STUDIUM WRAŻLIWOŚCI BEZPIECZEŃSTWA INFORMACJI W BAZACH DANYCH

Streszczenie: Informacje z baz danych mogą być pozyskiwane przez cyberataki wykorzystujących pewne luki. W pracy omówiono efektywne wykorzystanie bazy danych (na przykład do budowy systemów oceny ryzyka) związane z ich wyborem, według określonych kryteriów. W pracy badano także podstawy i określono kryteria, na podstawie których można przeprowadzić analizy. Zwiększa to efektywność oceny rozwiązań związanych z problem bezpieczeństwa danych.

Słowa kluczowe: ocena podatności systemów informatycznych, bezpieczeństwo informacji, analiza podatności baz danych

STUDY VULNERABILITY DATABASE INFORMATION SECURITY

Summary: Information vulnerabilities database contains preconditions and estimates that characterize attacks exploiting these vulnerabilities-sti. Effective use of databases (for example, to construct a risk assessment systems) associated with their choice according to certain criteria. For this investigated base and definite criteria that can be carried out their analysis. This increases the efficiency of the solution evaluation state of information security problems.

Keywords: base these vulnerabilities, vulnerability assessment, information systems, information security, database vulnerability analysis

In the construction of the various systems of information protection (IP) (e.g. information security management system (MS) [13] or complex communication system IP [5]), it is necessary to carry out the evaluation of the state of IS, based on known vulnerabilities Resources Information Systems (RIS). Therefore, the specialists involved in the study of the state of security of information systems (IS), raises the question of the effectiveness of the related database (DB) vulnerabilities that meet certain criteria [4, 6-9], such as the presence of CVE identifiers, to CVSS ratings, CWE categories, to CVSS

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calculator, risk calculator and etc., the use of such criteria will allow for the rational choice of database. In this regard, the relevant date is that of the database research to define a set of criteria by which you can effectively use it. Today, there are a wide variety of publicly available database RIS vulnerabilities that were analyzed in various sources. For example, in [7] carried out a study of open DB vulnerabilities, where the authors of the main fields of vulnerabilities records were identified, advantages and disadvantages of the considered DB, but not the definition of generalized criteria that can be carried out such an analysis. Also in the works [2, 8, 9] the DB in terms of availability of links to other DB, the possibility of obtaining the information in XML format, as well as the presentation format vulnerability in the DB. It should be noted that [2, 8] did not have clearly defined criteria that can be performed by analysis. The authors of [9] the justification for the choice of the database based on the following criteria were adopted: completeness (capacity, number of vulnerabilities); Data availability (free base); ease of obtaining data (interfaces); support the assessment of vulnerabilities according to CVSS system but greater emphasis is given to the vulnerability affecting accessibility. It should also be noted that [2, 4, 6-9] were not clearly marked criteria which can be compared and Vulnerability DB implements their choice to build different systems for estimating IB, such as the assay system and evaluating risks.

In this regard, the aim of this work is to study a wide range of existing vulnerabilities DB to determine the criteria by which it is possible to carry out a comparative analysis of such bases and use them in analyzing and evaluating the risk of IS.To carry out this study, we use the most known and publicly available DB of vulnerabilities: National Vulnerability Database (NVD), (USA) [15]; Data Bank information security threats (Russian Federation) [1]; Open Sourced Vulnerability Database (OSVDB), (USA) [16]; IBM X-Force, (USA) [13]; US-CERT - Vulnerability Notes Database US-CERT (VND), (USA) [19]; Security Focus, (USA) [18]. Let us consider each of them.

NVD. Base developed National Institute of Standards and Technology (NIST) Computer Security Division, Information Technology Laboratory, supported by Department of Homeland Security's National Cyber Security Division. It is a public repository of data, the US-based vulnerability management standards. Such data allow us to automate the management processes vulnerabilities, measure the state of information security and to determine its compliance. NVD database includes lists security control database, deficiencies RIS, misconfigurations, RIS and impact indicators.

This database has the main repository of data management standards vulnerabilities developed Content Automation Protocol (SCAP) [15]. There are the following SCAP components: Common Vulnerabilities and Exposures (CVE); Common Configuration Enumeration (CCE); Common Platform Enumeration (CPE); Common Weakness Enumeration (CWE); Common Vulnerability Scoring System (CVSS); Extensible Configuration Checklist Description Format (XCCDF); Open Vulnerability and Assessment Language (OVAL) [15]. Additionally, applies the next set of other protocols.

Threat Analysis Automation Protocol (TAAP) - Contains components: Malware Attribute Enumeration & Characterization (MAEC); Common Attack Pattern Enumeration & Classification (CAPEC); CPE; CWE; OVAL; CCE; CVE.

Event Management Automation Protocol (EMAP) –it has components: Common Event Expression (CEE); MAEC; CAPEC.

Incident Tracking and Assessment Protocol (ITAP) – it has components: OVAL; CPE; CCE; CVE; CVSS; MAEC; CAPEC; CWE; CEE; Incident Object Description Exchange Format (IODEF); National Information Exchange Model (NIEM); Cybersecurity Information Exchange Format (CYBEX) [15].

Protocols, standards, and data base NVD can be used for the following purposes: CPE; CVE; CVSS; CCE; XCCDF; OVAL; CWE; CAPEC; CEE; ARF; MAEC. The NVD is calculated workload index information I_W, which shows the number of critical vulnerabilities. The higher the number, the greater the load on the safety system. NVD Load Index is calculated by the following formula: $I_W = (N_h + (N_m / 5) + (N_l / 20)) / 30$, where N_h, N_m and N_l–the number of vulnerabilities with high, medium and low severity, respectively, which were published during the last 30 days. As can be seen from a high severity vulnerability is equivalent to five vulnerabilities with medium and low twenty degrees of severity [15]. Each vulnerability introduced into the database, described by the following set of parameters: a unique identifier CVE-; entering the date in the database; date of last edition; source of vulnerability (information); a brief description (review); evaluation results for each metric CVSS (see. Fig. 1 and Table. 1) -Base Score, Temporal Score and Environmental Score. The database CVSS available in two versions - v2.0 [10] and v3.0 [11]; vulnerable versions of the software; CWE category; additional links; other information [15]. Note that the condition of existence of the vulnerability is stored in the form of the disjunctive normal form. Let us consider in more detail each of the versions of the CVSS and define their differences.

CVSS v2.0. Metrics and their parameters in the CVSS v2.0 standard [10] shown in Fig. 1. In this version carried a standardized assessment of vulnerabilities, the system is open and is focused on the identification of priority risks. Each metric group (MG) defines the characteristics of vulnerability. We describe these groups (see. Fig. 1).

Figure 1. MGCVSS v2.0

Base Score Metrics –characteristics of vulnerabilities that are constant over long periods of time in the user environment, and do not depend on them. They also describe the difficulty of exploitation and potential damage to the confidentiality, integrity, and availability. MG used indicators consist of the following: Access Vector (AV); Access Complexity (AC); Authentication (Au); Confidentiality Impact (C); Integrity Impact (I); Availability Impact (A).

Temporal Score Metrics – vulnerability characteristics that vary over time, regardless of user environments. They contribute to the overall assessment of the amendment on the completeness of available information about the vulnerability, maturity, operated by a code (if any) and the availability of patches. Its indicators are: Exploitability (E); Remediation Level (RL); Report Confidence (RC).

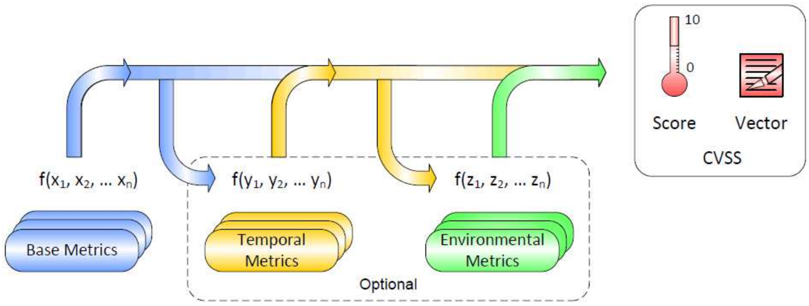
Table 1. Values of CVSS v2.0 ratings

MG	The set of indicators	Sets character values indicators	The numerical values of the respective indicators
Basic	**AV**	L; A; N	0,395; 0,646; 1
	AC	H; M; L	0,35; 0,61; 0,71
	Au	M; S; N	0,45; 0,56; 0,704
	C; I; A	N; P; C	0; 0,275; 0,66
Temporary	**E**	ND; U; POC; F; H	1; 0,85; 0,9; 0,95; 1
	RL	ND; OF; TF; W; U	1; 0,87; 0,9; 0,95; 1
	RC	ND; UC; UR; C	1; 0,90; 0,95; 1
Environment surroundings	**CDP**	ND; N; L; LM; MH; H	0; 0; 0,1; 0,3; 0,4; 0,5
	TD	ND; N; L; M; H	1; 0; 0,25; 0,75; 1
	CR; IR; AR	ND; L; M; H	1; 0,5; 1; 1,51

Environmental Score Metrics –characteristics of a vulnerability that are relevant and unique to a particular user environment. MG includes indicators General Modifiers -Collateral Damage Potential (CDP), Target Distribution (TD) and Impact Sub score Modifiers - Confidentiality Requirement (CR), Integrity Requirement (IR), Availability Requirement (AR).

Table 1 shows for each MG sets of symbol values and their corresponding numeric indicators.. Here, each character values define the corresponding linguistic interpretation - for AV (Access Vector): L - «Local access"; A - «Network Coupling"; N - «Network», for AC (Access Complexity): H - «high»; M - «average»; L - «low» for Au (Authentication): M - «Reusable"; S - «One-time"; N - «No», to C (Confidentiality Impact), I (Integrity Impact), A (Availability Impact): N - «No»; P - «Partial»; C - «full», to E (Exploitability): ND - «not a certainty"; U - «Theoretical (no evidence)"; POC - «Experimental»; F - «Function"; H - «high» for RL (Remediation Level): ND - «not defined"; OF - «official patch"; TF - «Workaround"; W - «The decision, based on advice and recommendations"; U - «No» to RC (Report Confidence): ND - «not a certainty"; UC - «Wears tentative"; UR - «not worked out"; C - «confirmed», for CDP (Collateral Damage Potential): ND - «not a certainty"; N - «No»; L - «low»; LM - «Low - medium"; MH - «Medium - High"; H - «high» for TD (Target Distribution): ND - «not defined"; N - «No»; L - «low»; M - «average»; H - «high» for CR (Confidentiality Requirement), IR (Integrity Requirement), AR (Availability Requirement): ND - «not defined"; H - «High"; M - «average»; L - «low» (see also Figures 1 and 2).

After assigning character values of specific numbers, it made the rating calculation (in the aisles [0; 10]) and the creation of vector AV: N / AC: L / Au: N / C: N / I: N / A: P, which displays the "openness "structure. This is a text string that contains the values assigned to each metric and is used to communicate assessments. Herewith, the vector should be displayed based on vulnerability [10]. Time and context MG are optional and are used for a more accurate assessment of the danger posed by this vulnerability for a particular infrastructure. Meaning MG is displayed as a pair (see. Fig. 2) of the vector and the numerical value calculated on the basis of performance through standard formulas [10]. Using Temporal allows you to combine the temporary and benchmarks that are displayed on a scale from outside [1; 10]. At this time estimate is not above the base, but it is not less than 33% [10].



Metric Group	Vector
Base	AV:[L,A,N]/AC:[H,M,L]/Au:[M,S,N]/C:[N,P,C]/I:[N,P,C]/A:[N,P,C]
Temporal	E:[U,POC,F,H,ND]/RL:[OF,TF,W,U,ND]/RC:[UC,UR,C,ND]
Environmental	CDP:[N,L,LM,MH,H,ND]/TD:[N,L,M,H,ND]/CR:[L,M,H,ND]/ IR:[L,M,H,ND]/AR:[L,M,H,ND]

Figure 2. CVSS v2.0 – MG and vector

CVSSv3.0. Calculator CVSS v3.0 is a development CVSS v2.0. Consider the vulnerability in the virtual machine, threatened the main operating system (OS). Here, the affected component is a virtual machine and affecting component - host OS. This is due to the fact that these two components independently control rights to computing resources. The virtual machine is controlled by "Administrator A", while the host OS controlled "by the Administrator in". When two components are operated simultaneously administrator, it can initiate the establishment of vulnerability. In this case, the CVSS believes that the changes have already occurred. This condition is now reflected in the new MG [11]. In the framework of the standard introduces the following two basic concepts. Vulnerable component - EC component that contains the vulnerability involved in the process of operation. Impacted component - EC component whose basic safety features (confidentiality, integrity, and availability) can be violated in the success of the attack. As a rule, the vulnerable and attacked the components are the same, but there are vulnerabilities classes for which this rule does not work, for example, going beyond the "sandbox" applications; to gain access to user data stored in the browser, through a vulnerability in web applications (XSS); going beyond the guest virtual machines, and others. In this version, exploited metrics are calculated for the affected component, and metrics for the impact attacked. Version CVSS v2 is not allowed to display a situation in which the affected component, and attacked different [3, 11]. In CVSS v3.0 Access Vector v2.0 was renamed the attack vector, but as before, reflects the "remoteness" attacker in relation to vulnerable components. In other words, the more distant an attacker is the relatively vulnerable component (in terms of logical and physical network distance), the larger the baseline assessment. In addition, the figure distinguishes local attacks that require local access to the system (the attack on the application software) and physical, that require physical access to exploit this vulnerability (FireWire, USB, or jail breaking attack) platform [10]. The changes affected the concept of the value of the indicator «Local», which previously has described any actions do not affect the network. The new standard introduces the following division of the index values. Local - for the operation of the attacker requires a local session or specific action on the part of a legitimate user. The physical - attack requires physical access to a vulnerable subsystem [3]. Change index AU, the complexity of exploitation, which is a qualitative assessment of the complexity of the attack. The more conditions must be met for exploitation - the higher the complexity [3]. Two values «Low» indicator and «Medium» There were merged. The difficulty of access was presented in two parameters - the complexity of the attack, and user interaction. [11] For vulnerabilities that allow implementing the attack "man in the middle" (active attack [10]) in the NVD database can meet a variety of assessment options AC. It offers two levels of difficulty «High», «Low» and clearly defined criteria for classifying vulnerabilities to them. Factors to be considered in a CVSS v2 parameter AC, the new standard is revealed by two indicators - Attack Complexity and User Interaction [3]. In CVSS v3.0, a new indicator Privileges Required proxy for "authentication" in v2.0 (authentication / required level of privilege - whether authentication is required to carry out the attack, and if required, which is it, [3]). Necessary privileges to reflect the level of access required for a successful attack. The approach to calculating the index, based on the number of independent authentication processes that need to undergo an attacker [3]. All other changes in CVSS v3.0 are shown in Table 2 [10]. For each MG for each set of indicators are given sets of symbol values and their corresponding numerical indicators (Table. 2).

Table 2.Values of CVSS v3.0 ratings

MG	Many index	Sets the character values of the indicators	The numerical values of the respective indicators
Basic	AV	N; A; L; P	0,85; 0,62; 0,55; 0,2
	AC	H; L	0,77; 0,44
	PR	H; L; N	0,85; 0,62 (0,68*); 0,27 (0,50*)
	UI	N; R	0,85; 0,62
	S	U; C	-
	C; I; A;	N; L; H;	0; 0,22; 0,56
Temporary	E	U; P; F; H; X	0,91; 0,94; 0,97; 1; 1
	RL	O; T; W; U; X	0,95; 0,96; 0,97; 1; 1
	RC	U; R; C; X	0,92; 0,96; 1; 1
The environment	CR; IR; AR	L; M; H; X	0,5; 1; 1,5; 1
Modified base	MAV; MAC; MPR; MUI; MS; MC; MI; MA	They have the same character and numeric indicators, the corresponding figures are not modified in the base of MG and «Not Defined» (default)	
*if the scope of the (S) / modified scope (MS) modified			

As each character values specify the corresponding linguistic interpretation - for AV (Attack Vector): N - «Network»; A - «Network Coupling"; L - «Local access"; P - «Physical access" to AC (Attack Complexity): H - «high»; L - «average» for PR (Privileges Required): H - «high»; L - «Medium»; N - «No», to C (Confidentiality Impact), I (Integrity Impact) and A (Availability Impact): H - «High"; L - «average»; N - «No», for the UI (User Interaction): N - «No»; R - «required» for S (Scope): U - «No change»; C - «change», for E (Exploitability): U - «Theoretical (no evidence)"; P - «Experimental»; F - «Function"; H - «high»; X - «not defined» for RL (Remediation Level): O - «official patch"; T - «Workaround"; W - «The decision, based on advice and recommendations"; U - «No»; X - «Not Defined" for the RC (Report Confidence): U - «No»; R - «grounded»; C - «confirmed»; X - «not defined" for (Security Requirements) CR (Confidentiality Requirement), IR (Integrity Requirement), AR (Availability Requirement): L - «low»; M - «average»; H - «High"; X - «not defined." A modified base group of metrics describes the indicators MAV (Modified Attack Vector), MAC (Modified Attack Complexity), MPR (Modified Privileges Required), MUI (Modified User Interaction), MS (Modified Scope), MC (Modified Confidentiality), MI (Modified Integrity) and MA (Modified Availability). For each vulnerability is assigned a CWE category, in accordance with which the grouping is carried out them on certain categories to reflect the weak points of the RIS. According to the present site in the CWE ™ report on 12.07.2015 was recorded in 1004 CWE categories weaknesses [12]. During the NVD database study found that 82.77% of vulnerabilities are owned applications, 12.28% - OS, and 3.59% - hardware [7].

Data Bank information security threats (Russian Federation) **(DBIST).** Bank DBIST developed by the Federal Service for Technical and Export Control of Russia and the State Scientific Research Testing Institute GI Russian technical problems. The Bank provides information about the major threats to information security and vulnerability in the first place, specific to public IP and automated production control systems and technological objects of critical infrastructures. Information about threats and vulnerabilities of information security software contained in BDUBI are not exhaustive and may be supplemented by an analysis of the relevant threats and vulnerabilities in the particular IC in view of features of its operation. The data contained in BDUBI are not elements of a hierarchical classification system and represent a generalized list of the main threats and potentially dangerous for the IB IP vulnerabilities. Last update on 7/11/16 BDUBI city contained 186 threats and vulnerabilities 14395 [1]. Each threat introduced into BDUBI, described by the following set of parameters: a unique identifier UBI (information security risk); threat name; description of the threat; threat source (intruder type and minimum required functionality (potential)); the impact of an object; consequences of the threat [1]. In the process of entering into BDUBI vulnerability information, use the following set of parameters: the ID (composed of year and number of the order); the name of the vulnerability; vulnerability; the vendor (the company - the manufacturer of the software in which the vulnerability is detected); the name of the software; version of the software; the type of software; OS and hardware platforms; the type of error; an error type identifier (ID set corresponding to the list of common errors CWE); the vulnerability of the class; identifying data; vector base MG vulnerability (for CVSS v2.0); Vulnerability Severity (on CVSS v2.0); possible measures to address the vulnerability; the status of the vulnerability; availability of exploit; the elimination of information; references to sources; Identifiers other systems vulnerability descriptions (e.g., CVE); other information [1]. The site also contains a calculator BDUBI CVSS v2.0, which is the Russian version of a similar calculator NVD. Here is an infographic, which displayed summary data on different parameters.

OSVDB. Base OSVDB established in 2002 as an independent and open database of vulnerabilities for specialists in the field of information security. The aim of the project was to provide accurate, detailed and current information about the vulnerabilities, to ensure information security systems EB [7]. On May 5, 2014, this database contained 105,413 vulnerabilities. OSVDB Web interface is not much different from the NVD database. Each vulnerability recorded OSVDB, described by the following entries: ID OSVDB; Detection date; the name of the manufacturer; product name; version of the product (symbolic value), which has this vulnerability; link pointing to the direct address of an Internet resource base or another base manufacturer, which describes this vulnerability; a decision that has the description "fix" vulnerabilities; Vulnerability metric containing Vulnerability Assessment criteria CVSS v2.0 format (are not required because the field is present with the reference to the base NVD) [7]. It is worth noting that OSVDB 2016 became conditionally open database now provides paid services for vulnerability information. At the same time, its developers have entered into the partnership with Risk Based Security, which sells licenses to customers for a data access.

IBM X-Force. Base IBM ISS (Internet Security Services) X-Force, created by the experts of IBM Internet Security Systems X-Force unit is one of the largest and most authoritative DB in the industry. It contains more than 30,000 entries and a detailed analysis of each known vulnerability, discovered in 1994. Moreover, experts X-Force unit cooperating with thousands of the world's largest companies and government agencies, the Center for Analysis and vertical information exchange (ISAC), the global focal points and other solution providers. [20] To access the vulnerability database must be registered on the IBM X-Force Exchange Online. After registering in the search string must specify the necessary information about the vulnerability. As can be seen from the description of the vulnerability used by analogy with the previous databases to CVSS assessment (v2.0 was used until 2016, when - v3.0), CVE identifier, a brief description, date of creation of the vulnerability report, affected products that have this vulnerability and external links. But unlike the other databases, there is the "Consequences" section expressing possible results of exploitation in a formalized manner, for example, «Gain Access» (for access) and "Fix", which shows the variations of countermeasures [7, 13].

US-CERT. The base belongs to VND United States Computer Emergency Readiness Team - US-CERT and developed jointly with the Office of Cybersecurity and Communications, Department of Homeland Security, Software Engineering Institute and Carnegie Mellon University. Each vulnerability is assigned a DB identifier «VU #». By analogy with the database considered above in VND, following are the main points of vulnerability: a review; short description; impact; recommendations on elimination; assessment CVSS; also in the additional information indicates (if any) identifier CVE; the date of the first publication and updates. Unlike the rest of the database is recorded, indicating the vulnerability of the affected party and the information about the seller. Also at VND database site has an option to obtain summary data CVSS vulnerability assessments [19].

SecurityFocus. The database was developed in 1999 and is owned by Symantec's [18]. The Security Focus by the addition of the latest vulnerability is assigned a Bugtraq ID and define a class. By analogy with other open source database vulnerability also has an identifier CVE; date of publication and updating; information remotely or locally; vulnerable products. The site for the specific vulnerability is further available information in separate tabs, discussion (description), information about the use, the solution countermeasures and recommendations. The study presented in the database, you can conclude that almost every vulnerability introduced into a particular database is assigned a CVE identifier and the score is determined

CVSS. Also during the study criteria were identified (see Table 3.) Such as the presence of CVSS evaluation of v2.0 and / or v3.0, Calculator CVSS, CVE identifier, the CWE category, expansion options, the output of critical threats / vulnerabilities integration capabilities and risk assessment / risk calculator, which can realize a comparison of similar databases. It should be noted that from the above criteria, the developers of information security assessment systems may be helpful, such as the presence of CVE identifier, according to CVSS v2.0 assessment and / or v3.0, to CVSS calculator, expansion capabilities, risk assessment / risk calculator, etc. Thus, in the defined set of criteria for database vulnerabilities RIS which can be carried out a comparative analysis of these databases and choose the most suitable for the construction of various state estimation of information security systems, such as risk assessment systems or risk calculators. It is also worth noting that the risk assessment procedure is not provided for in one of the provided databases.

Table 3. Summary of research DB vulnerabilities

DB	Criteria									
	Risk Assessment / Risk Calculator	VersionsCVSS		CalculatorCVSS		CVE identifier	CWEcategory	Expandable	Conclusion critical threats / vulnerability	Integration
		2.0	3.0	2.0	3.0					
NVD	-	+	+	+	+	+	+	+	-	+
DBIST	-	+	-	+	-	+	+	+	-	-
OSVDB	-	+	-	-	-	+	-	-	-	+
IBM X-Force	-	+	+	-	-	+	+	+	-	+
VND	-	+	+	-	-	+	+	+	+	+
Security Focus	-	-	-	-	-	+	-	+	-	+

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SYSTEMS ANALYSIS ALGORITHM FOR PROBLEMS OF HEALTH INSURANCE

Summary: The four-stage model of the disease was considered, where the residence time for every stage had the Gompertz distribution. The transition probabilities were calculated. For this purpose, the distributions of the total residence time at the disease stages was shown

Keywords: oncological diseases model, stage residence time, Gompertz distribution, algorithm for the transition probabilities search, computing the medical insurance policy parameters

ALGORYTM ANALIZY SYSTEMOWEJ DLA ZAGADNIEŃ UBEZPIECZENIA ZDROWOTNEGO

Streszczenie: Rozpatruje się cztero-fazowy model choroby, gdzie czas rezydencji dla każdej fazy ma dystrybucję Gompertza. Prawdopodobieństwa przejścia zostały obliczane. W tym celu wyznaczono dystrybucję sumarycznego czasu rezydencji w poszczególnych fazach choroby.

Słowa kluczowe: choroby onkologiczne, czas rezydencji w fazie, rozkład Gompertza, algorytm poszukiwania prawdopodobieństwo przemieszczenia, parametry ubezpieczenia zdrowotnego

1. Introduction

In this work there are presented new theoretical results on problem solution of the development of mathematical models of medical insurance processes and their implementation in the form of software environment of medical insurance indices determining dependencies on disease etiology.

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There is developed advanced model of medical insurance in case of epidemiological diseases considering SLIAR-models and calculating values of insurance premiums in different cases of annuity.

There is developed advanced model of medical insurance for multistage diseases considering waiting time for patient at stage.

There is obtained expressions for transmission probabilities for four-compartmental disease in case of exponential distributed waiting time for patient during stage and values of insurance functions and treatment costs.

In case of four-staged disease with waiting time due to Gompertzian distribution there is calculated transmission probability and investigated distribution law for total waiting time.

There is developed software environment for medical insurance indices calculation taking into account disease etiology.

In [1–3], a multistage model of the disease is considered as a compartmental process for which the residence time distribution laws of a patient at every stage are known.

For different types of diseases the stages can be classified variously. Thus, for infectious diseases the initial stages are connected with infectious and latent periods, for oncological diseases it is early stages of cancer, etc. An individual can move from one stage to the next stage with certain transition probabilities. At any time, an individual can die because of the reasons not connected with the disease, that is, it can go directly from a certain stage to the stage of death.

Currently, there are two basic approaches to modeling the disease as a multistage compartmental process.

In the first approach one takes into account the number of patients at every stage, which can be described mathematically both by means of differential equations, and with the help of a Markov chain with a single increment (birth-death processes). This approach has been applied mainly in the study of the infectious diseases described by epidemics. The complexity of this approach in practical applications, following, for example, from the problems of health insurance, is a difficulty of obtaining information on the number of all patients being on the stage.

In the second approach one uses the residence time of a patient at every stage, which is more accessible information, for example, when it is talked of oncological diseases.

In [4], a general model of the $m+3$ -stage disease, based on account the patient's residence time on the stage, has been proposed.

$S(t)$ is a stage (integer from 0 to $m+1$) in which the patient stays at the time moment t;

V_i is a patient's residence time on the stage i until passage to the stage $i+1,\ i=\overline{0,m}$;

U_i is a patient's residence time on the stage i until passage to the stage $m+2$.

Let us introduce the auxiliary random variables:

$$H_i = \min(U_i, V_i),\quad W_i = U_i - V_i,\quad i=\overline{0,m},\quad Y_{ij} = \sum_{k=i}^{j} H_k .$$

The main result of work [4] is formulated as a theorem.

Theorem. The transition probabilities $q_{ij}(t),\ i \le j,\ \ i, j = \overline{0, m+1}$, can be calculated according to the relation

$$q_{ij}(t) = P\{S(t) = j / S(0) = i\} = P\{W_k > 0, k = \overline{i, j-1}\} \times (P\{Y_{ij} > 0 / W_k > 0, k = \overline{i, j-1}\} -$$
$$- P\{Y_{i, j-1} > t / W_k > 0,\ k = \overline{i, j-1}\}).$$

Practical application of the theorem for real nosology requires consideration of specific classes of distributions of the values U_i and V_i.

In work [5] it was shown experimentally for the first time that the tumor growth corresponded to the Gompertz distribution law. The survival of cancer patients, as well as their residence time in the stages of the disease, follow this law. Therefore, the objective of this work is to calculate the patient's residence time in the stages of oncological disease. Such results are of practical importance while calculation of the parameters of a medical insurance policy.

2. Main part

Let us consider the case when the values $U_i, V_i,\ i = \overline{0,2}$ have Gompertz distribution, i.e., $U_i \sim G(\mu_i, \eta_i)$, $V_i \sim G(\alpha_i, \beta_i)$, $i = \overline{0,2}$. Here it is used the overdetermination of the Gompertz distribution parameters, according to which

$$F_{U_i}(t) = 1 - \exp\left[- e^{\frac{t-\mu_i}{\eta_i}} \right],$$

$$F_{V_i}(t) = 1 - \exp\left[- e^{\frac{t-\alpha_i}{\beta_i}} \right], \quad i = \overline{0,2}.$$

In the sequel, only the case when $\eta_i = \beta_i\ i = \overline{0,2}$ will be considered.

Distribution H_i**.** Let us find the distribution H_i, $i = \overline{0,2}$ when $\eta = \beta$.

One has

$$P\{H > t\} = P\{U > t, V > t\} = \exp\left[- e^{\frac{t-\mu}{\eta}} \right] \exp\left[- e^{\frac{t-\alpha}{\eta}} \right] =$$
$$= \exp\left[- e^{\frac{t-\mu}{\eta}} (1 + e^{\frac{t-\alpha}{\eta}}) \right], \quad t > 0, \tag{1}$$

and the corresponding probability density function has the form

$$f_H(t) = -\frac{d}{dt}P\{H>t\} = (-1)(1+e^{\frac{\mu-\alpha}{\eta}}) \times \exp\left[-e^{\frac{t-\mu}{\eta}}(1+e^{\frac{\mu-\alpha}{\eta}})\right](-e^{\frac{t-\mu}{\eta}}) \cdot \frac{1}{\eta} =$$

$$= \frac{1}{\eta}(e^{\frac{t-\mu}{\eta}} + e^{\frac{t-\alpha}{\eta}})\exp\left[-e^{\frac{t-\mu}{\eta}} - e^{\frac{t-\alpha}{\eta}}\right]. \tag{2}$$

Distribution W_i.

Statement 1. Let $U \sim G(\mu,\eta)$ and $V \sim G(\alpha,\beta)$ be random variables distributed by Gompertz, and $\eta = \beta$. Then the difference $W = U - V$ of the distribution has the probability density function

$$f_{U-V}(t) = \frac{\eta e^{-\frac{t+\mu+\alpha}{\eta}}}{(e^{-\frac{\mu}{\eta}} + e^{-\frac{t+\alpha}{\eta}})^2}. \tag{3}$$

Proof. One has the density function

$$f_U(t) = \frac{1}{\eta}\exp\left[\frac{x-\mu}{\eta} - e^{\frac{x-\mu}{\eta}}\right],$$

$$f_{-V}(t) = \frac{1}{\eta}\exp\left[\frac{-x-\alpha}{\beta} - e^{\frac{-x-\alpha}{\beta}}\right].$$

According to the convolution theorem and taking into account that $\eta = \beta$, one has

$$f_{U-V}(t) = \int_{-\infty}^{\infty} f_U(s) f_{-V}(t-s)\,ds = \frac{1}{\eta^2}\int_{-\infty}^{\infty}\exp\left[\frac{s-\mu}{\eta} - e^{\frac{s-\mu}{\eta}}\right]\exp\left[\frac{s-t-\alpha}{\beta} - e^{\frac{s-t-\alpha}{\beta}}\right]ds =$$

$$= \frac{1}{\eta^2}\int_{-\infty}^{\infty}\exp\left[\frac{2s-t-\mu-\alpha}{\eta} - e^{\frac{s-\mu}{\eta}} - e^{\frac{s-t-\alpha}{\eta}}\right]ds.$$

Let us use the change of the variables $s = \ln x.$ Then $ds = \frac{1}{x}dx,$ and the integration limits are changed to $x \in (0,\infty).$ The result is

$$f_{U-V}(t)=\frac{1}{\eta^2}\int_0^\infty \frac{1}{x}\exp\left[\frac{2\ln x-t-\mu-\alpha}{\eta}-e^{-\frac{\mu}{\eta}}x^{\frac{1}{\eta}}-e^{-\frac{t+\alpha}{\eta}}x^{\frac{1}{\eta}}\right]dx=$$

$$=\frac{1}{\eta^2}\int_0^\infty \frac{1}{x}x^{\frac{2}{\eta}}e^{-\frac{t+\mu+\alpha}{\eta}}\exp\left[-x^{1/\eta}(e^{-\frac{\mu}{\eta}}+e^{-\frac{t+\alpha}{\eta}})\right]dx.$$

Let us use the change of the variables $\varphi=x^{1/\eta}(e^{-\frac{\mu}{\eta}}+e^{-\frac{t+\alpha}{\eta}})$. Then $d\varphi=(e^{-\frac{\mu}{\eta}}+e^{-\frac{t+\alpha}{\eta}})\frac{1}{\eta}x^{\frac{1}{\eta}-1}dx$

$$f_{U-V}(t)=\frac{1}{\eta^2}e^{-\frac{t+\mu+\alpha}{\eta}}\int_0^\infty \eta x^{\frac{1}{\eta}}e^{-\varphi}\frac{d\varphi}{(e^{-\frac{\mu}{\eta}}+e^{-\frac{t+\alpha}{\eta}})}=\frac{1}{\eta}e^{-\frac{t+\mu+\alpha}{\eta}}\int_0^\infty\frac{\varphi e^{-\varphi}d\varphi}{(e^{-\frac{\mu}{\eta}}+e^{-\frac{t+\alpha}{\eta}})^2}=\frac{e^{-\frac{t+\mu+\alpha}{\eta}}}{\eta(e^{-\frac{\mu}{\eta}}+e^{-\frac{t+\alpha}{\eta}})^2},$$

which was to be proved.

The probabilities $P\{W_i>0\}$. Obviously, $P\{W_i>0\}=P\{$ the individual survived in the step i and moved to the step $(i+1)\}$. Consequently,

$$P\{W_i>0\}=\int_0^\infty\frac{e^{-\frac{t+\mu+\alpha}{\eta}}}{\eta(e^{-\frac{\mu}{\eta}}+e^{-\frac{t+\alpha}{\eta}})^2}dt.$$

Let us introduce the change of variables: $\varphi=e^{-\frac{\mu}{\eta}}+e^{-\frac{t+\alpha}{\eta}}$. Then $d\varphi=-\frac{1}{\eta}e^{-\frac{t+\alpha}{\eta}}dt=-\frac{1}{\eta}(\varphi-e^{-\frac{\mu}{\eta}})dt,$ and the integration limits are changed to $\varphi\in(e^{-\frac{\mu}{\eta}}+e^{-\frac{\alpha}{\eta}},e^{-\frac{\mu}{\eta}})$. The result is

$$P\{W>0\}=-\int_{e^{-\frac{\mu}{\eta}}}^{e^{-\frac{\mu}{\eta}}+e^{-\frac{\alpha}{\eta}}}\frac{(\varphi-e^{-\frac{\mu}{\eta}})e^{-\frac{\mu}{\eta}}}{\eta\varphi^2}\cdot\frac{d\varphi}{(-\frac{1}{\eta})(\varphi-e^{-\frac{\mu}{\eta}})}=\int_{e^{-\mu/\eta}}^{e^{-\frac{\mu}{\eta}}+e^{-\frac{\alpha}{\eta}}}e^{-\frac{\mu}{\eta}}\frac{d\varphi}{\varphi^2}=$$

$$=-e^{-\mu/\eta}\cdot\frac{1}{e^{-\frac{\mu}{\eta}}+e^{-\frac{\alpha}{\eta}}}-e^{-\frac{\mu}{\eta}}\cdot\frac{1}{e^{-\mu/\eta}}=1-\frac{e^{-\frac{\mu}{\eta}}}{e^{-\frac{\mu}{\eta}}+e^{-\frac{\alpha}{\eta}}}.\tag{4}$$

Total waiting time. In the case of the assumption $\eta_i = \beta_i$ let us consider the problem of finding the common waiting time $Y_{ij} = \sum_{k=1}^{j} H_k$.

Obviously, that for $i = j$ $Y_{ij} = H_i$, $i = \overline{0,2}$. At the same time the probability density function is of the form

$$f_{Y_{ii}}(t) = \frac{1}{\eta_i}\left(e^{\frac{t-\mu_i}{\eta_i}} + e^{\frac{t-\alpha_i}{\eta_i}}\right)\exp\left[-e^{\frac{t-\mu_i}{\eta_i}} - e^{\frac{t-\alpha_i}{\eta_i}}\right], \qquad i = \overline{0,2}.$$

Let us find the distribution of the value $Y_{01} = H_0 + H_1$. Let us use the representation

$$F_{H_i}(t) = 1 - \exp\left[-e^{\frac{t-\mu_1}{\eta_1}}\left(1 + e^{\frac{\mu_i-\alpha_1}{\eta_1}}\right)\right].$$

One has

$$f_{H_0+H_1}(t) = \int_{-\infty}^{\infty} F_{H_1}(t-s)\,dF_{H_0}(s) = \int_{-\infty}^{\infty}\left(1 - \exp\left[-e^{\frac{t-s-\mu_1}{\eta_1}}\left(1 + e^{\frac{\mu_1-\alpha_1}{\eta_1}}\right)\right]\right)dF_{H_0}(s) =$$

$$= 1 - \int_{-\infty}^{\infty}\exp\left[-e^{\frac{t-s-\mu_1}{\eta_1}}\left(1 + e^{\frac{\mu_1-\alpha_1}{\eta_1}}\right)\right]\frac{1}{\eta_0}\left(e^{\frac{s-\mu_0}{\eta_0}} + e^{\frac{s-\alpha_0}{\eta_0}}\right)\exp\left[-e^{\frac{s-\mu_0}{\eta_0}} - e^{\frac{s-\alpha_0}{\eta_0}}\right]ds =$$

$$= 1 - \frac{1}{\eta_0}e^{\frac{s-\mu_0}{\eta_0}}\exp\left[-e^{\frac{t-s-\mu_1}{\eta_1}} - e^{\frac{t-s-\alpha_1}{\eta_1}} - e^{\frac{s-\mu_0}{\eta_0}} - e^{\frac{s-\alpha_0}{\eta_0}}\right]ds -$$

$$- \frac{1}{\eta_0}\int_{-\infty}^{\infty} e^{\frac{s-\mu_0}{\eta_0}}\exp\left[-e^{\frac{t-s-\mu_1}{\eta_1}} - e^{\frac{t-s-\alpha_1}{\eta_1}} - e^{\frac{s-\mu_0}{\eta_0}} - e^{\frac{s-\alpha_0}{\eta_0}}\right]ds.$$

Note that in the right-hand side special functions are obtained, which study is a separate problem.

In a similar way one can calculate the distributions Y_{12} and Y_{02}.

The following result, obtained in the absence of mortality in the intermediate stages of the disease, points to the fact that at this stage one will certainly come to the special functions.

Statement 2. Let V_0 be distributed according to $G(\mu,\eta)$, and V_1 according to $G(0,\eta)$ are independent random variables. Here $\mu,\eta > 0$.

Then the random variable $Y = V_0 + V_1$ has the distribution function

$$F_Y(t) = 1 - 2\sqrt{Z}\, K_1(2\sqrt{Z}), \tag{5}$$

where $Z = e^{\frac{t-\mu}{\eta}}$, and $K_1(\cdot)$ is modified Bessel function of the second kind [6].

Proof.

$$F_{V_0+V_1}(t) = \int_{-\infty}^{\infty} (\int_{-\infty}^{t-t_1} f_{V_0}(t_1) f_{V_1}(t_2)\, dt_2)\, dt_1 = \int_{-\infty}^{\infty} f_{V_0}(t_1) (\int_{-\infty}^{t-t_1} f_{V_1}(t_2)\, dt_2) dt_1 =$$

$$= \int_{-\infty}^{\infty} f_{V_0}(t_1) F_{V_1}(t-t_1) dt_1 = \int_{-\infty}^{\infty} F_{V_1}(t-t_1) dF_{V_0}(t_1).$$

Using the representation

$$F_{V_0}(t) = 1 - e^{-e^{\frac{t-\mu}{\eta}}}, \quad F_{V_1}(t) = 1 - e^{-e^{\frac{t}{\eta}}},$$

one will get

$$F_{V_0+V_1}(t) = \int_{-\infty}^{\infty} (1 - e^{-e^{\frac{t-t_1}{\eta}}}) \exp\left[\frac{t_1-\mu}{\eta} - e^{\frac{t_1-\mu}{\eta}}\right] dt_1 =$$

$$= \int_{-\infty}^{\infty} f_{t_1}(t_1)\, dt_1 - \int_{-\infty}^{\infty} \exp\left[\frac{t_1-\mu}{\eta} - e^{\frac{t_1-\mu}{\eta}} - e^{\frac{t-t_1}{\eta}}\right] dt_1.$$

Let us use the change of variables: $e^{\frac{t_1-\mu}{\eta}} = u.$ Then $\frac{1}{b} e^{\frac{t_1-\mu}{\eta}}\, dt_1 = du,$ i.e., $\frac{1}{\eta} u dt_1 = du.$

In this case, $e^{\frac{t_1}{\eta}} = u e^{\frac{\mu}{\eta}}$, that is $e^{\frac{t-t_1}{\eta}} = \frac{1}{u} e^{\frac{t-\mu}{\eta}}$. This implies

$$F_{V_0+V_1}(t) = 1 - \eta \int_0^{\infty} \exp\left[\ln u - u - \frac{1}{u} e^{\frac{t_1-\mu}{\eta}}\right] \frac{du}{u} = 1 - \eta \int_0^{\infty} \exp\left[-u - \frac{1}{u} e^{\frac{t-\mu}{\eta}}\right] du =$$

$$= 1 - 2e^{\frac{t-\mu}{2\eta}} \int_0^{\infty} \frac{\eta}{2} \exp\left[-u - \frac{1}{u} e^{\frac{t-\mu}{\eta}} - \frac{t-\mu}{2\eta}\right] du.$$

Let us denote $Z = e^{\frac{t-\mu}{\eta}}$ and introduce the function

$$\int_0^\infty \frac{\eta}{2}\exp\left[-u-\frac{1}{u}Z-\frac{\ln Z}{2}\right]du=\int_0^\infty \eta\exp\left[-u-\frac{(2\sqrt{Z})^2}{4u}\right]\frac{1}{2\sqrt{Z}}du=:w(2\sqrt{Z}).$$

One can show that $w(t)$ is a solution of the differential equation

$$t^2\frac{d^2w}{dt^2}+t\frac{dw}{dt}-(t^2+1)w=0,$$

i.e., $w(t)=K_1(t)$ is a modified Bessel function of the second kind [4]. Therefore, finally one has

$$F_{V_0+V_1}(t)=1-2\sqrt{Z}K_1(2\sqrt{Z}).$$

A numerical example. Since the value H_i is an exact residence time on the stage i then the character of its distribution is an important information for calculating the parameters of the health insurance policy. *iH*
Let us consider the effect of the distribution of the value U_i on the distribution H_i.

To do this, let us calculate the distribution H_i by formula (2) on the example

$$U_i \sim G(6,2)\,,\ U_i \sim G(5,2)\,,\ U_i \sim G(4,2)\,, \tag{6}$$

$$V_i \sim G(5,2)\,. \tag{7}$$

Fig. 1 shows the distribution densities of the value H_i in three considered cases. It can be seen that while increasing the parameter μ in the distribution U_i the density curve H_i is shifted to the right.

The positiviness of the value W_i determines the direction of the disease: the positive sign means patient transition to the next stage; the negative sign means a stage of death. Fig. 2 shows the densities of the distribution W_i, calculated by formula (3). At $\mu=4$ the fatal outcome is most probable, for $\mu=6$ the patient most probably will move to the stage $i+1$
The probabilities corresponding to the transition from the stage i to the stage $i+1$, calculated by formula (4) on the example of the values (6), (7), are shown in the Table. When increasing the parameter μ in the distribution of the time U_i the probability of transition to the next stage of the disease increases.

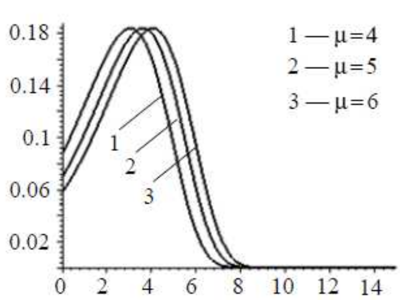

Figure 1

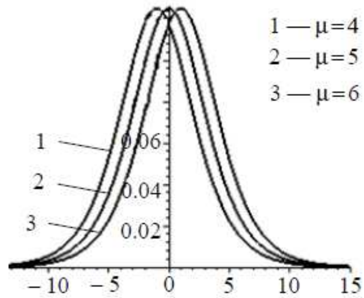

Figure 2

Table

μ_i	η_i	α_i	$P\{W_i > 0\}$
6	2	5	0.62
5	2	5	0.5
4	2	5	0.38

Distribution Y_{01}. Let us consider the case when V_0 corresponds to the distribution (6), and $V_1 \sim G(0,2)$. In all the cases it is assumed that $U_i > V_i$ i.e., it is known that for the patient at this stage of the disease the fatal outcome is impossible. Then $Y_{01} = V_0 + V_1$. The distribution functions Y_{01}, calculated using the formula (5), are shown in Fig. 3.

Fig. 4 shows a graph of the distribution density Y_{01}.

It can be seen that while increasing the scale parameter μ the patient's general residence time in the stages grows.

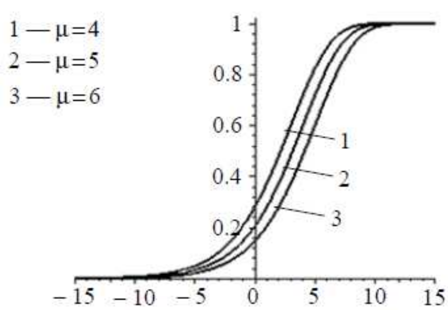

Figure 3

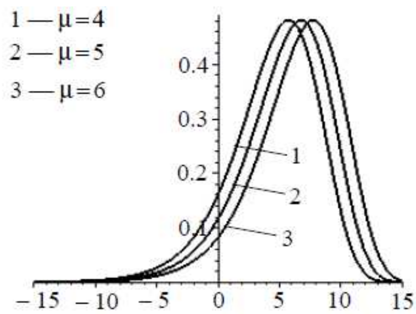

Figure 4

3. Conclusions

In this paper the model of a multistage disease is considered, where the residence time on every stage has the Gompertz distribution, that is most characteristic of oncological diseases. The algorithm for the search of the transition probabilities is proposed,

which implementation is demonstrated by the four stage-model. For such simplified model the structural formulas for the distribution of the difference and sum of random variables of the residence time, which have the Gompertz distribution, are obtained.
The stages effect of oncological diseases development in this model can be represented by the parameters of the Gompertz distribution for the values U_i and V_i, that is, the scale parameter μ_i, α_i and form parameters η_i and β_i.
The practical significance of the results of this work lies in computing the parameters of the medical insurance policy in case of cancer on the basis of the found distributions and transition probabilities.

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ROLA INFORMACYJNYCH I PSYCHOLOGICZNYCH WPŁYWÓW W WOJNIE INFORMACYJNEJ

Streszczenie: Postęp technologii informacyjnych doprowadził do możliwości ich wykorzystania w celach destrukcyjnych. Zatem, działania informacyjno-psychologiczne mogą stać się dobrą metodą na przeprowadzenie wojen informacyjnych. W niniejszej pracy określono kluczową rolę danych czynników podczas informacyjnych konfrontacji na międzypaństwowej skali. Otrzymane wyniki badań naukowych mogą stać podstawą do zaprojektowania teoretycznego modelu informacyjno-psychologicznych wpływów oraz być wykorzystywane do budowy systemu zarządzania procesami, które są typowe dla konfliktów informacyjnych.

Słowa kluczowe: działania informacyjno-psychologiczne, wojna informacyjna, społeczeństwo, technologie informacyjne, manipulacja, destabilizacja.

THE ROLE OF INFORMATION-PSYCHOLOGICAL INFLUENCES IN INFORMATION WARFARE

Summary: the progress of information technology has led to the possibility of its use for destructive purposes. Thus, information-psychological influences have become a significant method during information confrontations. The paper identifies the main role of these impacts during information confrontations at the interstate level. The obtained results of the research can become the basis for the development of the abstract model of information-psychological influences and be applied for building the process control systems specific to informational conflicts.

Keywords: information-psychological influences, information warfare, concept, role, psychology, society, information technology, manipulation, destabilization

Significant development of information technology during the last decades led to increased efficiency in communication and dissemination of information. On this basis the notion of the phenomenon of information warfare with a variety of impacts

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were approved and put into wide circulation. They are divided into information-psychological and information-technical influences and this is the basis for classification of the objects of impact during an information aggression.

The aim of this paper is to determine the role and importance of the application of the methods of informational impacts during the information warfare at the interstate level and to investigate the Effects-Based Operation concept and its use in the application process of information-psychological influences.

Human consciousness is the main object of the information-psychological influences. Therefore, the methods of influence are based on psychology and social engineering. The development of these sciences is enhanced by the application of information technologies in the field of communications, which provide the opportunity to reach a large audience.

Informational-psychological influences may occur not immediately, but after a while. This is the basis of the Effects-Based Operation (EBO, for short) concept, where the effects of the first, second, third and further orders are distinguished. Human mind is configured to perceive only the coming effects, but they can be remote in time. There are some occasions when the things that appear to be positive as a consequence of the first order, can become negative in the future and result in achieving the destructive purpose at the lowest cost.

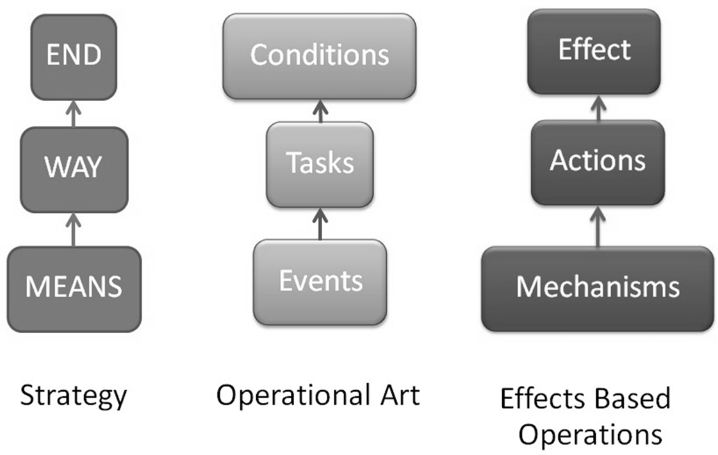

Figure 1. Model Effects Based Operations with other conceptions

The sense of EBO concept is described in the following sequence - "mechanism", "action", "effect". That is, the final stage is the effect that will be created by a particular information-psychological influences and the result of displaying the set effect on the psychological state of the opposing parties of the information conflict [1]. This approach is used for long-term planning and it usually leaves the open informational aggression behind. The least protected component against this is an information-psychological component of society belonging to a specified country, which has become the object of information aggression. Currently, in a general sense, the one who has the best programmers will win information warfare [2]. However, in the information warfare for society's psychological state, the techniques with all their ostentatious power are the means but not the goal. In addition, the more the information system is distributed in the world, spreading its networks, the more technically vulnerable it becomes in any point of this network. Yet the target of information warfare is not a technical failure, its aim is the global control of space by controlling people's consciousness. The legitimacy of any power including the information power is its voluntary adoption by the majority. Therefore, the control of consciousness of the particular society or its part can deprive it of power, or cause distrust, destabilize the situation in the country, engender separatism which will lead to an internal split [3].

But the most important thing is that new information technologies, being considered as a weapon, can become the total disaster for humanity, since information warfare, as a policy tool, means the existence of one society at the cost of exclusion of another one due to the destruction of cultural values and consciousness of the members of this society [4].

A variety of methods of information-psychological influences is used during information warfare. They are spread by the media and are offensive in nature. However, the principles of offensiveness and aggression in information warfare have their limits. It is appropriate to recall the phenomenon of the conversion of "superheated" means of communication into its opposite, that was investigated by M. McLuhan. Any means of communication have something that is usually called "breakthrough border", when the system suddenly changes and turns into another system with opposite functions, i.e. society may include the opposition mechanisms to suggestion (counter suggestion). This phenomenon is characteristic not only of mass media [5].

The audience that is most vulnerable to ongoing actions from the aggressor is selected by using information-psychological influences through mass media. Thus, it helps to form the category of people who receive more active actions to create the desired psychological state.

The current stage of the progress in information warfare is characterized as the second generation, and it is based on information-psychological influences. Thus, there are the following steps:

- creating the atmosphere of spirituality and immorality, negative attitude to the cultural heritage of the enemy;
- manipulating public consciousness of social groups of the population in order to create political tension;
- destabilizing political relations between the parties, associations and movements with the purpose of provoking conflicts, inciting distrust, suspicion, aggravation of political struggle, provoking repressions against the opposition and even civil war;
- reducing the level of informational support of government and administration, inspiring wrong management decisions;

- disinforming public about the work of state bodies, undermining their authority, discrediting the authorities;
- undermining the international prestige of the country, its cooperation with other countries;
- damaging the vital interests of the country in political, economic, defense and other fields [6].

Thus, the role of information-psychological influences in an information confrontation is important in current confrontations. While investigating this issue, the EBO concept was emphasized as one of the most pressing modern concepts of psychological confrontation and control of the mass media influence on the social mood of the population. It has been established that the information-psychological weapon is more dangerous than information and technical effects because it directly affects people's minds and covers a much larger audience. In addition, given the multi-format display of the effects of destructive information operations, the result of their application at the last levels is almost impossible to predict, which complicates response and monitoring the results [7]. Using the main provisions, the model of information-psychological influences will be developed in the most sensitive areas in terms of getting benefits during the active phase of the information warfare.

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SPOSÓB α - WYRÓWNANIA LICZB ROZMYTYCH ZASTOSOWANY W SYSTEMACH DETEKCJI CYBERATAKÓW

Streszczenie: Środki do wykrycia cyberataków są ciągle jeszcze źle zdefiniowane i słabo sformalizowane, a także mają pewne ograniczenia. Znane rozwiązania zwykle oparte są na metodzie wykrywania anomalii. Proces transformacji liczb rozmytych odniesienia oraz aktualnych wymaga właściwej formalizacji. W tym celu zaproponowano sposób formalizacji procesu kodowania odpowiadających liczb rozmytych pozwalający zwiększyć efektywność konstruowania odpowiednich systemów wykrywania włamań.

Słowa kluczowe: cyberataki, anomalie, rozmyte wzorniki, systemy wykrywania włamań, systemy wykrywania anomalii, systemy wykrywania ataku.

METHOD OF α-LEVELED NOMINALIZATION OF FUZZY NUMBERS FOR INTRUSION DETECTION SYSTEMS

Abstract: Means for cyberattack detection in the not clearly defined and weakly formalized environment, have some limitations. Known solutions usually based on anomalies detection method. Where transformation process of the reference and current fuzzy numbers requires a clear formalization. In this study propose the formalizing process method of forming a-leveled intervals corresponding fuzzy numbers which gives a possibility to increase the efficiency of constructing the relevant intrusion detection systems.

Keywords: cyberattacks, anomalies, fuzzy etalons, intrusion detection systems, anomaly detection systems, attack detection systems.

Today the modern theoretical and practical base, which is used for intrusion detection in information systems, has certain restrictions in the possibilities of identification new types of cyberattacks in not clearly defined and weakly formalized environment. Development of technical solutions for the modern intrusion detection

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systems will provide an opportunity to effectively solve the problem of dangerous anomaly states identification in computer systems and networks.

There are some quite effective developments used to solve these attack detection problems, such as: fuzzy approaches to intrusion detection [1 – 2] and the anomalies detection [3]; corresponding fuzzy model [4 – 6] and methods [7 – 8]; intrusion detection systems [9 – 19]; sets of fuzzy rules [1 – 2], [8], [13 –14], [16 – 21]; methods for constructing linguistic variables [20], [22] and fuzzy etalons [20], as well as other developments that are used to solve the security problems in fuzzy terms [23].

These studies have shown the appropriate application effectiveness for the fuzzy sets mathematical apparatus, and its use for the formalization of the approach to the cyberattacks identification, will improve the creation process of the corresponding intrusion detection systems. It should be noted that these and other sources, not perfect for the process of converting etalon and current fuzzy numbers (FN) to be used for control in fuzzy terms the state of environment parameters at a given time by which is possible to identify the anomaly condition, generated by the action of the relevant class of cyberattacks.

In this context, the aim of this work is to develop a method of α-leveled nominalization, which allows to formalize the formation process of α-leveled intervals for equivalent transformation of etalon and current FN. This will allow to determine the identification terms, displaying the current state of environment in solving attack detection tasks on computer systems.

The basis of the proposed method consists of three basic stages: the formation of α-levels; equivalent transformation of FN; the formation of generalizing tables and graphical interpretation of nominalized NF. Let`s examine each of these stages. **Stage 1 – the formation of α-levels.** To implement this step, create an appropriate mechanism, based on the introduction of the set for all possible α-levels $\mathbf{AL}$ and these α-levels subset $\mathbf{AL_{ij}} \subseteq \mathbf{AL}$:

$$\mathbf{AL_{ij}} = \{ \bigcup_{k=1}^{\pi} AL_{ijk} \} = \{ AL_{ij1},\ AL_{ij2},\ \ldots,\ AL_{ij\pi} \}, \tag{1}$$

used to convert the FN that represent $\mathbf{P_{ij}}$ with base term set $\mathbf{T_{ij}}$ (see item (7) in [5]), where π – the number of elements in the set $\mathbf{AL_{ij}}$, and AL_{ijk} $(k = \overline{1,\pi})$ – k element of set $\mathbf{AL_{ij}}$ corresponding to k α-level [23]. It should be noted that all elements of the set $\mathbf{AL_{ij}}$ formed according to the formula

$$\mathbf{AL_{ij}} = \{ \bigcup_{s=1}^{r} \{ \bigcup_{q=1}^{r_s} \mu_{ijsq}^{e} \} \}, \tag{2}$$

Its values were introduced in work [5] (see item (8)) and [24] (see item (14) at stage 5). From the expressions (1) and (2) follows that

$$\mathbf{AL_{ij}} = \{ \bigcup_{k=1}^{\pi} AL_{ijk} \} = \{ \bigcup_{s=1}^{r} \{ \bigcup_{q=1}^{r_s} \mu_{ijsq}^{e} \} \}. \tag{3}$$

Stage 2 – equivalent transformation of FN. According to this stage will give all etalon and current FN to the nominal (same for all), number of components by converting them using subsets $\mathbf{AL_{ij}}$.

Step 1. Consider the set of all possible or converted nominalized (reduced to z) etalon FN $\mathbf{T^{ep}_{ij}} \subseteq \mathbf{T^{ep}}$

$$\mathbf{T^{ep}_{ij}} = \{\bigcup_{s=1}^{r} \underset{\sim}{T}^{ep}_{ijs}\} = \{\underset{\sim}{T}^{ep}_{ij1},\ \underset{\sim}{T}^{ep}_{ij2},\ \ldots,\ \underset{\sim}{T}^{ep}_{ijs},\ \ldots,\ \underset{\sim}{T}^{ep}_{ijr}\},\ (s=\overline{1,r}) \tag{4}$$

and received on the basis of their current converted FN $\underset{\sim}{P}^{\tau_f p}_{ij}$.

Subject to (4) will form in a general view, converted etalon FN $\underset{\sim}{T}^{ep}_{ijs}$ (see (5)) and the current corresponding to the converted FN $\underset{\sim}{P}^{\tau_f p}_{ij}$ (see item (6)) that:

$$\underset{\sim}{T}^{ep}_{ijs} = \{\bigcup_{g=1}^{z} \mu^{ep}_{ijsg} / x^{ep}_{ijsg}\} = \{\mu^{ep}_{ijs1} / x^{ep}_{ijs1},\ \mu^{ep}_{ijs2} / x^{ep}_{ijs2}, \ldots,\ \mu^{ep}_{ijsz} / x^{ep}_{ijsz}\},$$
$$(g=\overline{1,z}),\ (z=2\pi\text{-}1),\ (s=\overline{1,r}) \tag{5}$$

where $\mu^{ep}_{ijsg} = \mu^{ep}_{ijs(z-g+1)} = AL_{ijg}$, $\mu^{ep}_{ijs1} = \mu^{e}_{ijs1}$, $x^{ep}_{ijs1} = x^{e}_{ijs1}$, z – number of components in $\underset{\sim}{T}^{ep}_{ijs}$ and

$$\underset{\sim}{P}^{\tau_f p}_{ij} = \{\bigcup_{g=1}^{z} \mu^{p}_{ijg} / x^{p}_{ijg}\} = \{\mu^{p}_{ij1} / x^{p}_{ij1},\ \mu^{p}_{ij2} / x^{p}_{ij2}, \ldots,\ \mu^{p}_{ijz} / x^{p}_{ijz}\},\ (g=\overline{1,z}),$$
$$(z=2\pi\text{-}1), \tag{6}$$

where $\mu^{p}_{ijg} = \mu^{p}_{ij(z-g+1)} = AL_{ijg}$, $\mu^{p}_{ij1} = \mu_{ij1}$, $x^{p}_{ij1} = x_{ij1}$, z – number of components in $\underset{\sim}{P}^{\tau_f p}_{ij}$.

It is clear that the number of components of the FN is the same and defined by parameter z, which will be called the nominal number of components, or simply nominal.

Step 2. Nominalizing (transforming to z) of etalon FN $\underset{\sim}{T}^{ep}_{ijs}$ performed by introducing a subset α-leveled intervals $\mathbf{AL^{Ie}_{ij}} \subseteq \mathbf{AL}$, consists of r elements and represents $\mathbf{T^{e}_{ij}}$ (see item (12) in [24]), that.

$$\mathbf{AL^{Ie}_{ij}} = \{\bigcup_{\mathbf{s=1}}^{\mathbf{r}} \mathbf{AL^{Ie}_{ijs}}\} = \{\mathbf{AL^{Ie}_{ij1}},\ \mathbf{AL^{Ie}_{ij2}},\ \ldots,\ \mathbf{AL^{Ie}_{ijr}}\},\ (s=\overline{1,r}),\ \text{where} \tag{7}$$

$$\mathbf{AL^{Ie}_{ijs}} = \{\bigcup_{\mathbf{b=1}}^{\mathbf{r_s-1}} \mathbf{AL^{Ie}_{ijsb}}\} = \{\mathbf{AL^{Ie}_{ijs1}},\ \mathbf{AL^{Ie}_{ijs2}},\ \ldots,\ \mathbf{AL^{Ie}_{ijsr_s-1}}\},\ (b=\overline{1,r_s-1}), \tag{8}$$

where $\mathbf{AL^{Ie}_{ijs}} \subseteq \mathbf{AL^{Ie}_{ij}}$, and r_s $(s=\overline{1,r})$ defines the number of components in $\underset{\sim}{T}^{e}_{ijs}$ (see item (14) in [24]).

Considering (8) let`s represent (7) as

$$\mathbf{AL_{ij}^{Ie}} = \{\bigcup_{s=1}^{r} \mathbf{AL_{ijs}^{Ie}}\} = \{\bigcup_{s=1}^{r}\{\bigcup_{b=1}^{r_s-1} \mathbf{AL_{ijsb}^{Ie}}\}\} =$$
$$\{\{\mathbf{AL_{ij11}^{Ie}},\ \mathbf{AL_{ij12}^{Ie}},\ \ldots,\ \mathbf{AL_{ij1r_1-1}^{Ie}}\},\ \{\mathbf{AL_{ij21}^{Ie}},\ \mathbf{AL_{ij22}^{Ie}},\ \ldots,\ \mathbf{AL_{ij2r_2-1}^{Ie}}\},\ \ldots, \tag{9}$$
$$\{\mathbf{AL_{ijs1}^{Ie}},\ \mathbf{AL_{ijs2}^{Ie}},\ \ldots,\ \mathbf{AL_{ijrr_r-1}^{Ie}}\}\},$$

where $\mathbf{AL_{ijsb}^{Ie}} \subseteq \mathbf{AL_{ijs}^{Ie}}$ is a subset of between the point α-leveled intervals, represented as

$$\mathbf{AL_{ijsb}^{Ie}} = \{\bigcup_{c=1}^{k_b} AL_{ijsbc}^{Ie}\} = \{\ AL_{ijsb1}^{Ie},\ AL_{ijsb2}^{Ie},\ \ldots,\ AL_{ijsbk_b}^{Ie}\ \},\ (b=\overline{1,r_s-1}), \tag{10}$$

where k_b – the number of elements in the subset $\mathbf{AL_{ijsb}^{Ie}}$, value of each of which is in the interval between two points μ_{ijsq}^{e} and μ_{ijsq+1}^{e}, that for all elements $\mathbf{AL_{ijsb}^{Ie}}$ works the condition:

$$\begin{cases} \mu_{ijsq}^{e} < AL_{ijsbc}^{Ie} \le \mu_{ijsq+1}^{e}, on\ x_{ijsq+1}^{e} \le x_{ijsmax}^{e} \\ \mu_{ijsq}^{e} > AL_{ijsbc}^{Ie} \ge \mu_{ijsq+1}^{e},\ on\ x_{ijsq+1}^{e} \ge x_{ijsmax}^{e} \end{cases} (c=\overline{1,k_b}\ ),\ (q=\overline{1,r_s}\ ),$$

where x_{ijsmax}^{e} is such a carrier FN $\underset{\sim}{T}_{ijs}^{e}$, membership function (MF) of which is defined by expression $\mu_{ijsmax}^{e} = \bigvee_{q=1}^{r_s} \mu_{ijsq}^{e}$. In other words the support x_{ijsmax}^{e} in FN $\underset{\sim}{T}_{ijs}^{e}$, contains the maximum value of MF μ_{ijsmax}^{e} that, there is a component $\mu_{ijsmax}^{e} / x_{ijsmax}^{e}$.

Next, for $\mathbf{AL_{ij}^{Ie}}$ with considering (10) represent (9) as follows:

$$\mathbf{AL_{ij}^{Ie}} = \{\bigcup_{s=1}^{r} AL_{ijs}^{Ie}\ \} = \{\bigcup_{s=1}^{r}\{\bigcup_{b=1}^{r_s-1}\{\bigcup_{c=1}^{k_b} AL_{ijsbc}^{Ie}\ \}\}\} =$$
$$\{\ AL_{ij111}^{Ie},\ AL_{ij112}^{Ie},\ \ldots,\ AL_{ij11k_1}^{Ie}\ \},\ \{\ AL_{ij121}^{Ie},\ AL_{ij122}^{Ie},\ \ldots,\ AL_{ij12k_2}^{Ie}\ \},\ \ldots,$$
$$\{\ AL_{ij1(r_1-1)1}^{Ie},\ AL_{ij1(r_1-1)2}^{Ie},\ \ldots,\ AL_{ij1(r_1-1)k_{r_1-1}}^{Ie}\ \}\},$$
$$\{\{\ AL_{ij211}^{Ie},\ AL_{ij212}^{Ie},\ \ldots,\ AL_{ij21k_1}^{Ie}\ \},\ \{\ AL_{ij221}^{Ie},\ AL_{ij222}^{Ie},\ \ldots,\ AL_{ij22k_2}^{Ie}\ \},\ \ldots, \tag{11}$$
$$\{\ AL_{ij2(r_2-1)1}^{Ie},\ AL_{ij2(r_2-1)2}^{Ie},\ \ldots,\ AL_{ij2(r_2-1)k_{r_2-1}}^{Ie}\ \}\},$$
$$\ldots,$$
$$\{\ AL_{ijr11}^{Ie},\ AL_{ijr12}^{Ie},\ \ldots,\ AL_{ijr1k_1}^{Ie}\ \},\ \{\ AL_{ijr21}^{Ie},\ AL_{ijr22}^{Ie},\ \ldots,\ AL_{ijr2k_2}^{Ie}\ \},\ \ldots,$$
$$\{\ AL_{ijr(r_r-1)1}^{Ie},\ AL_{ijr(r_r-1)2}^{Ie},\ \ldots,\ AL_{ijr(r_r-1)k_{r_r-1}}^{Ie}\ \}\}\}.$$

Step 3. Formation of the converted (nominalized) of the current FN $\underset{\sim}{P}_{ij}^{\tau_f p}$ by analogy with (10) carried out by introducing the appropriate subset between the point α-leveled intervals

$$\mathbf{AL^{Ip}_{ijb}} = \{ \bigcup_{c=1}^{k_b} AL^{Ip}_{ijbc} \} = \{ AL^{Ip}_{ijb1},\ AL^{Ip}_{ijb2},\ \ldots,\ AL^{Ip}_{ijbk_b} \},\ (b = \overline{1, \rho - 1}), \qquad (12)$$

where ρ – number of components in current FN $\underset{\sim}{P}^{\tau_f}_{ij}$ (see item (6) in [25]), k_b – number of elements in subset $\mathbf{AL^{Ip}_{ijb}}$, the value of each of which is between two points μ_{ijq} and μ_{ijq+1}, that for all elements of $\mathbf{AL^{Ip}_{ijb}}$ works the condition:

$$\begin{cases} \mu_{ijq} < AL^{Ip}_{ijbc} \le \mu_{ijq+1}, on\ x_{ijq+1} \le x_{ijmax} \\ \mu_{ijq} > AL^{Ip}_{ijbc} \ge \mu_{ijq+1},\ on\ x_{ijq+1} \ge x_{ijmax} \end{cases} (c = \overline{1, k_b}),\ (q = \overline{1, \rho}),$$

where x_{ijmax} is such a carrier of FN $\underset{\sim}{P}^{\tau_f}_{ij}$, value MF of which is determined by the expression $\mu_{ijmax} = \bigvee_{q=1}^{\rho} \mu_{ijq}$, that with support x_{ijmax} in FN $\underset{\sim}{P}^{\tau_f}_{ij}$ contains the maximum value of MF μ_{ijmax}.

Next in analogy to (11) with considering to (12) make necessary conversions, that will form

$$\mathbf{AL^{Ip}_{ij}} = \{ \bigcup_{b=1}^{\rho-1} \{ \bigcup_{c=1}^{k_b} AL^{Ip}_{ijbc} \} \} = \{ \{ AL^{Ip}_{ij11},\ AL^{Ip}_{ij12},\ \ldots,\ AL^{Ip}_{ij1k_1} \},\ \{ AL^{Ip}_{ij21},\ AL^{Ip}_{ij22},\ \ldots,\ AL^{Ip}_{ij2k_2} \},\ \ldots,\ \{ AL^{Ip}_{ij(\rho-1)1},\ AL^{Ip}_{ij(\rho-1)2},\ \ldots,\ AL^{Ip}_{ij(\rho-1)k_{\rho-1}} \} \}. \qquad (13)$$

Step 4. The calculation of values x^{ep}_{ijsg}, $(g = \overline{1, z})$ for nominalized and etalon FN is carried out by expression

$$x^{ep}_{ijsg} = x^{e}_{ijsq} + \frac{(\mu^{ep}_{ijsg} - \mu^{e}_{ijsq})(x^{e}_{ijsq+1} - x^{e}_{ijsq})}{\mu^{e}_{ijsq+1} - \mu^{e}_{ijsq}},\ (g = \overline{2, z}), \qquad (14)$$

where $\mu^{ep}_{ijs1} = \mu^{e}_{ijs1}$, $x^{ep}_{ijs1} = x^{e}_{ijs1}$, and

$$\begin{aligned} &\mu^{ep}_{ijs1} = AL^{Ie}_{ijs11},\ \mu^{ep}_{ijs2} = AL^{Ie}_{ijs12},\ \ldots,\ \mu^{ep}_{ijsk_1} = AL^{Ie}_{ijs1k_1}, \\ &\mu^{ep}_{ijs(k_1+1)} = AL^{Ie}_{ijs21},\ \mu^{ep}_{ijs(k_1+2)} = AL^{Ie}_{ijs22},\ \ldots,\ \mu^{ep}_{ijs(k_1+k_2)} = AL^{Ie}_{ijs2k_2},\ \ldots, \\ &\mu^{ep}_{ijs(k_1+k_2+k_3+\ldots+k_{b-1}+1)} = AL^{Ie}_{ijr(r_s-1)1},\ \mu^{ep}_{ijs(k_1+k_2+k_3+\ldots+k_{b-1}+2)} = AL^{Ie}_{ijr(r_s-1)2},\ \ldots, \\ &\mu^{ep}_{ijsz} = AL^{Ie}_{ijr(r_s-1)k_b}, \end{aligned} \qquad (15)$$

where $z = \sum_{h=1}^{b} k_h$.

Step 5. The calculation of values x^{p}_{ijg}, $(g = \overline{1, z})$ for nominalized current FN performed similarly to step 4 by expression

$$x^{p}_{ijg} = x_{ijq} + \frac{(\mu^{p}_{ijg} - \mu_{ijq})(x_{ijq+1} - x_{ijq})}{\mu_{ijq+1} - \mu_{ijq}},\ (g = \overline{2, z}), \qquad (16)$$

where $\mu^{p}_{ij1} = \mu_{ij1}$, $x^{p}_{ij1} = x_{ij1}$, and

$$
\begin{gathered}
\mu^{p}_{ij1} = AL^{lp}_{ij11},\ \mu^{p}_{ij2} = AL^{lp}_{ij12},\ \ldots,\ \mu^{p}_{ijk_1} = AL^{lp}_{ij1k_1},\\
\mu^{p}_{ij(k_1+1)} = AL^{lp}_{ij21},\ \mu^{p}_{ij(k_1+2)} = AL^{lp}_{ij22},\ \ldots,\ \mu^{p}_{ij(k_1+k_2)} = AL^{lp}_{ij2k_2},\\
\ldots, \mu^{p}_{ij(k_1+k_2+k_3+\ldots+k_{b-1}+1)} = AL^{lp}_{ij(\rho-1)1},\ \mu^{p}_{ij(k_1+k_2+k_3+\ldots+k_{b-1}+2)} = AL^{lp}_{ij(\rho-1)2},\\
\ldots,\ \mu^{p}_{ijz} = AL^{lp}_{ij(\rho-1)k_b},
\end{gathered} \tag{17}
$$

where $z = \sum_{h=1}^{b} k_h$.

Stage 3 – the formation of generalizing tables and graphical interpretation of nominalized FN. To get such tables all nominalized etalon $\underset{\sim}{T}^{ep}_{ijs}$ and current $\underset{\sim}{P}^{\tau_f p}_{ij}$ FN summarized in the generalizing tables (see items 1, 2).

Table 1. Generalizing table for $\underset{\sim}{T}^{ep}_{ijs}$ $(s = \overline{1,r})$

$\underset{\sim}{T}^{ep}_{ijs}$	μ^{ep}_{ijsg} $(g = \overline{1,z})$							
	μ^{ep}_{ijs1}	μ^{ep}_{ijs2}	…	μ^{ep}_{ijsg-1}	μ^{ep}_{ijsg}	μ^{ep}_{ijsg+1}	…	μ^{ep}_{ijsz}
	AL_{ij1}	AL_{ij2}	.	$AL_{ij\pi-1}$	$AL_{ij\pi}$	$AL_{ij\pi-1}$	.	AL_{ij1}
$\underset{\sim}{T}^{ep}_{ij1}$	x^{ep}_{ij11}	x^{ep}_{ij12}	.	x^{ep}_{ij1g-1}	x^{ep}_{ij1g}	x^{ep}_{ij1g+1}	.	x^{ep}_{ij1z}
$\underset{\sim}{T}^{ep}_{ij2}$	x^{ep}_{ij21}	x^{ep}_{ij22}	.	x^{ep}_{ij2g-1}	x^{ep}_{ij2g}	x^{ep}_{ij2g+1}	.	x^{ep}_{ij2z}
…	…	…	.	…	…	…	.	…
$\underset{\sim}{T}^{ep}_{ijs}$	x^{ep}_{ijs1}	x^{ep}_{ijs2}	.	x^{ep}_{ijsg-1}	x^{ep}_{ijsg}	x^{ep}_{ijsg+1}	.	x^{ep}_{ijsz}
…	…	…	.	…	…	…	.	…
$\underset{\sim}{T}^{ep}_{ijr}$	x^{ep}_{ijr1}	x^{ep}_{ijr2}	.	x^{ep}_{ijrg-1}	x^{ep}_{ijrg}	x^{ep}_{ijrg+1}	.	x^{ep}_{ijrz}

Table 2. Generalizing table for $\underset{\sim}{P}_{ij}^{\tau_f p}$

$\underset{\sim}{P}_{ij}^{\tau_f}$	$\mu_{ijg}^{p}\ \ (g=\overline{1,z})$							
	μ_{ij1}^{p}	μ_{ij2}^{p}	…	μ_{ijg-1}^{p}	μ_{ijg}^{p}	μ_{ijg+1}^{p}	…	μ_{ijz}^{p}
	AL_{ij1}	AL_{ij2}	.	$AL_{ij\pi-1}$	$AL_{ij\pi}$	$AL_{ij\pi-1}$	.	AL_{ij1}
$\underset{\sim}{P}_{ij}^{\tau_f}$	x_{ij1}^{p}	x_{ij2}^{p}	.	x_{ijg-1}^{p}	x_{ijg}^{p}	x_{ijg+1}^{p}	.	x_{ijz}^{p}

Graphical interpretation of nominalized FN based on the construction of geometric image of α-levels $\mathbf{AL_{ij}}$ (see item (1)), and also all converted etalon $\underset{\sim}{T}_{ijs}^{ep}$ (see item (5)) and current $\underset{\sim}{P}_{ij}^{\tau_f p}$ (see item (6)) FN. Geometrical locus of points on the plane defined by the broken line connecting points that display components of nominalized FN in order of increasing carriers x_{ijsg}^{ep}. Visualization of the FN represented as a broken line —•— on fig. 1.

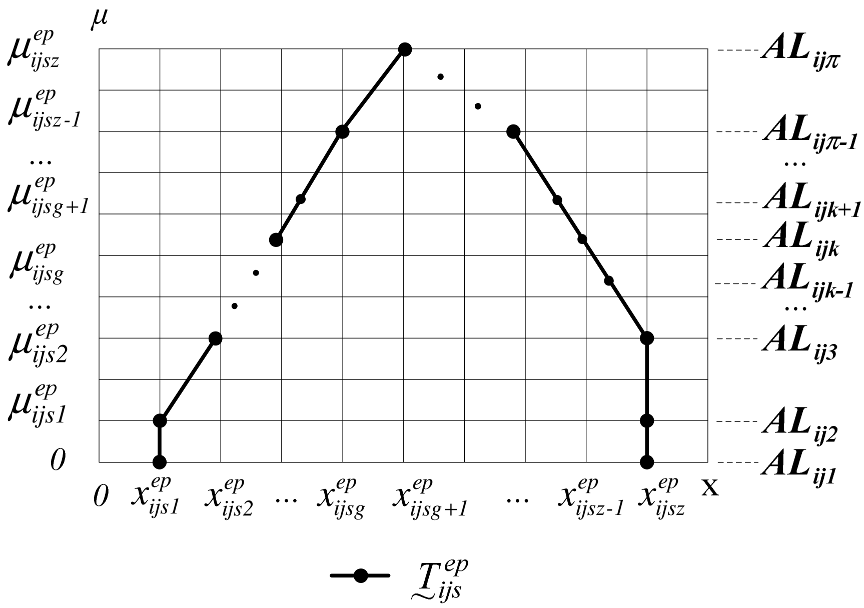

Figure 1. Generalizing graphic interpretation of the converted FN

The proposed in this work method of α-leveled nominalization of fuzzy numbers for systems intrusion detection, which is due to the construction for the formation mechanism of sets α-levels, auxiliary subsets for α-leveled and between the point α-

leveled intervals, and nominalization process and determine the required etalon and current FN supports values, allows graphically interpreted fuzzy variables and determine the identifying the terms on the current environment state, which is typical for the particular type realization of cyberattacks on information systems resources.

For the subsequent anomalies state detection in the computer systems is necessary to determine identification term, that is the etalon FN, which is closest to the current FN, and which will indicate the level of the anomaly condition in the computer systems.

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OPRACOWANIE OPTYMALNYCH ALGORYTMÓW STEROWANIA WYMIANY INFORMACJI W SIECI FIRMOWEJ

Streszczenie: W artykule przedstawiono rozważania na temat opracowania optymalnych algorytmów sterowania, przetwarzania i wymiany informacji w sieci firmowej. Zalecenia mogą być stosowane w projektowaniu i modernizacji sieci korporacyjnych.

Słowa kluczowe: bezpieczeństwo informacji, sieci korporacyjny, bezpieczeństwo cybernetyczne, optymalne algorytmy sterowania

DEVELOPMENT OF OPTIMAL ALGORITHMS CONTROL THE EXCHANGE OF INFORMATION ON THE CORPORATE NETWORK

Summary: The paper considered the development of optimal control algorithms process the exchange of information on the corporate network. The recommendations can be used in the design and modernization of corporate networks.

Keywords: information security, corporate networks, cyber security, optimal control algorithms

1. Formulation of the problem

One of the areas of mathematical cybernetics, steadily developing, is the theory and methods for solving optimization problems. This is due to the fact that many problems in the management, planning, design and other fields, is well described by mathematical optimization models. The use of such models can justify recommendations for decision-making and improve their quality. Currently, significant progress has been made in the study of structure, complexity and stability optimization problems, developing methods for their solution, software implementation algorithms.

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An important area of research in this area is to analyze and solve problems of optimal placement of objects. Such problems need to be addressed in the design of enterprise technology systems, determining locations of service points, automated design of electronic devices and performing many other works, especially when designing or upgrading information protected corporate networks. Among the problems of optimum placement of nodes and elements of corporate networks can be divided into two classes: the placement problem related objects and task flow distribution information.

The difference is that the problems of the first class need to find the location of facilities, among which are some links (not necessarily by all). In problems of the second class relationships established as a result of their decision.

The development of optimal algorithms of information exchange process control in the integral service networks and local networks is an actual problem, especially under the condition of observing information protection measures.

The solution of this problem in accordance with the principles of a systematic approach is to be closely related to that of all the other problems of the integral service networks design.

2. Analysis of recent research and publications

There is a large number of variants of the integral service networks construction, linking a great number of local network users. These variants can differ by a topology structure, algorithms of management, communication channels productivity, commutation devices, reliability, protection, vitality, creation and exploitation expenditures etc [1]. A great number of possible variants can be presented an union of two sub pluralities.

The first one includes variants, providing the implementation of integral service networks, uses requirements, the second – the variants which do not provide the implementation of the proper requirements. The basic task of integral service networks planning is the choice of the variant: related to first sub plurality and requiring minimum expenditures on construction of network [1].

The process of integral service networks planning includes two basic stages; systematic and engineering design. The systematic design consists in the choice of the topology network structure of integral service, network performance, methods and algorithms of control by network and its elements functioning. The engineering design consists in the realization of vehicle-program decisions in accordance with the results of the systematic design [2-4].

For the development of the control system it is necessary to select the following particular tasks solved consistently: the choice of methods and development of the algorithms of the information process exchange control in a network; the development, verification and optimization of the protocols of integral service networks; the determination of requirements, the development of the structure and algorithms of commutation; device providing the necessary level of information protection [5-7].

Each of these tasks can be solved repeatedly, if the results will testify to the necessity of the repeated decisions.

3. Problem definition

Suggest an integrated approach, methodology and possible algorithm for building and optimizing the architecture of separate corporate network and control the exchange of information in order to obtain the minimum cost and maximum bandwidth.

4. Statement of the main material

We will consider in detail these particular tasks of design, otherwise it is impossible to solve the task of analysis and synthesis of the control algorithms by the exchange of information in integral service network.

The basic features of information is the treatment and transfer in the integral service network can be considered on the basis of the two types of repetitive processes, namely: the processes of cooperation between the pair of points of an integral service network and the processes going in the commutation devices. It is possible because the process of information treatment and transfer consists of repetitive cycles. A package (request for connection) enters the commutation device, which a sender is connected to, is processed and passed farther through the intermediate commutation equipments to the knot which a recipient is connected to. The cycle of the treatment is similar in every commutation device.

Thus, the control of information exchange process must contain the control by flows at the input of switching device, inside of it and its output. The input control of switching device includes procedures of control by intensity of passed on a network flows. The control in the switching device is flows routing, and its output control – aggregate of procedures of network structure control.

The last sort of control is the powerful mean of increase of network performance of integrated service and improvement of quality of maintenance of queries of users. However realization of control by the network structure of integrated service can demand expensive facilities. Thus, under the process control of exchange by information in the integrated service network we will understand the complex of methods of control by the choice of routes (routing) and intensity of passed on a network flows.

Algorithms of control of information exchange process together with protocols of transport network and switching algorithms make the basis of functional software of switching devices. From point of the system design of integrated service networks, it is important to estimate efficiency of introduction of concrete version of each of algorithms. Preliminary decision about the use of that or other algorithm, as a rule, is made on the basis of enough approximated analytical models. At the choice of concrete version the expenditures of resources on realization of algorithm in the process of functioning of integrated service network must be taken into account. The expenditures of resources are related to the necessity of involvement of capacity of switching device and service information transfer over communication channels [4,5].

In the process of decision of the given task of development, to verification and optimization of protocols of integrated service networks the final laying of functions of control on the levels of program network structure of integrated service is conducted out, formalization and verification of protocols is carried out and their parameters are optimized. Taking into account relative independence and specificity of the given task, in the given paper it is not considered.

As input data in the task of development of structure and algorithms of functioning of switching devices are used topology network structure of integrated service; parameters of flows of information acting on the inputs of switching device; algorithms of control of information exchange process; algorithm of switching; functions of expenditures on the equipment of switching device. A task consists of choice of such structure and algorithms of functioning of switching device, at which a node would have a minimum cost at implementation of requirements to quality of maintenance of users.

Research of efficiency of methods of control by routing and intensity of flows of information in the network of integrated maintenance of largeness with the set topology structure is the primary purpose of the given lecture and development of optimum algorithms of control of information exchange process in local networks.

The formulated task is organically related to other private tasks arising up at construction of integrated service networks. Thus as networks of integrated maintenance of largeness are considered, in a number of cases there is the necessity of transition to the area process control of exchange by information.

In this connection a task disintegrates on two subtasks: allocation of zone of control and development of intrazone control algorithms of information exchange process.

The decision of these tasks includes two substages: research of efficiency methods of adaptive process control of exchange by information (analysis) and choice of optimum algorithm in relation to a definite criterion (synthesis). On the stage of analysis the decision of next tasks is foreseen.

1. Development of the generalized model of process exchange by information in the integrated service networks, on the basis of which it will be possible to build private models for estimation of efficiency of process of exchange by information.
2. Development and ground of criterion estimation efficiency algorithms of control information exchange process in the integrated service networks allowing to take into account a network performance and indexes of quality of maintenance of queries of users during realization in the network of different methods of control.
3. Construction of analytical model of process exchange by information in the integrated service networks with the static control with the use of the developed criterion and apparatus of theory of mass service. The results received on this stage can be used for close estimation of indexes of quality of functioning of integrated service networks at the use in them of algorithms of adaptive control. The necessity of this stage is conditioned to those, that to the present tense the methods allowing to estimate the indexes of quality of functioning of integrated service networks in the conditions of realization in the network of methods of adaptive control are not developed.
4. Construction of analytical model for estimation of efficiency methods of adaptive process control of exchange by information on indirect indexes characterizing the degree of approaching of the set method to the method of ideal observer. On this stage the estimation of expenditures on realization of methods adaptive control is produced, expressed in deteriorating indexes of

quality of functioning of network due to the presence of service information and necessity of its acquisition in the switching device.

5. Development and machine realization of simulation model of process of exchange by information in the integrated service networks, necessary for the obtaining experimental estimation of efficiency of concrete realization of methods of adaptive control. As a result of decision of this task the values of the estimations received on the second and third stages are specified.

5. Conclusion

Being guided by the developed generalized model of the process of integral service networks functioning and selected criteria of efficiency estimation, the problems the process of the information exchange particular models in the integral service networks as well as the problem of the development of the analyzed process algorithms have been considered in the presented paper .

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COMPUTER-ASSISTED LANGUAGE LEARNING IN ORDER TO IMPROVE LANGUAGE COMPETENCE FOR MEDICAL STUDENTS IN ENGLISH AS A FOREIGN LANGUAGE (EFL)

Summary: In this work the aim is to develop and substantiate computer-oriented method of foreign language competence of future doctors on the basis of information technologies and algorithms of applied system analysis. The following tasks are identified: to define innovative computer-oriented methods in acquiring foreign language competence by medical students; to develop computer-oriented method of foreign language competence of medical students and justify efficiency of its use; to apply a systematic analysis algorithm based on the analytic hierarchy process to prioritize innovation in computer-oriented methods of foreign language competence of medical students; to offer innovative approaches of evaluation in computer-oriented methods of foreign language competence of medical students and justify their objectivity by using correlation analysis; to develop a course of foreign language teaching for medical students based on computer-oriented techniques and methodical instructions for its implementation in high medical educational institutions.

Keywords: computer-assisted language learning, English as a foreign language, English for medical purposes

NAUKA JĘZYKÓW WSPOMAGANA KOMPUTEREM W CELU POLEPSZENIA KOMPETENCJI JĘZYKOWEJ DLA STUDENTÓW MEDYCYNY Z JĘZYKA ANGIELSKIEGO

Streszczenie: Celem artykułu jest rozwijać i wspierać wspomaganą komputerem metodę nauki języków obcych dla przyszłych doktorów na podstawie technologii informacyjnych i algorytmów analizy systemowej. Określono następujące zadania: (i) wprowadzić innowacyjne metody wspomagane komputerem dla uzyskania kompetencji języków obcych dla studentów medycyny; (ii) rozwijać wspomaganą komputerem metodę testowania kompetencji językowej studentów medycyny i sprawdzić efektywność jej użycia; (iii) zastosować algorytm analizy systemowej, oparty na analizie hierarchii w celu wskazania priorytetowej innowacyjnej metody dla nauczania języków obcych dla studentów medycyny; (iv) zaproponować innowacyjne

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podejścia do oceny we wspomaganych komputerowo metodach nauki języków obcych dla studentów medycyny i potwierdzić ich obiektywizm, korzystając z analizy korelacji.

Słowa kluczowe: nauka języków wspomagana komputerem, język angielski jako obcy, język angielski dla studentów medycyny

1. Introduction

The higher medical educational institution is required to graduate doctor not only with stable knowledge of foreign language, but with a high level of professional foreign language competence nowadays. The methods of studying foreign languages must comply to the system of knowledge and respond to changes and innovations at the same time. The course "Foreign language" should not only be in line with the theoretical and clinical professional directed subjects, but comprehend it, preparing students for the realities of professional medical practice. The intersubject integration, support for cross-cultural aspect of language acquisition, variability, multilevel are necessary for it. The consideration forms of foreign language study through learning language and speech, where book is the main tool and source of information is not sufficient today. The modern approaches to learning a foreign language not only provide students with full complex of knowledge, skills and abilities in different kinds of speaking, but should provide sufficient knowledge about subject professional sector. The traditional methods include learning a foreign language in artificial situations, that's why future doctor can't see any connection between research subject and his future profession. The specificity of learning any foreign language is that the student cant study it quite independently, without professional monitoring and surveillance. The computer is perfect assistant teacher in the process of formation of phonetic, lexical and grammatical competences of students in such situation. The computer has greatly expanded our understanding about the educational environment, because computer programs significantly expand the area of it to so-called world of educational environment

Integration into the global medical educational space requires the development of new educational information resources. These resources have experienced several technological stages of development. Such information is usually placed on CD-, then on DVD-ROM till the 2000-s. Review of such information was provided for installation into the computer software.

Since the 2000s with the advent of high-speed Internet channel that allowed the transfer of video, Web portals of medical educational materials are created. This Web portal has been created in the Ternopil State Medical University. The portal features more than 23,000 teaching materials now, including materials to prepare for lectures and practical classes, training videos and videos of practical skills, lectures on audio-video support, electronic versions of textbooks published by publishing house "Ukrmedknyha."

One of the objective of the portal is its application for improvement of language competence for EFL for medical courses

2. Main part

2.1. Multimedia in language learning

There is no gainsaying the fact that technology has considerably affected our lives and brought about numerous changes in the past few decades. Language teaching/learning is one of the areas that have been feeling the impact of the changes afforded by technology. As Chapelle (2007) points it out, not only are these changes going to lessen, but also technology will continue to influence every aspect of the lives of language learners, including their formal as well as informal language learning experiences.

One of the aspects of the new technologies that have become prevalent in language learning contexts is the use of audiovisual materials. The ubiquity of audiovisual materials has never been more obvious than it is nowadays for the new generation of language learners (McNulty & Lazarevic, 2012). In today's world, which is filled with audiovisual programs, language learners and teachers are lucky enough to have access to a virtually unlimited storehouse of authentic language materials such as movies, series, cartoons, music videos, documentaries, etc. which they can exploit for the purposes of language learning. These materials have helped learners as well as teachers to make classroom language learning more effective and efficient than it used to be (Tschirner, 2001). However, the following questions arise at this point: Why has the use of multimedia and audiovisual materials in language learning contexts earned so much interest in the recent years? What factors have contributed to the appeal of using these materials for language learning purposes?

One of the factors that has been mentioned throughout the literature in favor of the use of videos is the difference they make when compared with printed materials such as textbooks and dictionaries. According to McNulty and Lazarevic (2012), unlike printed materials, videos provide learners with the chance to see and hear simultaneous communication, speakers' gestures, facial expressions and other paralinguistic features. which can lead to improving second language learning.

Another factor relates to the kind of language that audiovisual materials supply language learners with. Baltova (1999) sees the value of videos in their recreating real-life experiences of language. In line with the same view, Shrosbree (2008) contends that videos expose learners to the language in its real context, drawing their attention to speakers' body language and other visual aids which enhance comprehension.

2.2. Empirical findings on the effect of using multimedia

A large number of studies have been conducted to investigate the impact of multimedia on different aspects of language learning, revealing the fact that learners profit from exposure to authentic multimedia. Washang (2004) carried out a study to investigate the effect of English movies on Iranian students' development of idiomatic expressions. The results pointed to better performance of the experimental group. Yuksel (2009) reported that watching movie clips had a positive impact on learners' vocabulary knowledge. He attributed this improvement to the contextual clues that movies can provide for learners and thus concluded that movies have the potential to facilitate incidental vocabulary learning.

Karakas and Saricoban (2012) sought to determine the impact of watching subtitled cartoons on incidental vocabulary learning through conducting a study with 42 first grade ELT students. However, the findings of their study did not support the assumption that the subtitle group would outperform the non-subtitle group.

More relevant to the current research is the study carried out by Ilin, Kutlu and Kutluay (2013), who aimed at investigating the effect of videos on teaching grammar in an ESP grammar class. The results revealed the positive impact of videos on teaching grammar. It was also found that the usage of videos motivated students to take part in the lessons as well as to learn grammar.

Another relevant study is the classroom-based research conducted by Mohammed (2013). She explored the effectiveness of subtitled videos on grammar learning. In this study she made use of the noticing hypothesis in order to investigate the effect of using enhanced subtitles and input flooding of a specific grammatical structure, the Past Perfect form, on learning. The findings of this study showed that students had a positive attitude toward this approach to teaching grammar. It also helped them better understand the context in which a particular grammatical structure was used.

Although there is a large body of research on the effect of audiovisual materials in second language teaching and learning, not so many studies have yet investigated their effectiveness in grammar instruction. Using authentic videos in grammar teaching and learning is an interesting and motivating way to add a communicative sense to the classroom. By doing so, foreign and second language learners' passive command of grammatical knowledge can be lowered to a great extent. They also wake up to the fact that grammar is an essential component of successful language learning, which cannot be taken for granted.

3. Methodology

3.1. Aims of the study

In this study we are based on the following assumption: if the process of acquiring by medical students of foreign professional language vocabulary to make on specially-developed methodical system, that is based on information and communication technologies, and includes software developed methodology, it would increase the level of theoretical knowledge and foreign language competence of medical students.

Thus the aim is to develop and substantiate computer-oriented method of foreign language competence of future doctors on the basis of information technologies and algorithms of applied system analysis.

In our study, we identified the following tasks:

1. To define innovative computer-oriented methods in acquiring foreign language competence by medical students

2. To develop computer-oriented method of foreign language competence of medical students and justify efficiency of its use.

3. To apply a systematic analysis algorithm based on the analytic hierarchy process to prioritize innovation in computer-oriented methods of foreign language competence of medical students

4. To offer innovative approaches of evaluation in computer-oriented methods of foreign language competence of medical students and justify their objectivity by using correlation analysis.

5. To develop a course of foreign language teaching for medical students based on computer-oriented techniques and methodical instructions for its implementation in high medical educational institutions.

3.2. Data collection and analysis procedures

Two methods were used to answer on the questions of the study. – current control we used MCQ test implemented in electronic learning system (ELS) Moodle; - for final examination - results of exam based on MCQ tests also. All these MCQ test included also multimedia images and some of them were stated as situative tasks

The study consisted of 3 parts.

The efficiency of Web-portal of training materials for the development of foreign language competence is explored in first part. The data of the level of the knowledge and practical skills of 259 dentistry students in 2014/015 and 2015/16 academic years in the Ternopil State Medical University is analyzed. The average age of students was 21. Ladies – 52%. The students were divided into two groups: experimental (2015/16 academic year, 142 students) and control (2014/15 academic year, 117 students). Students in the control group mastered the course in the usual format, and research group of the same course - accessing multimedia materials to prepare for lectures and practical classes, hosted on the website of the university with authorized access.

In second part a correlation analysis of the current and final success was performed with the application for the final success of the innovative technique semester test examination. In a study attended domestic students of the Medical Faculty of TSMU 2014/2015 academic year Students were divided into groups: experimental (99 students of 2nd year 1st stream and 99 students of the 5th year of the 1st flow) and control (99 students 2nd year 2nd stream and 90 students of the 5th year 2nd flow). Ladies – 51%. Students of control group made control module in the traditional format, and research group – using methods of semester test examination.

In a third part neural network clustering and forecast compiling medical students state licensing exam “Step” based on the current progress in accordance with procedures of “single day” method, daily remote monitoring and final exam - based on semester test examination. The 3-rd year domestic students of Medical Faculty of TSMU 2014/2015 a.y. took part in study. Students were divided into 5 clusters by use neural network algorithm of clustering NeuroXLClassifier

3.3. Data analysis

Taking into consideration that the main goal of this study was to explore and analyze the existence of the connection between foreign language competence of future doctors and the use of computer-oriented technology, the researchers analyzed the data quantitatively. The analysis included frequencies and percentages of foreign

professional medical language, which was classified according to its stylistic properties, and its linguistic realization.
The samples of students' answers were first collected, analyzed to find out any instances of English professional medical language, and categorized.Afterwards, we identified and contextually interpreted the linguistic medical items which seemed to serve the need of this study. Then, these instances were classified according to their stylistic properties and linguistic realization.
The R package statistical software was used to analyze and find out if there are any significant differences in the foreign language competence among the medical students due to the methodology they use (custom vs. CALL). Since the forth aim of the study was to evidence the estimating technologies towards the use of CALL, the questionnaire data were analyzed quantitatively by showing frequencies, means and Standard Deviations in dependence of different type of tests.

Statistical analysis of the experimental data was carried out according to the Glass and U Mann-Whitney critetion. According Glass test data subject to the normal distribution. According U Mann-Whitney is shown that difference in the results is statistically significant ($p \leq 0{,}05$)

During the processing of the third aim of research we determined priority of innovative techniques as part of CALL for development of foreign language competence of medical students using the Saaty's analytic hierarchy.

4. Results

4.1. CALL methods based on information system WebMedEdu for learning foreign professional medical vocabulary

Information system WebMedEdu focuses on the development of the training network system, the main tasks are:
- efficient and complete presentation of educational documentation of departments;
- the use of Internet connection "teacher-student" in the educational process;
- presentation in local network of university educational multimedia information sources used in the preparation of specialists: electronic library books, textbooks and monographs (about 400 items); training table (3000 items); 8 full-text electronic versions of journals that made in publishing "Ukrmedknyha";
- creating a universal information space of higher medical (pharmaceutical) educational institutions based on Internet technologies, shared resources, educational and methodical character within.

The materials for preparation for practical classes.
Student can review material for practical classes going into this menu item through the website of the university. It is quite necessary for better foreign language learning. Student can check in advance exercises for reading, grammar and listening. This gives opportunity to learn the material on their own without outside interference.
In these materials, students can also find links to additional literature or websites with additional information.
One of the most necessary applications to prepare materials for practical classes are **methodical instructions.**

In the methodical instructions the student can view the following:
- theme of class;
- aim of the class;
- structure of class;
- basic theoretical issues;
- practical issues;
-questions for fixing material;
- models of tests;
- basic and additional literature.

Educational videos for better language acquisition and improvement of practical skills are also present at information portal, that are quite important to the practical skills of students and for foreign language - and even to improve listening.

Quite important instituted method of learning a foreign language is **lectures with audio-video support** where the teacher combines lecture with short audio-video films whereby students can listen to the theoretical material, overview the practical skills, which are very important in medicine, and listen directly to a native speaker, which is quite important for listening and dialogue.

There are daily computer test control in system “Moodle” and semester test control for monitoring of students knowledge.

We held 2 studies In order to study the effectiveness of using student information system WebMedEdu for foreign professional medical vocabulary learning.

The efficiency of Web-portal of teaching materials in the educational process was explored in the first part. The data of the knowledge and practical skills of 259 dentistry students in 2014/15 and 2015/16 a.y. in the Ternopil State Medical University are analyzed. The average age of students was 21, ladies – 52%. The students were divided into two groups: experimental (2014/15 a. y., 142 students) and control (2015/16 academic year, 117 students). Students in the control group mastered the course in the usual format, and research group, the same course, - accessing multimedia materials for lectures and practical classes preparation, hosted on the website of the university with authorized access.

Type of task	Number of questions	Control group, 117 students			Main group, 142 students		
		all tasks	correct	%	all tasks	correct	%
with open short answers	32	3744	2576	68.8	4544	2985	65.7
with pictures	12	1404	650	46.3	1704	931	54.6
in situational taks form	4	468	152	32.5	568	198	34.8

The efficiency of lectures with audio-video support on the study of foreign professional medical vocabulary with use of final success of the innovative technique for semester test examination was explored in second part. Domestic students of the Medical Faculty of TSMU 2014/2015 a.y. attended in a study. Students were divided into groups: experimental (99 students of 2nd year 1st stream and 99 students of the 5th year of the 1st stream) and control (99 students 2nd year 2nd stream and 90 students of the 5th year 2nd stream). Ladies – 51%. Students made up the control module using the semester test examination method.

Type of task	Number of questions	Control group, 117 students			Main group, 142 students		
		all tasks	correct	%	all tasks	correct	%
with open short answers	48	3860	2476	64.1	4687	3123	66.6
with pictures	12	1310	640	48.9	1802	958	53.2
in situational tasks form	6	523	169	32.3	586	228	38.9

4.2. Methods of assessment of foreign language competence for medical students

Current distance test examination of knowledge. The daily electronic control of student's knowledge according to the program "Moodle" is introduced in university, which is held on the eve of practical classes exhibiting appropriate mark. The assessment results can be viewed by all students and by each one also. The histogram of success is formed for each class.

The daily test control system "Moodle" allows the student at the appropriate time, in comfortable conditions for him, before the class to make a test, which he can find at the Website of university. This is one of the best methods introduced by university. Students can prepare for class very well. There is not enough time for learn English perfectly in class. It needs to improve all skills. Student has the opportunity to prepare for classes using all the materials at the university and check the quality of learning by passing test. If student pass test with positive mark and satisfied with the result, he is able not to do it at the end of class next day.

Semester complex test examination. One of the factors that will significantly influence the improvement of quality of knowledge and encourage students to take an active independent work is independent and objective evaluation. According with this aim, it was proposed to make at the end of each semester test complex exam at the same time from all disciplines that were studied during this period.

For students who are already studied in the credit system, the final score for discipline will consist of the following ratio: 60% for the current progress and 40% in the number of points obtained in the preparation of test examination. This conforms to the assessment of student learning activities set out in the approved Ministry of Health of Ukraine Temporary Instruction evaluation of students learning the introduction of credit-modular education system.

The difference is that each module is assessed not immediately after its learning, but at the end of the semester. This will more accurately indicate the so-called survival knowledge, the principle of which hold test exams Krok 1 and 2, and therefore contribute to their preparation and assembly.

The special attention we should give to the use of computer technology during the semester test exams. We relied on the European experience and today our system of independent testing is not inferior to that which is used in the Vienna Medical University.

The software, which was developed by the Department of Information Technology, includes three main programs:

- the formation by departments of the bank tests - more than 450 thousand tests. The formation of booklets tests and standards of answers;
- the encrypted scanned recognition works of students and their assessment;
- the decryption of works and formation of information dispatch estimates on the pages of students.

To analyze the validity of the tests for the first time in Ukraine was implemented based on the histogram method of validity. For example, we present table of results of module for students from Latin and foreign language at the 1st year of study.

Name of module (subject)	unsatisfactorily	satisfactorily	good	perfectly	Average score	Current average score	Number of students
Foreign Language	136 (50.4%)	67 (24.8%)	60 (22.2%)	7 (2.6%)	4.26	7.74	270
Latin Language	131 (48.5%)	80 (29.6%)	54 (20%)	5 (1.8%)	4.06	6.97	270

5. Conclusions

A language competence is an underlying characteristic of an medical professional which enables him/her to deliver healthcare in a given situation in foreign country. Language competences consist of clusters of knowledge, attitude and skill set. For example, interpersonal or communication language skills play an important role in healthcare organization.

Here we would like to present our results in field of application of CALL methods to problem of gaining language competences in EFL for medical students. We emphasize effects of uncertainty that should be taken into account in such complex processes. We used T.Saati's method of hirerarchy analysis to solve problem of priorities of innovative CALL methodologies used in language education.

The skilled health care professionals are at the heart of any health system. Preparing health care professionals to take on task of English for Medical Purposes (EMP) requires a common vision across the professions centered on a commitment to, first and foremost, meeting needs of communication with patients.

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DYSKRETNY MODEL DYNAMICZNEGO SYSTEMU ENERGETYCZNEGO I NIEZAWODNOŚCI DANYCH OKREŚLAJĄCYCH POBÓR MOCY

Streszczenie: W artykule opisano zautomatyzowane monitorowanie i rozliczanie systemów energetycznych dla infrastruktury komunalnej, które obejmują zaawansowane rozwiązania techniczne. Warunkiem koniecznym dla skutecznego funkcjonowania i zarządzania siecią energetyki rozproszonej jest zrozumienie właściwości dynamicznych rozwiązań systemowych i strukturyzacji w zakresie sprzętu i oprogramowania.

Słowa kluczowe: automatyczny odczyt rejestratorów, zarzadzanie, dyskretne modele, systemy pomiarowe

THE DISCRETE MODEL OF DYNAMIC ENERGY SYSTEMS AND RELIABILITY OF DATA CONSUMPTION

Summary: Automated monitoring and accounting of municipal infrastructure energy systems include advanced technical solutions. A necessary conditions for the successful functioning and management of distributed energy network are the definition of the dynamic properties of the system and structuring of solutions in terms of hardware and software.

Keywords: Automatic meter reading/Automatic meter management, discrete models, measuring systems

1. The process of accounting of energy consumption

Any information and telecommunication system consists of a field device, the transmission environment, and stationary objects. Data collection and formation of control signals occurs in certain period of time, i.e. discrete. The process of accounting of energy consumption is also discrete and is fixed by the corresponding meter.

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1.1. Discrete-time model

At developing of discrete-time model of a process a simplification is used, consisting in that measured data and control signals remain constant over the sampling interval. In accordance with [1] there are two ways to describe the discrete model analog system.
The first - an approximation of the original equations by difference:

$$x[(k+1)h] \approx x(kh) + f(x,u) \tag{1}$$

where h - sample interval;
k - its serial number;
f(x,u) –the time derivative of the state vector of the system x.
The second - to provide the transfer of H based on a discrete description of the system with the help of equation

$$H(q) = H*(q-^1) = \frac{y(kh)}{u(kh)} = C \cdot (q \cdot I - \Phi)-^1 \cdot \Gamma + D \tag{2}$$

The description of the system in the form of the transfer operator is unambiguous.
The key objective of the sampling is to collect sufficient information for subsequent signal processing, which is directly connected with the correct definition of the analog signal sampling interval. Sampling interval ***h*** should be short enough so that the output signal with an acceptable accuracy describes the analog input change.
Analog signals generated by the measuring field devices are converted into a digital sequence measurand. There are two competing techniques for signal transmission by conductors - transfer by voltage and transfer by current. Transmission of signal by voltage has one significant drawback - low noise immunity. Therefore, in the digital measurement systems (MS) the most appropriate method is a method of a measurement signal transmission by current, not sensitive to electromagnetic interference generated by an external environment. Recommendations for its use are contained in the International Standard IEC 60381-1: 1982 [2]. System which is using "current loop" for signal transmission, and a sensor, galvanically insulated from the output signal, has the following advantages:

- stable work on extension communications;
- allows a simple checking process;
- provides a reasonable protection against interference;
- uses a normal "twisted pair", which reduces the cost of installation and operation.

Any measured parameter by which desired signal is formed is obtained using special transducers or sensors. Accordingly, accuracy of measurements and it's compliance to the real picture, directly related to the accuracy of definition of physical quantities and measurement methodology. The technical basis of the implementation of this model is programmable automatic systems for commercial accounting of power consumption (AMR/ AMM) [3].

The analog measurement processes focused only on it's lower level - level of meters with a long time store digital database in it. External access to it realized through digital interfaces and communication channels [4].
The measurements are made with a clear fixation of beginning and end of the relevant time period, measuring data "attached" to the temporary grid, and the error of that grid is seen as contributing factor. If all MS elements are synchronized, we can assume that all measurements in digital systems completed in system's low level - in meters [5].
The basic principle of the creation of modern digital measurement systems is a mandatory application on the lower level of primary measuring transducer with digital output, and long-term storage of digital data base formed at the point of measurement. The result of the application of this technology is that measurement systems are becoming poorly connected systems not only in the area(space), but also in time.
The data from the measuring devices used by companies for the purposes of its licensed activities. Therefore, the main requirement for the accounting system is a correctness and reliability of transmitted information. By collecting data from metering devices, utility companies can automate billing processes and control the status of metering devices via centralized interface. Addition of a control element allows companies to implement functions of control energy consumption also centrally.
Accounting systems are composed of a whole set of "mechanical» IT-assets, which are used for the measurement functions. Meter Devices should contain a switching device that can be controlled by the computer to turn off the consumer if necessary. The functionality of modern allow to control the built-in switching devices centrally. This process is a typical use of information technology for the realization of the full benefits of centralized management.

2. Conclusion

Discrete-time approach in the work of AMR allows to implement load control program automatically when generating capacities are exhausted. In view of the above the presence of energy consumption information close to real time allows utility companies to regulate electric power generation (supply of water, gas, etc.), based on data on voltage levels (pressure) in the remote parts of the network, and to monitor the effectiveness of programs reduce energy consumption. Such improvements in the scale of companies with hundreds of thousands of consumers do benefit during the peak load hours apparent.

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METHOD OF SEMANTIC MASKING OF AN AERIAL PHOTOGRAPH

Summary: A direction of improving the efficiency of aerial monitoring is proposed. The proposed system of processing an aerial photography is based on the principle of identification the important semantical content of the image segments directly onboard. Quantitative metrics to assess masking techniques for their subsequent implementation in systems of automatic teleprocessing of video information are explained. Experimental results of masking techniques evaluated on basis of quantitative indices of planimetric information quality is given.

Keywords: aero monitoring, aerial photograph, decryption, masking

METODA SEMANTYCZNEGO MASKOWANIA FOTOGRAFII LOTNICZEJ

Streszczenie: W pracy omówiono działania prowadzące do podniesienia efektywności zdjęć lotniczych. Metoda oparta jest na przetwarzaniu zdjęć lotniczych z uwzględnieniem specjalnych zasad m.in. "identyfikacji semantycznej zawartości informacji we wybranych segmentach zdjęć lotniczych". Ilościowe zasady kodowania oraz metody oceany jakości technik maskowania w automatycznych systemach przetwarzania informacji wizualnych na pokładzie – zostały przebadane oraz potwierdzono ich przydatność. Eksperymentalna ocena technik maskowania na podstawie wskaźników ilościowych została opisana w artykule. Pozwala ona ocenę jakości uzyskanych informacji planimetrycznych.

Słowa kluczowe: aero-monitoring, fotografia lotnicza, dekodowanie, maskowanie

1. Introduction

The main issue of information systems based on aerial monitoring today is the time of signal delivery and reliability of its decoding. The increase of structural complexity of an aerial photography and low throughput of onboard communication devices provoke certain difficulties of information decoding in expected time. The proposed direction of improving effectiveness of an aerial monitoring device is to define a new

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format of video data representation. This would allow the increment of efficiency of the codebreaker's work.

2. State of the art

An overview of a near real time airborne monitoring system for monitoring of natural disasters, mass events, and large traffic disasters developed at the German Aerospace Center (DLR) was described in [4]. This system consists of an optical wide-angle camera system (3K system), a SAR sensor, an optical and microwave data downlink, an onboard processing unit and ground processing station with online data transmission to the DLR traffic and disaster portals.
In [5] Berni et al. demonstrate the ability to generate quantitative remote sensing products by means of a helicopter-based UAV equipped with inexpensive thermal and narrowband multispectral imaging sensors in agricultural applications. Several possibilities of vehicle extraction from different airborne sensor systems (visual, thermal IR and radar) are described in [6]. Choi and Lee consider in [7] accuracy and speed of georeferencing image sequences acquired by airborne systems.
De Benedetti et al. consider in [8] an algorithm aiming at coordinating a set of multirotor UAVs to self-organise in order to create a flock performing a monitoring mission. The aim of the flock is to acquire data relevant to a certain area of the terrain and transmit them to a base station.

3. Methods of research

In the process of aerial monitoring, a big role is assigned to a codebreaker. The codebreaker, before creating a report, systematizes basic data about key objects by a sequential logical course from detection of an object to the analysis of its status. The efficiency of the codebreaker's work is influenced by the time of delivery of an aerial photograph from an aircraft (this is due to information aging), and by the skill level of the codebreaker. Decryption is complicated in connection with a big flow of the video information arriving from the aircraft.

The first stage of decryption is the detection of objects. Here the codebreaker meets difficulty of separation of important objects from a total quantity of information. It is connected with a lot of information on an aerial photograph. Excess of information is due to the presence in the image of fine details and sets of various objects which recognition isn't included into the task of decryption (distract the attention of the codebreaker). It carries to the erratic perception of an object (ignoring of important objects) and growth of time expenditure on the perception of objects. As the first stage of decryption (detection of objects) is offered to transfer on aboard the aircraft as a form of the option of object key information separation by application of a masking technique. Detection of key information as a component of the interpretive signs is the result of masking. Methods of detection of boundaries or otherwise separation of planimetric information are used for receiving and assessment of an aerial photograph semantic component. There are no universal masking techniques for different types of images. In the case of assessment of the efficiency of aerial photographs masking techniques, it is necessary to consider the efficiency of separation of planimetric information, the maximizing accuracy of its separation and localization of objects, and also minimization of time and computing expenditure. For automatic onboard processing of an aerial photograph it is offered to research the quantitative assessment of masking techniques on the basis of metrics of detection quality and localization of objects circuits. Namely they are:

1) error of first type (false positive) α - the relation of quantity *n(B\X)* of incorrectly selected boundary pixels to a total quantity n(C\X) of the elements which aren't boundary:

$$\alpha(X,B) = \frac{n(B \setminus X)}{n(C \setminus X)} \tag{1}$$

Where *B* is the set of selected boundary elements and *X* is the set of actual boundary elements in the initial set of elements *C* of the image *A*.

It is possible to use also a derivative of an error of the 1st type - specificity s_p as the attitude of the selected not boundary pixels *n(C\B)* against total number of non-boundary pixels *n(C\X)* of the image:

$$s_p = \frac{n(C \setminus B)}{n(C \setminus X)} = 1 - \alpha \tag{2}$$

2) error of second type (false negative) β - the relation of quantity *n(X\B)* of not selected edge elements to a total quantity *n(X)* of edge elements:

$$\beta(X,B) = \frac{n(X \setminus B)}{n(X)} \tag{3}$$

It is also possible to use a derivative of an error of second kind - sensitivity s_e – the attitude of correctly selected edge elements $n(B \cap X)$ towards total number of edge elements $n(X)$ of the image;

3) frequency n_{true} of the correct determination of edge elements in comparison with an ideal circuit:

$$n_{true} = \frac{N_{true}}{n(x)} \tag{4}$$

where: N_{true} – quantity of correctly certain edge elements of a circuit;

4) frequency n_{false} of the wrong separation of edge elements in comparison with an ideal circuit:

$$n_{false} = \frac{N_{false}}{n(x)} \tag{5}$$

where: N_{false} - quantity of the wrong certain elements in comparison with an ideal circuit;

5) the mean squared error of *RMSE* (Root Mean Square Error) defined as distance between two elements of the compared images A and A'':

$$RMS(A, A'') = \left[\frac{1}{card(X)} \cdot \sum_{x \in X} (a(x) - a''(x))^2 \right]^{\frac{1}{2}} \tag{6}$$

6) peak relation signal/noise PSNR:

$$PSNR = 10 \cdot \lg\left(\frac{MAX_I^2}{MSE}\right) = 20 \cdot \lg\left(\frac{MAX_I}{\sqrt{MSE}}\right) \tag{7}$$

where: MAX_I - the maximum value which accepts an image element; MSE - root mean square deviation which for two images A and A' with m x n size, is defined as:

$$MSE = \frac{1}{m \cdot n} \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} \left| a(x, y) - a''(x, y) \right|^2 \tag{8}$$

7) t_{job} - assessment of time for execution of the aerial photograph (segment) masking algorithm:

$$t_{job} = K_{+;-}^{(job)} / U_{+;-} + K_{\times}^{(job)} / U_{\times} \tag{9}$$

where: $K_{+;-}^{(job)}$, $K_{\times}^{(job)}$ - summary quantity, respectively, addition operations (subtraction) and multiplication operations, necessary for masking algorithm implementation; $U_{+;-}$, $U_{\times}$ - high-speed performance of execution, respectively, addition operations (subtraction) and multiplication.

The metrics set by formulas (1) – (4) allow carrying out an assessment of the quality of circuits detection, and metrics (5) – (9) execute an assessment of the quality of circuits localization. For carrying out the comparative assessment of the efficiency of functioning of planimetric information formation methods were used: realistic images with the increased semantic information (interelement correlation 0,5); with sufficient semantic information (interelement correlation 0,7); with insignificant semantic information (interelement correlation 0,9). For comparing of the efficiency of obtaining planimetric information were used masking techniques: Sobel; Prewitt; Sharu; Laplace; Hryashchev; Canny.

4. Conclusions

1) The quantitative metrics provide rather all-round assessment of character of errors and distortions, namely gaps, local offsets, spreads and thickenings of circuits which are shown for binary masks in the course of use of methods of separation of aerial photographs planimetric information on onboard complexes.
2) Results of estimates of obtaining planimetric information quality on the basis of processing of brightness components and pictures not significantly differ from each other. Therefore for lowering of time of processing it is admissible to carry out masking of aerial photographs on their brightness components.
3) The considered metrics of the quantitative assessment of quality of planimetric information separation in an aerial photograph are admissible to be used in the course of automatic processing of aerial photographs on onboard complexes.
4) For lowering of processing time it is admissible to carry out masking of aerial photographs only on their brightness components.
5) One of the best masking techniques in the conditions of support of the required semantic integrity (support of detection of planimetric information the greatest number, are Prewitt's method. Application of such approach together with an estimated metrics, concerning the importance of semantic contents, gives the best effect in the case of separation of segments with the greatest interpretive informational content.

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STRUKTURA BEZPIECZEŃSTWA INFORMACJI W WIELOPOZIOMOWYCH INTELIGENTNYCH SYSTEMACH STEROWANIA

Streszczenie: W pracy rozpatruje się podejście do budowania struktury bezpieczeństwa w wielopoziomowym inteligentnym systemie sterowania (WISS). Analizowana jest struktura systemu bezpieczeństwa informacji na podstawie oprogramowania «SCADA – ZigBee - Inteligentne obiekty». Przeprowadzono symulację działania systemu ekspertowego w Rapid SCADA. Omówiono wymagania dotyczące oprogramowania krytycznego, odmowa wykonania funkcji którego lub jego nieprawidłowa obsługa może doprowadzić do katastrofalnych lub krytyczne konsekwencje. Bezpieczeństwo informacji w WISS powinno być oparte na wielopoziomowym systemie ochrony.

Słowa kluczowe: bezpieczeństwo systemu informacji, inteligentny system sterowania, struktura, wielopoziomowe

THE STRUCTURE OF INFORMATION SECURITY IN MULTILEVEL INTELLIGENT CONTROL SYSTEM

Summary: Considered approach to building security architecture in a multi-level intelligent control system (MICS). Analyzed the structure of the information security system based on "SCADA - ZigBee - Intelligent objects". Simulation of an expert system in Rapid SCADA. Describes the requirements for software critical applications, failure of performance or its improper use can result in catastrophic or critical consequences. Information security in MICS should be based on multi-level protection.

Keywords: the security of information systems, intelligent control system, structure, multilevel

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1. Introduction

The tendency to intellectualization of industrial processes and implementation of robotics in industry, which are included to the program of European Union - Horizon 2020, actualize researches in the area of multi-level intelligent control systems. Functioning of these systems is based on finding solution of unformalized and poorly structured problems using mathematical tools of expert systems, artificial neural networks, fuzzy logic, evolutionary methods and genetic algorithms. Multi-level intelligent control systems are hardware and software tools for critical purpose, which execute control process, using an object, which is complex and distributed in space and time object (critical object). Such kind of multi level functionality requires ensuring of necessary level of information security, which can be achieved by implementation of complex information security system. Since intelligent control system is multi-level by itself, information security in it should be multi level as well. It can be explained by heterogeneity of environments in which the information circulates, therefore we have different requirements for security policy. Thanks to multi level of information security system it is possible to realize independent information security system on each level and separately research them.

2. Multilevel intelligent control system – „SCADA – ZigBee – Intelligent objects"

Structure of information security system was selected based on analysis of environment in which will circulate the information. In multi-level intelligent control systems information about the control object will be selected by using different kinds of sensors and transmitted via communication environment to control as the data. Control system will decide to change (keep) parameters of control object and transmit necessary commands via communication environment to executive mechanisms, which functionally response on changing the settings of control object.
Multilevel intelligent control system can be realized through [1]:
1. Expert System (ES) – a class of artificial intelligence designed for receiving, storage, updating knowledge provided by experts from some domain to obtain new knowledge that can solve certain tasks relating to the class of informal and poorly structured ones, explaining course of their decision. Expert system for tasks of a multilevel intelligent control system can be realized based on SCADA – large, distributed systems of monitoring and control;
2. ZigBee – the standard for a set of high-level communication protocols, which use small, low-power digital receivers based on the standard IEEE 802.15.4-2006 for wireless personal networks [2];
3. Intelligent objects can be realized by the example of an intelligent building, which is a set of organizational, technical and software measures aimed at creating a highly efficient economic infrastructure of a complex service.
The multilevel intelligent control system "SCADA – ZigBee – Intelligent objects" security depends on the ability to protect the system at these levels. SCADA in the physical sense is an expert system that implements the algorithm for decision support and has a strategic impact on the multilevel intelligent control system. ZigBee in this structure is a communication environment of multilevel intelligent control system,

which provides connection between the SCADA system and intelligent objects. Intelligent objects are sensors (sensors groups) which can singly interact with an object control (tactical management level). Impact on communication environment of multi intellectual control system may cause serious security threats, since integrity, confidentiality and availability can be impacted through it. ZigBee technology has several advantages for achieving communication environment security. ZigBee devices on the network are divided into a coordinator, router and end device. This type of network is self-organized, ways of data communication are determined by the coordinator, and in case of loss an alternative way of communication will belaid. Encryption (AES 128bit), an integrity and authenticity verify mechanism and trust center are used for data protection. Modelling of multilevel intelligent control system structure has been performed Rapid SCADA environment. Rapid SCADA – is free, fully functional SCADA-system with open source code. By using Rapid SCADA you can create following kinds of automated systems: control systems of technological processes; "smart house" systems, energy accounting systems; fire and security alarm systems; access control systems; any systems which contains controllers, sensors and switches [3].

Figure 1 shows the structural model of interaction between sensors and control objects. As an example of expert system realization, the process of interconnection between sensors and control objects with using of SCADA systems has been modeled.

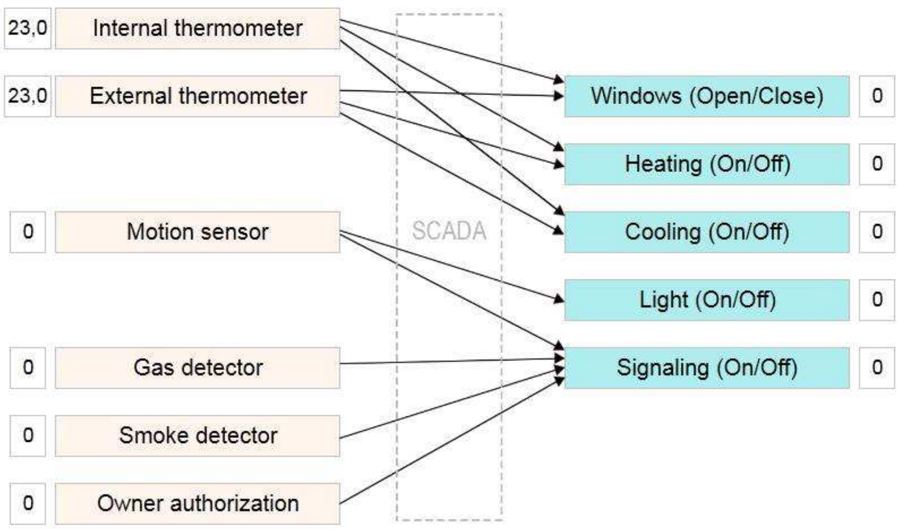

Figure 1. Structural model of interaction between sensors and control objects.

SCADA system receive information from temperature sensors (internal/external) and controll the work of air conditioning, heating and window position (open/close). state of system balance - external and internal temperature is 23 degrees. When external temperature falls to 13 degrees and internal to 17 degrees, SCADA system starts working in expert system mode and turns off the heating (Fig. 2).

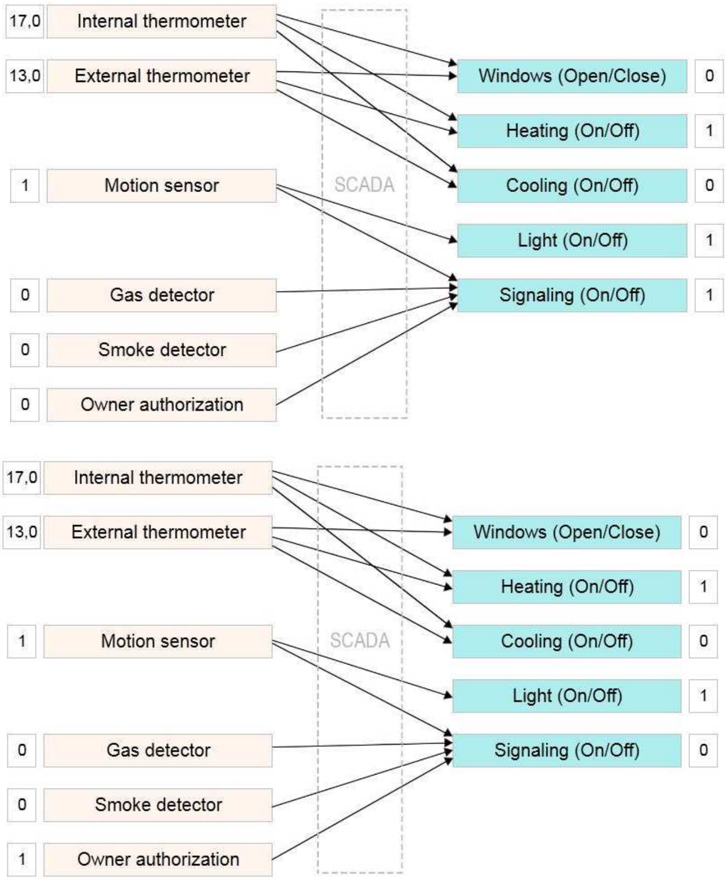

Figure 2. SCADA operates in expert system

When motion sensor is triggered, light and alarms will turn on, since the person didn't pass an authorization. If the person passed an authorization the light turns on, but the alarm in this case will be not triggered. When the gas sensor is triggered - the alarm turns on.

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ANALIZA PORÓWNAWCZA NOWOCZESNYCH METOD E-LEARNINGU W ZAKRESIE GRAFIKI KOMPUTEROWEJ DLA INŻYNIERÓW INFORMATYKÓW

Streszczenie: W artykule opisano zasady analizy oraz tworzenia sytemu e-learningu. W szczególności rozważa się systematyczne podejście do stworzenia systemu e-learningu w zakresie grafiki komputerowej. Opracowany system jest przeznaczony dla studentów studiów inżynierskich. Ich wysokie kwalifikacje mają znaczenie dla przyszłości informatyki na Ukrainie, a także za jej granicami.

Słowa kluczowe: elektroniczne zasoby dla edukacji, przyszłościowe technologie w dziedzinie informatyki, jakość edukacji, grafika komputerowa

COMPARATIVE ANALYSIS OF MODERN METHODS OF E-LEARNING OF COMPUTER GRAPHICS FOR IT INDUSTRY BACHELORS

Abstract: This article analyzes the particular qualities of the formation methods of systematic approach to e-learning of computer graphics professionals for the future of information technology in Ukraine and abroad.

Keywords: electronic educational resources, future information technology, quality of education, computer graphics

1. Introduction

During the development of the Ukrainian statehood, new strategies of information technology (IT) in higher education system were legislatively defined, to specify: content, purpose and strategic directions of reforms in all sectors of education in accordance to international standards. Now the Ukrainian government is building its own national system of education in IT that came to the forefront of the Ukrainian market in terms of development of Ukraine, thus showing considerable potential and

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scope for further successful growth.

1.1. Main goals

Developing the new standards for e-learning of IT professionals, ensuring maximum conformity of e-learning content to the demands that are set by the future profession for the graduates of a higher education institution (HEI) is the content of our research, and that will provide lessons and will reveal the consistent patterns of education and implementations of educational reforms in other countries.

1.2. The purpose of the scientific research

identifying the characteristics and formation of a systematic approach to the educational methods of computer graphics for future IT specialists in Ukraine and abroad, and elicit the differences.

2. The position of information technologies in educational services in Ukraine and abroad

According to the Resolution of 29 April 2015 r. Number 266 "About approval of the list of disciplines and specialties which specifies preparation of candidates in higher education system "in Ukraine introduced a new set of disciplines and specialties. Considering current trends and global standards of education: educational branch "Information Technologies" and the security have found their place in the educational services of our country and specified educational sector.
12 - Information technology [1]
However, in other countries such as Russia, Kazakhstan, Poland IT professionals are prepared by following directions:
Order of The Ministry of Education and Science (MES) of the Russian Federation number 1061, of 12/09/13.

- 09.00.00. Informatics and computer engineering [2].

Order of The MES of Kazakhstan of June 21, 2010 number 316

- 5B070300 - Information systems (IS) [3].

Order of the Ministry of Science and Education of Poland №1065 of 09.08.2011: 5 Technical sciences overview: 12) informatics [4].
After processing of electronic educational resources of different countries regarding the classification of professions in information technology, the author concluded that the content of preparation of IT specialists in Ukraine today is constantly updated, improved and approved by European, American standards developed for training of the IT professionals and specialists. Analyzing the IT strategies conducted by the public scientific community of various countries set in electronic curricula and training programs for Bachelors, consist of theoretical and practical approach to the study of subjects as to basic and professional areas.
Humanities courses bloc of Ukrainian higher education courses has a lot in common with Polish Higher School of Philosophy - Przedmiot hum. II Podstawy filozofii, foreign language - Język obcy [inf./ lab.], Physical Education - Kultura fizyczna [inf.], Ethics of official communication - Przedmiot hum. I: Etyka zawodu.
It is necessary to mention that in Polish curriculum the subjects of professional area have minor differences. In the series of mathematical and natural sciences for

bachelors of IT Poland and Ukraine both include common subjects, such as "Higher Mathematics", "Physics", "Probability Theory, probabilistic processes and mathematical statistics", "Discrete Mathematics", "Theory of algorithms."

The curricula for training of IT bachelors emphasizes professional activities, design, industrial and technological activities presented in the requirements for educational programs.

In the professional and practical cycle of training of bachelors in Ukrainian curricula the "Engineering and computer graphics" is presented, as in Polish curricula «Grafika komputerowa i komunikacja człowiek-komputer».

Studying a course of practices of electronic resources both in Ukrainian and Polish plans, can be traced the meaningful and in-depth educational work and character of students passing acquaintance in various types of practices - professional, practical training, computer training, technological practice, pre-diploma practice. Practice in Polish universities that provides training of IT professionals conducted practice in leading IT organizations for 4 weeks per year with mandatory certification.

The current domestic educational community integrating to Europe seeks the ways to synthesize the curricula and programs of disciplines for bachelors of IT in general electronic information direction in accordance with international standards. When creating EQC and OPP for IT in Ukraine some significant changes occure. Now the priority directions of the state policy on development of IT education is defined and is reviewing the new standards of EQC and OPP; formation of future bachelors of IT professional skills, creation of students laboratories where the students engaged to IT, IT companies, that create conditions for the selection and employment of students and realize the concept of combining traditional deep comprehensive education and requirements for specialist by modern IT market [6].

The system of training of IT professionals in Eurasian countries such as Kazakhstan and Russia, unlike Ukraine and Poland, have no differences in curricula available in electronic information space [7,8].

In the typical curriculum for bachelors of IT in all these countries are in the electronic media space publicly available, the author finds a lot in common, and at the same time, a lot of differences in the subject "Computer Graphics". Mostly the subject has a common name in Russian and Ukrainian curriculum for the Bachelor of IT - "Engineering and Computer Graphics", " Descriptive computer Geometry and Graphics" (Kazakh curriculum), Poland - Grafika komputerowa i komunikacja człowiek-komputer, in particular, the high similarity in the way of teaching and presenting the educational material.

Most of attention in the IT specialized training of bachelors in Poland and Ukraine for the "Computer graphics" is paid to training students in Cycle of professional and practical training that develops ina process of their training and meets the individual needs of students in the specialization, creating individual learning paths. In Russia and Kazakhstan, this subject is given to cycle of training students in as main course subject.

Thus, from the perspective of educators in Kazakhstan for "Information system" course the study of the subject " Descriptive computer Geometry and Graphics" is offered, using electronic applications in the design of information systems.

IT undergraduate students of all the above mentioned countries on the basis of the "Computer Graphics" are taught by the same materials and have the ability to acquire knowledge and learn the different types of 3D graphs, charts RGB, CMYK, HSB, Adobe Photoshop, Gouraud method, Phong and more.

Thus, all the universities provide subject "Computer Graphics" and satisfy the needs of consumers in website politics, socio-economic management and solving a wide spectrum of problems, the possibility of deepening the development of this discipline from different types of additional electronic courses . Such training of IT specialists determines the high level of competitiveness of graduates in this area on the labor market.

Training on this subject can be realized only with proper logistics, for example computers with appropriate software.

Considering the electronic form of teaching methods (EEMC) in the mentioned above countries, the successful development of the discipline "Computer Graphics" scientific and teaching staff develops EEMC under standardized form approved by their own institutions, subjected to the necessary basic components. First of all, it concerns the development of a single standard representation of university teaching materials and provide free access to the teaching materials in university for managing board, professors and students within the defined security policy.

Based on the experience of teaching "Computer Graphics" for various IT disciplines, it was noted that to improve the quality of the preparation of the EEMC, it is necessary to implement professional engineering design vision of the information for the competency of the components in the course.

The implementation of e-learning contributes to solving strategic tasks and problems such as improving the quality of education; convergence of science, implementation of advanced technologies and education, implementation to the educational process of the latest achievements in science and technology; increasing both external and internal university mobility; ensuring academic freedom, creating the possibility of formation of individual educational trajectories for students, as the main principles of education.

We developed not only EEMC but also the computer textbooks for students of Bachelor of IT, which is inextricably linked to the basic educational program for students and their specialty.

In general, e-learning (EL) is becoming one of the most important areas of Ukrainian educational system, giving students additional opportunities and convenience in education process.

EL can be most effectively used for people with limited physical abilities, people who are in prisons, the ones with lack of sufficient time. Interest in e-learning is growing steadily. In domestic and foreign universities a large number of educational programs focused on e-education has being developed.

In particular, the training of Bachelor of IT is managed through the implementation of complex electronic applications based on modular principles, as well as the use in learning of the common electronic information and educational system. Information and educational system, which is a conglomeration of technologies, methods, based on educational and methodological support and organizational and pedagogical content. The basis of the architecture of informational and educational system that forms the core platform is integrating the database management and specific services and educational materials such as webinars, interactive laboratories, etc.

On this basis, the demands of openness, scalability, stability, and sustainability of documentation base platform are formed.

The logical structure of information systems (IS) of building information and

educational multimedia interactive space designed on the main features and includes basic subsystems.
In electronic educational documents analyzed various universities in general, we concluded that the total standardized content and final EEMC version are established by the university and its management.
Improving of the teaching methods and stages reforms, was the high issue concerning this topic in Ukraine and enshrined in law by the Ministry of Education and Science of Ukraine of 01.10.2012 № 1060 On approval of electronic educational resources. The Office provides advice on creating EEMC and outlines certain requirements for positioning in the electronic media space of scientific achievements.
Note that the new curriculum for the subject "Engineering and computer graphics" in the Ukrainian higher educational establishments differs by such innovations as the requirements for the positioning in the electronic media space training and working educational programs, especially since not every leading university provides electronic teaching systems, and also the only standardized set EEMC for general use in universities is not provided.
In line with the implementation by Ministry of Education and Science of Ukraine of the Order "On approval of rules for the use of computer programs in educational institutions" of 02.12.2004 number 903 (registered with the Ministry of Justice of Ukraine of 17.01.2005 № 44/10324) [9] raises the question of improving and diversifying of the forms and teaching methods, declaring the main form of e-learning and educational work at the same time entering the organizational and pedagogical usage of EEMC in universities as innovative forms of work with students, encouraging their mental activity, learning, skills improvement, ability to apply their knowledge in practice. Thus, in order to improve the quality of IT education and training in universities, the improvement of electronic educational content, informational and educational interactive multimedia space based on cloud technologies has to be provided.

3. Conclusion

Innovative approaches consider the idea of improving the basic form of electronic learning resources for future bachelors of computer graphics based on the theoretical content EEMC, that has incorporated new programs due to the restructuring of general and specific didactic teaching methods aimed to enhance self-learning of IT students. In addition, the important role of workshops for improving knowledge-based on participation in online conferences, debates, courses of individual interests and abilities of students in IT education.

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STOSOWANIE ONLIZER-A JAKO EFEKTYWNEGO I WYDAJNEGO NARZĘDZIA NA KOLEJNYCH ETAPACH CYKLU ŻYCIA OPROGRAMOWANIA

Streszczenie: W tym artykule omówiono stosowanie oprogramowania o nazwie „Onlizer" jako narzędzia analizy efektywności na wszystkich etapach cyklu życia oprogramowania. Ponadto, w pracy pokazano jak używać Onlizer-a najbardziej wydajnie dla następujących działań i zakresów: zarządzanie wymaganiami, architektura projektowanego oprogramowania, testowanie i wdrażanie oprogramowania. Wykazano, że Onlizer jest bardzo ważny dla zautomatyzowania różnych działań użytkowników aplikacji programistycznych i sieciowych: biznesu, tzw. startup-ów (inkubatorów przedsiębiorczości) oraz specjalistów IT i programistów.

Słowa kluczowe: oprogramowanie, platforma jako usługa, Onlizer, wydajność

USING ONLIZER AS EFFICIENT AND PRODUCTIVE TOOL AT THE SOFTWARE LIFE CYCLE STAGES

Summary: In this article we approved to using Onlizer as efficiency tool at the software life cycle stages. We showed how to use Onlizer most efficiently on the stages: requirement management, architecture design, testing and deploy software. We approved that Onlizer is very important for automate different human activities: business, startup, IT professional and software developers.

Keywords: software as a service, platform as a service, Onlizer, efficiency

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1. Overview modern state in information technology area

In modern conditions of development of IT industry, software engineering needs to attract new approaches to designing software, modernization duty cycle of project development, reducing the cost to produce the product or its parts (if outsourced), reduce the cost of work at various stages and life cycle stages [1]. In addition, it is important to adapt organizational and additional life cycle processes to the current challenges in the field of IT industry. In particular, those connected with intensive development of IoT-technologies, cloud services, cloud computing, data growth that must quickly handle and which are usually mixed and distributed. Consequently, the actual task both academic and business contexts is the development and implementation of technologies and their implementations, which would allow to optimize the development of software systems at all levels of the life cycle, taking into account the features of existing models in companies working cycle [1-4].
Draw analysis of the effectiveness of the basic processes of life cycle of software are using Onlizer.

2. Short description of Onlizer

Onlizer is online development platform and maintenance of software, built on component based architecture with a focus on the use of multi agents and cloud services that together are PaaS. Provides interoperability of data repositories, including relational and document-oriented structures, hardware with access to the Internet (support IoT), has a set of visual tools for building back-end logic of web-based software. On figure 1, we dispalyed basic proccess which Onlizer can automated.

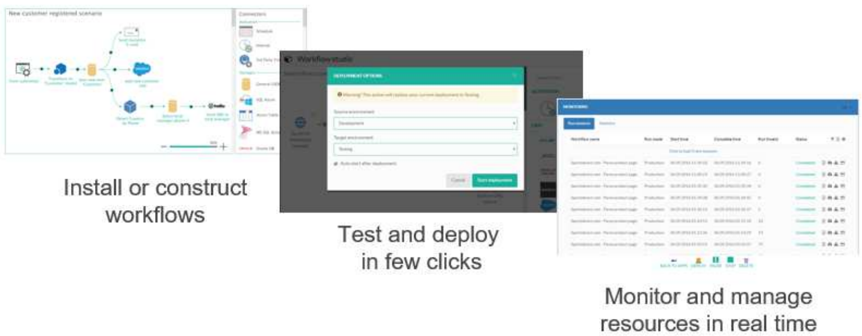

Figure 1. Automated procces with Onlizer

Onlizer includes connectors market place in which, besides their own connectors, you can post connectors from other developers. There is a good tool to integrate uniform and not uniform software and migration "ground" software in the "cloud."

3. Analysis and assembly of the requirements

The most important and time-consuming process life cycle is the collection and analysis of software requirements, from the results of their implementation depends the quality of future software system, the timing and cost of implementation [2]. Since the collection and analysis of requirements, always accompanied by the introduction of changes in data requirements, it is important to speed and ease of making changes in software architecture. When using Onlizer, speed changes in software architecture, compared to classical development environments that require coding, on average, increased by 60%. The speed and ease of making changes to the architecture due to the use of visual components, which specifies parameters and settings required for the implementation of a requirement. If necessary, you can use pseudocode platform metaprogramming, which is quite simple and straightforward, and their features provides the help service.

4. Design software architecture

Architecture software is an important aspect of software development [3]. To the architecture put forward a number of requirements, the most important of which are:
- extensibility;
- ease;
- intelligibility;
- ability to transformation.

In addition, in designing architecture must provide high connectivity inside the module and minimal coupling between modules.

Onlizer provides tools of architecture scaling and instantly publish them in the new version of developed software. So, every component of the system is designed on the basis of Onlizer, is a service that interacts with others via the API, the implementation of scale-out architecture on average is 40% faster than when using traditional approaches to writing code.

Because Onlizer in the process of designing architecture is using visual components, the perception of architecture and its implementation ensures the fulfillment of the requirements for its simplicity and understandability.

The comprehensibility of the architecture emphasizes the use of friendly names of components and connections between them. For example, on figure 1 we showed scenario how to use and connect some IoT and cloud services with Onlizer.

The ability to transform architecture, as in the case of scalability due to the use of components as services. Connectivity within the software modules designed system has provided at the platform level, as the components are recycled, meaning that they have been verified by practice and proved their reliability. Connection between modules designed system should provide developers themselves, based on the real problems that appear before them.

Note that the composition of microservices using Onlizer platform can be combined into a single application, which is a component of architecture a higher level of abstraction.

Therefore Onlizer platform significant advantage is the possibility of a descending and rising design architecture.

On the figure 3 we dispalyed basic scenario for customer registration and for this we use Onlizer.

Figure 2. Sample for use IoT with cloud with Onlizer

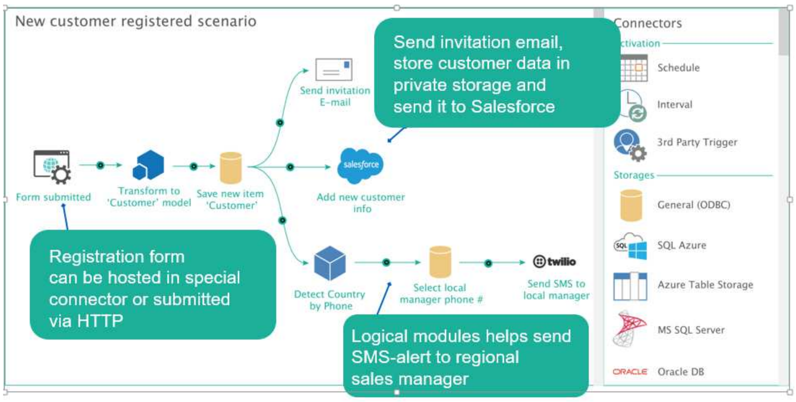

Figure 3. Scenario for basic customer registration

If we use classic way to create all components, which include writting code, testing and deploy application, than we spent time from 3 to 5 days. Because we use Onlizer time spent to development is near one hour.
Given the possibilities of designing architecture based Onlizer, the average time and cost of designing architecture reduced by 40-50% depending on project size and characteristics of the subject area(domain features).

5. Encoding software implementation

The process of encoding software architecture based on Onlizer platform the criteria of productivity and efficiency increases by 65%, whereas writing backend logic requires writing a significant amount of tape code, and domain features the features of the subject area and processes that occur in it takes less than 35%. Frontend logic software systems implemented by development your own templates presentation and

display products, and software point of connection to the backend logic. Currently, based on the Onlizer platform is developing release package to build external user interface with the ability to integrate into the platform and interoperability projects with backend logic.
Onlizer we can use as platform for create smart tools in self-organization systems. For example on figure 4 we integreted some data collection, connect Azure ML and built some logical components for automated process to sent contractor's orders.

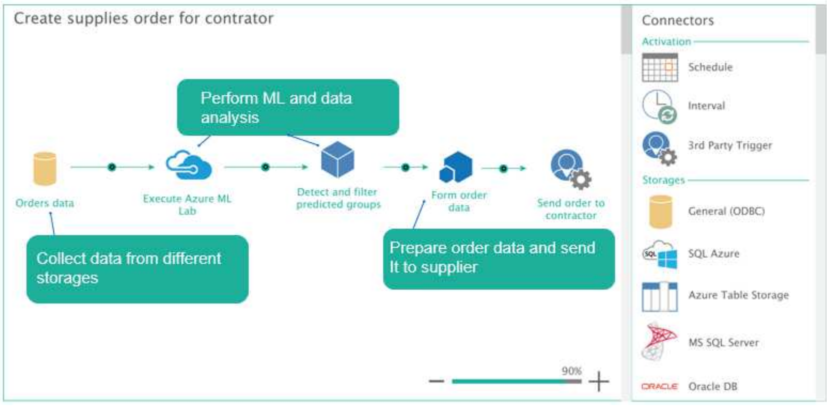

Figure 4. Use Onlizer as platform for create smart software

The process of testing software systems based Onlizer organized as a set of tools for viewing and analyzing test data sets in the «near real time» as in testing individual services and integrated components in a higher level of abstraction. On each service and communication between services can automatically analyze parameters and data values, and inspect the performance of services. In addition, as in the classical approach to testing software systems using Onlizer can build scripts validation of component-level unit testing, integration and system testing. Time and costs for testing and inspection process using Onlizer 30% lower relative to the classical approach, and the completeness of the results are slightly higher because there is the possibility of using proprietary information, especially when working with various database and data warehouse.

6. Input operation (Deploy) and maintenance of software systems

An important and final stage of software development is the deploy and maintenance. When implementing software systems rather complicated and time-consuming task is to deploy infrastructure in customer environment, supporting system in working condition for specified time, training users and others [3,4].
Based on the Onlizer platform infrastructure deployment among customer and users is not a serious problem, because the platform is web-centric and developer environment has no different from the end-user environment. And considering the factor that Onlizer interact with cloud services, the scalability of the system while increasing the burden on processing time, RAM or storage space is virtually infinite, which don't not affect the overall system performance. Therefore, the time to deploy

infrastructure and changes to existing projects are not significant and its value goes to zero. An important aspect of using Onlizer and cloud services is that with increasing load on any of the criteria for processing or storage, increasing payment for their use, but the platform allows at any time disable the use of services, and the end user can manage processes to the use of resources itself. If a cloud service is not used, the payment in accordance with the users will not be charged. So, we can use Onlizer in different type of subject areas for automate different process of human activity as showed on figure 5.

Figure 5. Using Onlizer in different domain fratures

7. Conclusion

So, use Onlizer the criteria of productivity and efficiency of software development makes it possible to reduce the deadlines of projects in the range of 30% to 60% depending on the type and size, and reduce the cost - from 40% to 65%.

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PRZEGLĄD ARCHITEKTURY SIECI 5G

Streszczenie: W najbliższej przyszłości, po wprowadzeniu do powszechnego użytkowania sieci bezprzewodowych 4-tej generacji, operatorzy telekomunikacyjni muszą ulepszyć swoją ofertę. Zadania jakie powinni zrealizować są następujące: wzrost przepustowości, redukcja opóźnień oraz poprawa jakości wszelkich usług sieciowych. Aby zrealizować te zadnia, trzeba będzie przeprowadzić istotne zmiany w istniejących bezprzewodowych sieciach komunikacji mobilnej (komórkowej). Ten artykuł jest poświęcony m.in. historii czterech pierwszych generacji sieci komunikacji bezprzewodowej. Ponadto, zidentyfikowano wyzwania przez jakimi stoją sieci info-komunikacji obecnej generacji. Ograniczenia te muszą być pokonane, aby nastąpił dalszy rozwój komunikacji sieciowej. Ponadto, zamieszczono krótką analizę proponowanych architektur nowoczesnych sieci 5-tej generacji.

Słowa kluczowe: historia sieci komórkowych, 5-ta generacja, architektura sieci bezprzewodowych

BRIEF REVIEW OF 5G NETWORK ARCHITECTURE

Abstract: In the near future, after the introduction fourth generation of wireless communication, important tasks would be increasing capacity, reducing delays and improving the quality of network services. To perform these tasks it would require substantial changes to the current wireless cellular communication system. This paper devoted to the history of the first four generations of wireless cellular communications, as well as the challenges faced by the current generation of info-communications, which must be overcome for the successful future of sustainable development. Also there is a brief analysis of the proposed architecture of the fifth generation of the modern network.

Keywords: cellular network history, 5G, wireless based architecture

1. Introduction

Today wireless technology has a fixed position in our everyday life. In order to satisfy rising demand for high-speed wireless connection in near future, the wireless based

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networks of today will have to advance in various ways. Various current constituent technologies such as high-speed packet access (HSPA) and long-term evolution (LTE) will be used to develop future wireless based technologies. Nevertheless, auxiliary components may also constitute future new wireless based technologies, which may adjunct the evolved technologies. Ultra-dense deployments, direct device-to-device communication, different ways of accessing spectrum and considerably higher frequency ranges and instigation of massive antenna configurations these are all kinds of new technology components [1].

From analog voice calls to current technologies mobile wireless communication has come to high quality mobile broadband services with end-user data rates of several megabits per second over wide areas and tens to hundreds, of megabits per second locally. Evolution of various mobile devices such as smartphones and tablets and extensive improvements in terms of potentiality of mobile communication networks, have resultant exponential growth in network traffic. This paper tries to include a survey from 1G to 5G technologies and general 5G architecture.

We assume that in future there would be network with unbounded access to information and sharing of data which is accessible anytime and everywhere for everyone and everything. To make it true, new technology components need to be examined for the evolution of existing wireless based technologies. Present wireless based technologies, like Wi-Fi, LTE technology, HSPA and 3rd Generation Partnership Project will be incorporating new technology components that will be helping to meet the needs of the future. Nevertheless, there may be certain scenarios that cannot be adequately addressed along with the evolution of ongoing existing technologies. The instigation of completely new wireless based technologies will complement the current technologies which are needed for the long term realization of the future networks.

2. Evolution of wireless technologies

Wireless communications history starts with communicating the letter ‘S’ for 3 km in the form of three dot Morse code with the help of electromagnetic waves by Italian inventor G. Marconi. After this inception, wireless communications have become an important part of present day society. Since satellite communication, television and radio transmission has advanced to pervasive mobile telephone, wireless communications has transformed the style in which society runs. The evolution of wireless technologies is shown in figure 1.

It shows the evolving generations of wireless technologies in terms of data rate and mobility. With evolution of wireless technologies, the data rate, mobility, coverage and spectral efficiency increases. Technologies of 1G and 2G use circuit switching while 2.5G and 3G uses both circuit and packet switching and the next generations from 3.5G are using packet switching. Along with these factors, it also differentiate between licensed spectrum and unlicensed spectrum. All the evolving generations use the licensed spectrum while the Wi-Fi, Bluetooth and WiMAX are using the unlicensed spectrum.

An overview about the evolving wireless technologies is below:

The 1st generation was announced in initial 1980’s and has a data rate up to 2.4kbps. Major subscribers were Advanced Mobile Phone System, Nordic Mobile Telephone, and Total Access Communication System. It has a lot of disadvantages like below par capacity, reckless handoff, inferior voice associations, and with no security, since voice calls were stored and played in radio towers due to which vulnerability of these calls from unwanted eavesdropping by third party increases [4].

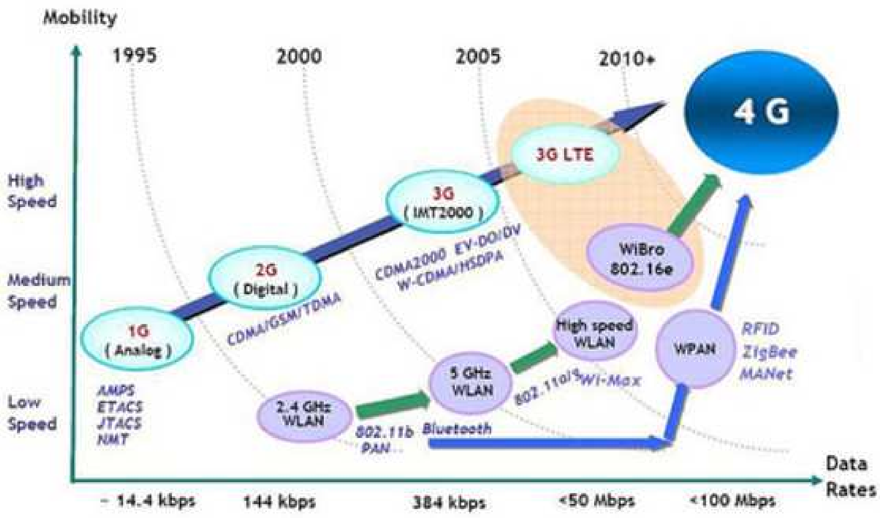

Figure 1. Evolution of wireless technologies

The 2nd generation was introduced in late 1990's. Digital technology is used in 2nd generation mobile telephones. Global Systems for Mobile communications (GSM) was the first 2nd generation system used for voice communication and having a data rate up to 64kbps. 2G mobile handset battery lasts longer because of the radio signals having low power. It also provides services like Short Message Service and e-mail. Vital eminent technologies were GSM, Code Division Multiple Access (CDMA), and IS-95 [4].

The 2.5G generation generally subscribes a 2nd generation cellular system merged with General Packet Radio Services (GPRS) and other amenities doesn't commonly endow in 2G or 1G networks. A 2.5G system generally uses 2G system frameworks, but it applies packet switching along with circuit switching and has a data rate up to 144kbps. The main 2.5G technologies were GPRS, Enhanced Data Rate for GSM Evolution (EDGE), and CDMA 2000 [4].

The 3G generation was established in late 2000 and imparts transmission rate up to 2Mbps. Third generation systems merge high speed mobile access to services based on Internet Protocol (IP). Aside from transmission rate, unconventional improvement was made for maintaining quality of service. Additional amenities like global roaming and improved voice quality made 3G as a remarkable generation. The major disadvantage for 3G handsets is that, they require more power than most 2G models. Along with this 3G network plans are more expensive than 2G [4]. Since 3G involves the introduction and utilization of Wideband CDMA, Universal Mobile Telecommunications Systems and CDMA 2000 technologies, the evolving technologies like High Speed Uplink/Downlink Packet Access and Evolution-Data

Optimized has made an intermediate wireless generation between 3G and 4G named as 3.5G with improved data rate of 5-30 Mbps.

LTE technology and Fixed Worldwide Interoperability for Microwave Access (WIMAX) is the future of mobile data services. LTE and Fixed WIMAX has the potential to supplement the capacity of the network and provides a substantial number of users the facility to access a broad range of high speed services like on demand video, peer to peer file sharing and composite Web services. Along with this, a supplementary spectrum is accessible which accredit operators manage their network very compliantly and offers better coverage with improved performance for less cost [3], [4].

4G is generally referred as the descendant of the 3G and 2G standards. 3rd Generation Partnership Project is presently standardizing LTE Advanced as forthcoming 4G standard along with WIMAX. A 4G system improves the prevailing communication networks by imparting a complete and reliable solution based on IP. Features like voice, data and multimedia will be imparted to subscribers on anytime and everywhere basis and at quite higher data rates as related to earlier generations. Applications that are being made to use a 4G network are Multimedia Messaging Service, Digital Video Broadcasting, and video chat, High Definition TV content and mobile TV [2], [3].

With an exponential increasing users demand, 4G will be replaced with 5G with an advanced access technology named Non- and quasi-orthogonal or filter bank multi carrier multiple access and Beam Division Multiple Access (BDMA). BDMA technique concept is explained by considering the case of the base station communicating with the mobile stations. In this communication, an orthogonal beam is allocated to each mobile station and BDMA technique will divide that antenna beam according to locations of the mobile stations for giving multiple accesses to the mobile stations, which correspondingly increase the capacity of the system [5]. Incentives to move towards 5G is based on current drifts, it is commonly assumed that 5G cellular networks must eliminate six weaknesses of 4G i.e. higher capacity, higher data rate, lower End-to-End latency, massive device connectivity, reduced cost and consistent quality of experience provisioning. These challenges are concisely shown in table 1 along with some potential facilitators to address them. An overview of the challenges, facilitators, and corresponding design fundamentals for 5G is shown in table 1 [8].

Table 1. 5G challenges, potential enablers and design principles

<table>
<tr><th>Challenges</th><th>Enablers to address challenges</th><th>Design principles</th></tr>
<tr><td rowspan="8">Capacity (x1000 >70% indoor)

Data rate (x10-100)

E2E latency (<1ms)

Massive number of connections (x10-100)</td><td>Spectrum</td><td>Use high frequencies and other spectrum options</td></tr>
<tr><td>Massive/3D MIMO</td><td rowspan="2">Design new air interface, new multiple access scheme and L1/L2 techniques that can be optimized for high frequencies, latency and massive connectivity</td></tr>
<tr><td>New air interface</td></tr>
<tr><td>Optical networks</td><td>Optical transmission and switching wherever possible</td></tr>
<tr><td>Small sells</td><td rowspan="3">Bring communicating endpoints closer together</td></tr>
<tr><td>Local offload</td></tr>
<tr><td>Caching/Pre-caching/CDN</td></tr>
<tr><td>C/U-plane split</td><td>Address coverage and capacity separately.</td></tr>
</table>

Cost (sustainable)	NFV/SDN/Cloud	Minimize number of network layers and pool resources as much as possible
QoE (consistent)	3rd party/User deployment models	Minimize functionalities performed by access points
	Simple access points	
	Energy-efficient hardware	Maximize energy efficiency across all network entities
	Energy management techniques	
	SON	Use an intelligent agent to manage QoE, routing, mobility and resource allocation. Redesign NAS protocols, services and service complexity
	Traffic management	
	Big data-driven network intelligence	

3. 5G cellular network architecture

Before the demonstration 5G technology to end user it is necessary to modernize the existing basis. Current technologies like OFDMA will work at least for next 50 years, so there is no need to change wireless setup which had come about from 1G to 4G. In order to please user requirements, we could only complement existing fundamental network. This will provoke the package providers to drift for a 5G network as early as 4G is commercially set up [5]. We have to make drastic changes in the strategy of designing the 5G wireless cellular architecture, to meet the users demands and to overcome challenges that has been put forward in the 5G system. A general researchers' observation has shown that most of the wireless users stay inside for 80% and outside 20% of time [6]. In present wireless cellular architecture we have an outside base station in the middle of a cell, that allows a mobile user to communicate. While users inside, the signals from outside base station will have to travel through the walls, and this will result in high penetration loss, which correspondingly costs with reduced spectral efficiency, data rate and energy efficiency of wireless communications. To overcome this challenge there was proposed a new designing technique for scheming the 5G cellular architecture [5]. With this designing technique, the penetration loss through the walls of the building will be slightly reduced. This idea will be supported with the help of massive MIMO technology, in which geographically dispersed array of antenna's are deployed which have tens or hundreds of antenna units.

To build or construct a large massive MIMO network, firstly the outside base stations will be fitted with large antenna arrays and among them some are dispersed around the hexagonal cell and linked to the base station through optical fiber cables, aided with massive MIMO technologies. The mobile users present outside are usually fitted with a certain number of antenna units but with cooperation a large virtual antenna array can be constructed, which together with antenna arrays of base station form virtual massive MIMO links. Secondly, every building will be installed with large antenna arrays from outside, to communicate with outdoor base stations with the help of line of sight components. The wireless access points inside the building are connected with the large antenna arrays through cables for communicating with indoor users. This will significantly improves the energy efficiency, cell average throughput, data rate, and spectral efficiency of the cellular system but at the expense of increased infrastructure cost. With the introduction of such an architecture, the inside users will only have to connect or communicate with inside wireless access points while larger antenna arrays remained installed outside the buildings [5]. For indoor communication, certain technologies like Wi-Fi, Small cell, ultra wideband, millimeter wave communications, and visible light communications are useful for small range communications having large data rates [6]. But technologies like millimeter wave and visible light communication are utilizing higher frequencies which are not conventionally used for cellular communications. But it is not an efficient idea to use these high frequency waves for outside and long distance applications because these waves. Technical comparison between recent 802.11 standards. will not infiltrate from dense materials efficiently and can easily be dispersed by rain droplets, gases, and flora. Though, millimeter waves and visible light communications technologies can enhance the transmission data rate for indoor setups because they have come up with large bandwidth. Along with the introduction of new spectrum, which is not being conventionally used for wireless communication, there is one more method to solve the spectrum shortage problem by improving the spectrum utilization of current radio spectra through cognitive radio (CR) networks [6].

Since the 5G cellular architecture is heterogeneous, so it must include relays, macro, micro and small cells. A mobile small cell concept is an integral part of 5G wireless cellular network and partially comprises of mobile relay and small cell concepts [7]. It is being introduced to put up high mobility users, which are inside the automobiles and high speed trains. Mobile small cells are positioned inside the moving automobiles to communicate with the users inside the automobile, while the massive MIMO unit consisting of large antenna arrays is placed outside the automobile to communicate with the outside base station. According to user's opinion, a mobile small cell is realized as a regular base station and its allied users are all observed as a single unit to the base station which proves the above idea of splitting indoor and outdoor setups. Mobile small cell users [7] have a high data rate for data rate services with considerably reduced signaling overhead, as shown in [5]. As the 5G wireless cellular network architecture consists of only two logical layers: a radio network and a network cloud. Different types of components performing different functions are constituting the radio network. The network function virtualization cloud consists of User and Control plane entities that perform higher layer functionalities related to the User and Control plane, respectively. Special network functionality as a service (XaaS) will provide service as per need, resource pooling is one of the examples. XaaS is the connection between a radio network and a network cloud [8].

The 5G cellular network architecture is explained in [5] and [8]. It has equal importance in terms of front end and backhaul network respectively. In this paper, a general 5G cellular network architecture has been proposed as shown in figure 2. It describes the interconnectivity among the different emerging technologies like Massive MIMO network, Cognitive Radio network, mobile and static small-cell networks. This proposed architecture also explains the role of network function virtualization cloud in the 5G cellular network architecture. The concept of Device-to-Device communication, small cell access points and Internet of things has also been incorporated in this proposed 5G cellular network architecture. In general, this proposed 5G cellular network architecture may provide a good platform for future 5G standardization network.

Figure 2 illustrates a 5G mobile network architecture that utilizes the enablers discussed previously. The key elements in the architecture are summarized below.

- Two logical network layers, namely a radio network (RN) that provides only a minimum set of L1/L2 functionalities and a network cloud that provides all higher layer functionalities.
- Dynamic deployment and scaling of functions in the network cloud through SDN and NFV.
- Lean protocol stack achieved through elimination of redundant functionalities and integration of AS and NAS.
- Separate provisioning of coverage and capacity in the RN by use of C/U-plane split architecture and different frequency bands for coverage and capacity.
- Relaying and nesting (connecting devices with limited resources non-transparently to the network through one or more devices that have more resources) to support multiple devices, group mobility and nomadic hotspots.
- Connectionless and contention-based access with new waveforms for asynchronous access of massive number of MTC devices.
- Data-driven network intelligence to optimize network resource usage and planning.

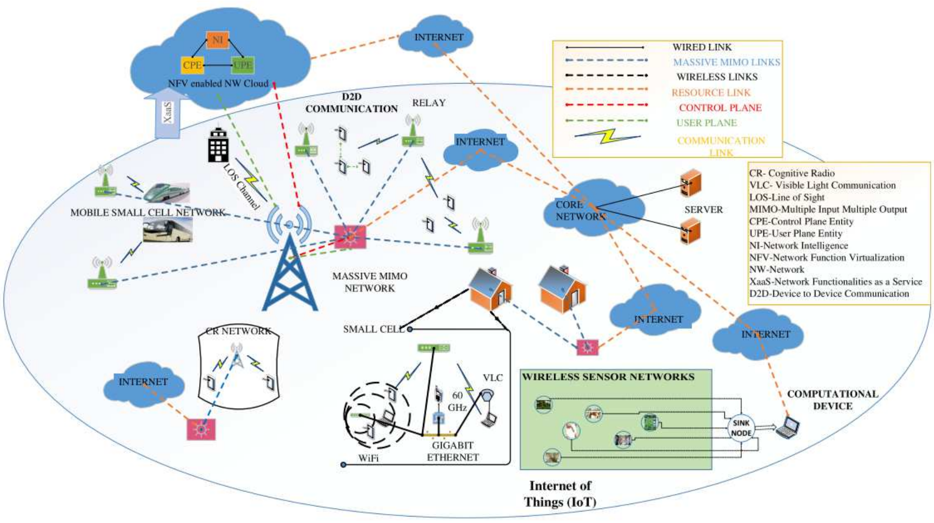

Figure 2. A general 5G cellular network architecture [8]

4. Conclusions

The modern world needs everything recently developed especially in terms of technologies also. First generation starts in the year of 1980s but now it seems to be older than a century because of its speed. From there onwards a new step or ladder is leaned as proportional to speed and year. In this paper, a detailed survey has been done on the generations history of cellular networks, network architecture and performance requirements for 5G wireless cellular communication systems that have been defined in terms of capacity, data rate, spectral efficiency, latency, energy efficiency, and quality of service. A 5G wireless has been explained in this paper with massive MIMO technology, network function virtualization cloud and device to device communication. This paper may be giving a good platform to motivate the researchers for better outcome of different types of problems in next generation networks.

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TECHNOLOGY OF CODING OF DIGITAL AERIAL PHOTOGRAPHS TAKING INTO ACCOUNT CLASSES OF A SEMANTIC SATURATION OF BLOCKS IN SYSTEM OF AIR MONITORING

TECHNOLOGIA KODOWANIA CYFROWYCH FOTOGRAFII LOTNICZYCH Z UWZGLĘDNIENIEM KLAS SEMANTYCZNEGO NASYCENIA BLOKÓW DLA SYSTEMU MONITORINGU POWIETRZNEGO

Summary: The questions connected with processing of digital aerial photographs which are received in the course of conducting aerial monitoring by the unmanned aerial vehicle (UAV) are considered. Digital images are presented in the form of aerial photographs, characterized by different degree of a semantic saturation. By means of various methods of processing of images it is possible to select significant information on an aerial photograph on semantic characteristics of objects. For this purpose the need of application of orthogonal transformations is proved, and also the technology of two-hierarchical coding of blocks of an aerial photograph onboard the UAV is offered.

Keywords: air monitoring, aerial photograph, coding, semantics, block, sequence, vector.

1. Introduction

A possibility of gathering information by systems of aerial monitoring with use of UAV (Unmanned Aerial Vehicle) is of high interest today. Here, as the information received in the process of aerial monitoring, by means of photographic optical-electronic systems, digital aerial images are considered.
The UAV onboard unit performs an information transfer through communication channels to a land device. Aerial photographs gain high degree of saturation of small

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details and contain approximately 100 Mbit of information. At the same time the onboard unit is restricted by dimension, power of the onboard generator and low capacity of radio data transmission channels. Due to such shortcomings data transmission channels between the UAV and a land device don't provide a real-time delivery of the information. Suppression in the delivery of information in the process of aerial monitoring leads to obsolescence in reporting and decision making.

One of the effective ways to improve the delivery of the information is a volume reduction of the transmitted data. For this purpose it is proposed to carry out processing of the images directly onboard the UAV. Such reduction of information may however carry out another constraint, which is a loss or distortion of semantic information significant for the decryption process.

Efficiency of decryption depends on saving key information on an object. Therefore we propose to allocate the objects carrying crucial information in the processing, so that they would be transferred with preservation of the finest details. Such approach will allow to keep informational content of an aerial photograph, taking into account the low capacity of communication channels.

The existing technologies and methods of information processing have number of shortcomings [2]. These methods are characterized by both high computing complexity, and loss of information in aerial photograph blocks.

When processing images, application of orthogonal transformations by means of DCT [3] is the most often used. The received frequency coefficients will allow to select significant information in the aerial photography block. Classification of a semantic saturation of blocks and also application of methods of coding of an aerial photograph will allow not only to allocate the most informative blocks but also to save information on key signs of decryption. It will allow to lower the flow of unnecessary information at data transmission on communication channels.Thus, the purpose is development of technology of coding of aerial photographs which in processing will allow to allocate the areas on an aerial photograph bearing the main semantic saturation taking into account the admissible level of loss of quality that will lead to reduction of volume of the processed and transmitted data on communication channels.

1.1. Creation of classification of a semantic saturation of blocks of an aerial photograph on the basis of DCT

High-contrast areas of an aerial photograph, differences of brightness, the linear sizes of objects make the most informative part of an aerial photograph. Therefore when processing it is necessary to consider a set of details: picture scale, resolution, quantity of objects, etc. However special attention needs to be paid to the choice of a semantic saturation in the considered aerial photographs.

Under a semantic saturation of an aerial photograph we awake to understand the most significant information on contours, borders of objects of the area.

One of problems of processing of images is their classification. Among different types of classifications by importance degree, the problem of a semantic saturation which allows to obtain substantial information on the importance of the block of an aerial photograph is allocated

For creation of technologies of data processing onboard it is required to consider how features of functioning of an onboard complex, and the fact that the main class of the data formed onboard means of aerial monitoring are aerial photographs of a different saturation. It is offered to consider blocks aerial photographs on degree of a semantic saturation:

a) "Low saturated"; b) "middle saturated"; c) "high saturated"

We offer, to classify these blocks of an aerial photograph on two general groups [4]:

- I group - the blocks which are high-coherent and with rather uniform content of structure.
- II group - the blocks with non-uniform structure which are low-coherent.
- We will carry out classification of groups of blocks of the image on classes. On the basis of classification we will receive:
- I.1. Uniform blocks, which image elements close or identical on color.
- I.2. Blocks with smooth transition of flowers in which there is a gradual change of one color of an element of the image to another.
- II.1. Planimetric blocks which can be divided into two areas with sharp difference of color between image elements.
- II.2. Textural blocks at which there are sharp differences of colours of an element of the image at some local area).
- The following step we will apply dct-transformation to processing of blocks of an aerial photograph of these classes. In the beginning will be executed segmentation of an aerial photograph on blocks of the sizes 8×8 of pixels which are exposed further to two-dimensional discrete cosine transformation. As a result of performance of dct-transformation matrixes (transformant) of frequency coefficients, the size 8×8 of elements turn out.

There are most significant coefficients, correspond to the lowest frequency (are grouped in low-frequency area). All other components are high-frequency components. They contain insignificant information on the image. Thus, DCT creates conditions for assessment of a structural saturation of blocks of an aerial photograph.

As a result of redistribution of energy between components transformant we will carry out distribution of its frequency coefficients on groups:

I - all frequency coefficients; II - low-frequency coefficients; III - high-frequency coefficients; IV - zero coefficients.

On the basis of the distributed frequency coefficients in a transformant of dct-transformation on groups, we will define structural characteristics of the classified aerial photograph blocks. For the analysis of the distributed frequency coefficients transformant we will calculate parameter P_{dct} for each group.

The value of parameter P_{dct} is analyzed for zones of coefficients on a formula:

$$P_{DCT} = [\log_2 (\prod_{\gamma=1}^{D_d} \prod_{\xi=1}^{N_y} (y_{\gamma,\xi}))], \qquad (1)$$

where: $y_{\gamma,\xi}$ - component of transformant C on position with coordinates (γ ,ξ), to diagonal D ;

D_d - quantity of diagonals in indicative group of a component;

N_γ - quantity a component which correspond to diagonals in indicative group.

For a research the full-color realistic image – the aerial photograph received as a result of aerial photography with the UAV has been selected. The choice of an aerial photograph is connected with the fact that he covers possible blocks of use of the

developed method. Further on a test aerial photograph 9 characteristic areas of which the most characteristic blocks of 8*8 pixels, on above to the developed classification got out have been chosen.
The following step for the analysis of the distributed frequency coefficients of the studied blocks of an aerial photograph calculates parameter P_{dct} for each group of frequency coefficients on (forms. 1).
The carried-out calculations allow to draw a conclusion that there is a dependence between frequency coefficients in the block and parameter in each group.
Further the technology of classification of blocks of an aerial photograph for degree of a semantic saturation is carried out that is presented by the following steps:
1) Choice of indicative characteristics of blocks: saturation index $p_{k,\ell}^{(1)}$ and structural index $p_{k,\ell}^{(2)}$;
2) Assessment of the indicational characteristics of the block on the basis of which degree of accessory of blocks each other in uniform indicational space is defined;
3) Clustering of blocks of an aerial photograph which results in the distributed blocks $m_{i,j}$ by clusters M_j , on a basis indicational characteristics, what in turn leads to formation of three classes of a saturation of blocks (high-, middle- and low saturated) [5]. It will allow to make a choice concerning a class of a saturation of the studied blocks, taking into account the choice of j -th type of block $m_{i,j}$. At the same time the parameter g of quality of the saved information on key signs of decryption will be chosen according to a class of a semantic saturation.
In this case, dependence of parameter g of quality of transfer of key signs on degree of a saturation is presented by expression:

$$g = f(m_{i,j}, j),$$

where: $m_{i,j}$ – i -th block that belong to j -th cluster according to a class of a semantic saturation.
On the basis of the received classes of a saturation of blocks there is a choice of strategy of quantization a component of transformant.

1.2. Technology of two-hierarchical coding of blocks of the aerial photograph taking into account the class of the semantic saturation of blocks

The first step is the elaboration of strategy of quantization a component transformant. Each component $y_{\gamma,\xi}$ of the transformant C is exposed to correction, according to quantization coefficients. Here the balance is provided, on the one hand, between increase of the length of the zero chains q_{χ} of the component transformant and growth of extent of reduction of volume of transmitted data, on the other hand – increase in efficiency of decryption of aerial photographs due to preservation of key and significant signs of decryption (a contour, texture and uniformity of landscape areas). Thanks to it there is an increase in efficiency of delivery of information at the set quality of decryption.
The final result of the first step is receiving of quantized component of transformant C', according to a saturation of key signs.

The first level of two-hierarchical coding consists in receiving of the structured representation of the transformant with further allocation of the sequence $\hat{R}_{\nu_{vkt}}$ of two-element vectors.
At first it is carried out structurization of the transformant, by formation of a one-dimensional vector, i.e. it is carried out an allocation of lengths q_{χ} of chains, consisting from a component transformant, having zero values after quantization. Further it is carried out a formation of the vector consisting of two components: q_{χ} - length of a chain zero components; b_{χ} - value components different from zero value. Thus, we receive a two-element vector $\{q_{\chi};\, b_{\chi}\}$ of structural characteristics of transformant. The following step carries out creation of vectors $\{q_{\chi};\, b_{\chi}\}$ in the sequence $\hat{R}_{\nu_{вкр}}$ of two-element vectors that is presented by expression:

$$\hat{R}_{\nu\, vkt-2} = \{ (q_2; b_2), \ldots, (q_{\chi}; b_{\chi}), \ldots, (q_{\nu_{вкт}-1}; b_{\nu_{вкт}-1}) \},$$

where: ν_{vkt} - length of the sequence $\hat{R}_{\nu_{вкр}}$ of two-element vectors.
At the second level of two-hierarchical coding occurs formation of code representation for separate two-element vectors $\Xi_{\chi}^{(2)}$. Здесь for each vector, as two-element number $\Xi_{\chi}^{(2)}$ of the first level, code value $\mathrm{Z}(\Xi_{\chi}^{(2)})$ is formed.
On the following step it is carried out a formation of a chain S, maked of values of codes $\mathrm{Z}(\Xi_{\chi}^{(2)})$, which is the generalized number in a base of structural constraints of a transformant that is provided by expression:

$$S = \{ Z(\Xi_2^{(2)}) \; ; \ldots ; Z(\Xi_{\chi}^{(2)}) \; ; \ldots ; Z(\Xi_{\nu_{вкт}-1}^{(2)}) \} .$$

Proceeding from it, there is a formation of the general code conception $\mathrm{Z(S)}$ taking into account the received code values $\mathrm{Z}(\Xi_{\chi}^{(2)})$ at the first level that is represented by expression:

$$Z(S) = \sum_{\chi=2}^{\nu_{vkt}-1} Z(\Xi_{\chi}^{(2)})\, N(S^{(\chi)}) .$$

Value $N(S^{(\chi)})$ acts as weight coefficient χ -th element of the generalized position number in basis of structural restrictions of transformant.
Thus, received generalized code representations $Z(S)$ to allow to receive a codegram Ω for the generalized number, that necessary for data presentation in a binary form.

2. Conclusions

1. Need of application of DCT for classification of blocks of an aerial photograph of different classes is proved. The analysis of values of frequency coefficients of a matrix of DCT in blocks on groups is carried out.

2. Classification of blocks of aerial photographs by degree of a semantic saturation is received.
3. The technology of two-hierarchical coding of blocks of an aerial photograph taking into account semantic important information in system of aerial monitoring is developed. It is based on formation of the sequence of significant two-element vectors for the structurized transformants.
4. Interpretation of the sequence of significant two-element vectors as the generalized number of uncertain length is stated. At the same time elements of the generalized number are the codes of two-element numbers of the first level formed for separate two-element vectors.

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MODEL ADAPTERA TELEFONICZNEGO OPARTEGO NA FILTRZE ŚRODKOWO ZAPOROWYM

Streszczenie: Niniejsza praca jest poświęcona omówieniu roli urządzeń podsłuchowych w lokalnej pętli telefonicznej. Pokazuje się zasadę linii telefonicznej abonenta do sterowania tym urządzeniem. Zaprezentowano także zasilacz obwodu linii napowietrznej.

Słowa kluczowe: zakładka telefoniczna, filtr wycinający (środkowo zaporowy), urządzenie wykrywające telefoniczne zakładki

MODEL OF A TELEPHONE ADAPTER BASED ON A BAND-REJECT FILTER

Summary: This work is devoted to revealing wiretaping devices in the local telephone loop. Showing the principle of the device control subscriber telephone line. Presented adapter circuit of overhead line.

Keywords: phone bookmark, notch filter, telephone bugs detection device

1. Introduction

Threats to information security of telephone subscribers are often implemented by a contact connection of technical intelligence tools to a telephone subscriber line (TSL).Thus, such type of connection is unlikely to happen on the area with a set of multipair telephone cables (it concerns, especially, the trunk area where the cable is laid underground). The simplest and, therefore, the most credible one is a connection to the exposed areas of subscriber wire drop[1].
The technical characteristics improvement of telephone eavesdropping devices enforces the search for new methods of designing monitoring tools against

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unauthorized connections to the TSL. The authors were researching the possibility to design a telephone adapter model based on a band-reject filter.
The purpose of this paper is to substantiate the selection of a band-reject filter for a telephone adapter, to develop a measuring path structure as well as to study the telephone adapter model based on a band-reject filter.

2. Principles and classification of technical intelligence tools used in telephone lines

Technical intelligence tools (TIT) can be used both for interception of telephone calls and room eavesdropping where the phone itself is placed, thus, they are often called devices of establishment on subscriber public-call lines. Fig. 1 summarizes the general structure of devices of establishment on subscriber public-call lines.
The TIT basis is a telephone adapter that provides a removal signal from TSL. Another important element is a signal processing node, which has a function to extract an informative signal from the background of different kinds of inconvenient factors and to amplify it to the level suitable for further use.
Devices of establishment on subscriber public-call lines are usually implemented in a separate module or hidden in various telephone elements, for instance, capacitor, telephone or microphone capsule, phone plug, socket and so on. Devices of establishment on subscriber public-call lines are small (a size from one to several) and weight from 10 to 70 g. For example, a devices of establishment on subscriber public-call lines HKG-3122 has a size of 33x20x12 mm and SIM-A64 - 8x6x20 mm.
The devices of establishment on subscriber public-call lines provide the following types of usage of intercepted signals:

- real time conversations eavesdropping
- recording of a speech signal
- retransmitting the signal outside the controlled zone

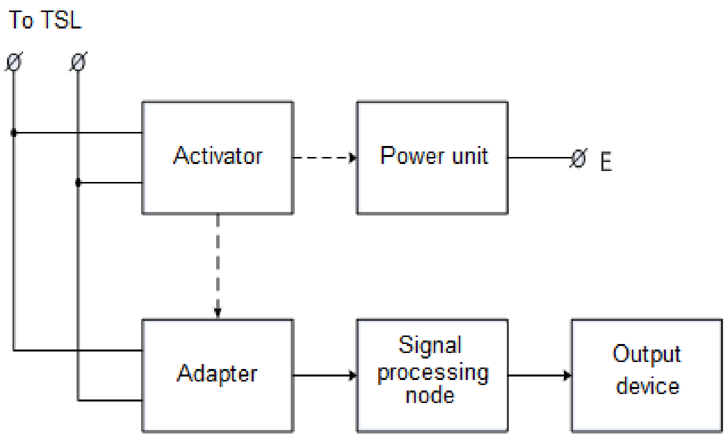

Figure 1. TIT generalized structure to use in TSL

While eavesdropping, a converter from electronic signal to acoustic one is used, while recording - a device for speech signal recording on a magnetic tape or flash memory is applied, and while retransmitting – a transmitter that implements the emission of signals intercepted from telephone line to the transmitting channel with the subsequent radio reception is the best option. To conceal a transmitting channel some special coding and modulation formats, in particular, a noise signals technology can be used. Power supply for devices of establishment on subscriber public-call lines can be provided in two ways - directly from TSL or from an independent source. In the first case the power supply is realized in the form of a special matching device and provides virtually unlimited lifetime, however, it may be detected due to the additional load on TSL while the latter has the opposite properties.

To save the resource for masking and spare the autonomous power supply, there were inserted some special device-activators into TIT. Their work can be based on analysis of the telephone line (TIT activation starts with answering a call) or spoken signal detection in TSL.

Depending on how you're connected to the telephone subscriber line one can distinguish contactless and contact TIT. Contact TIT, in return, are divided into serial and parallel ones.

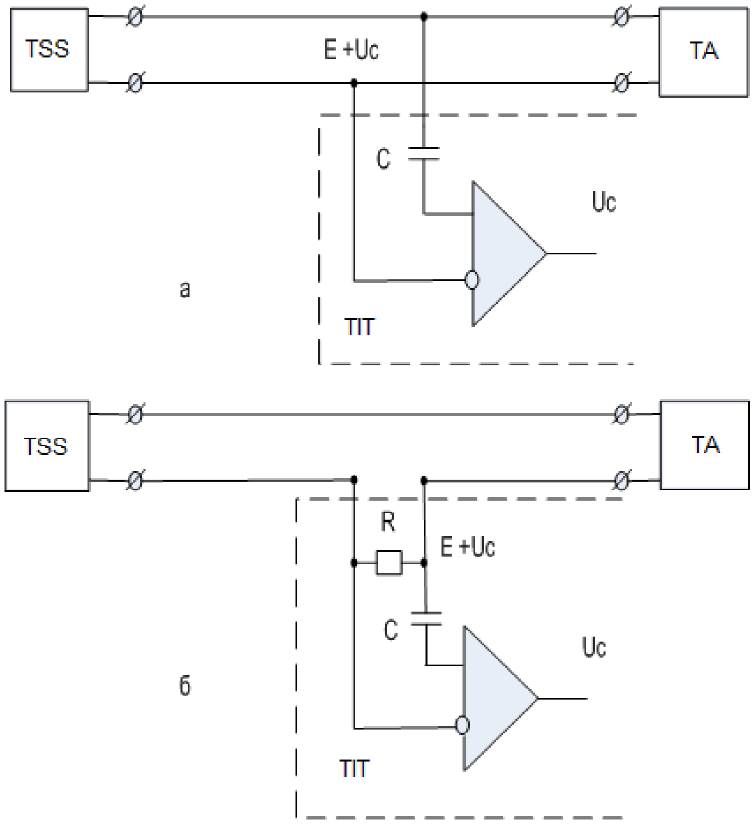

Figure 2. Parallel (a) and sequential (b)TIT connection to the TSL

This classification criteria, first and foremost, defines a type of phone adapter. So, contactless adapter can be made in the form of a inductive puller, which, in the simplest version, is coil reeled on a cut ferrite ring. Due to a TSL ring coverage, there

starts a transformation of electromagnetic waves created by current passing through the spoken lines to the electrical signal that comes to recording or playback device after amplification.
Contactless TIT can not be detected by measuring the electrical parameters of the telephone line, but its performance or recording is not very high because of the sensitivity of the induction puller to various electromagnetic interference. Contact adapters have galvanic contact with the telephone line and, therefore, are able to provide a much higher quality.
Parallel adapter is being connected to the parallel lines. It stands out due to a high input impedance and low input capacitance, which makes its detection much more difficult (Fig. 2, a). Serial adapter is inserted in the gap in some of the telephone lines wires (Fig. 2, b) and has an input impedance of several hundred ohms and a large input capacity, which facilitates its detection.
Fig. 3 the scheme of parallel where the role of adapter is performed by the relay. There is a way to intercept telephone conversations, by realizing the radiation signals from a telephone line into the transmitting channel with their subsequent reception on the radio.

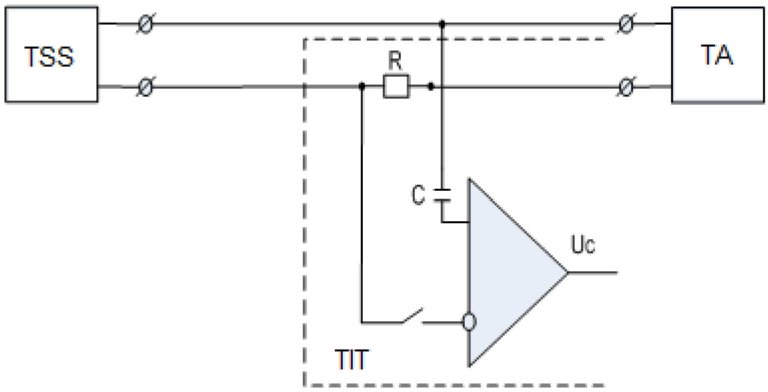

Figure 3. Using a relay as the trigger for a parallel TIT

3. Selecting the type of band-reject filter for a telephone adapter

The traditional application of band-reject filter of Notch Filter type is the suppression of network interference (50 or 60 Hz). Perfect notch filter frequency response is quite flat in range, except from a very narrow frequency band suppression. Characteristic decreases very rapidly at these frequencies, providing a high level of attenuation that is able to remove the unwanted signal [2].
Probably the best known implementation of the notch filter is a double-T filter, which is shown in Fig. 4. To construct this filter one needs six high precision components for configuration, besides two of them are parts of others. If a developer wants to have the components of the same size, in that case eight precision components are needed: for $R_0/2$ Component = two parallel switched resistors R_0, and correspondingly for $2\times C_0$ = C0 two parallel capacitors.

Besides, the resistance values of resistors becomes larger by requiring $R_Q << R_0$ (R_Q - resistors to adjust the quality of Q-filter). The variations in the resistor affect the depth of cut and the central frequency. Also it becomes difficult to adjust double T filter topology to the unipolar power.
However, topology is quite usable for applications where only one operational amplifier (OA) can be used.

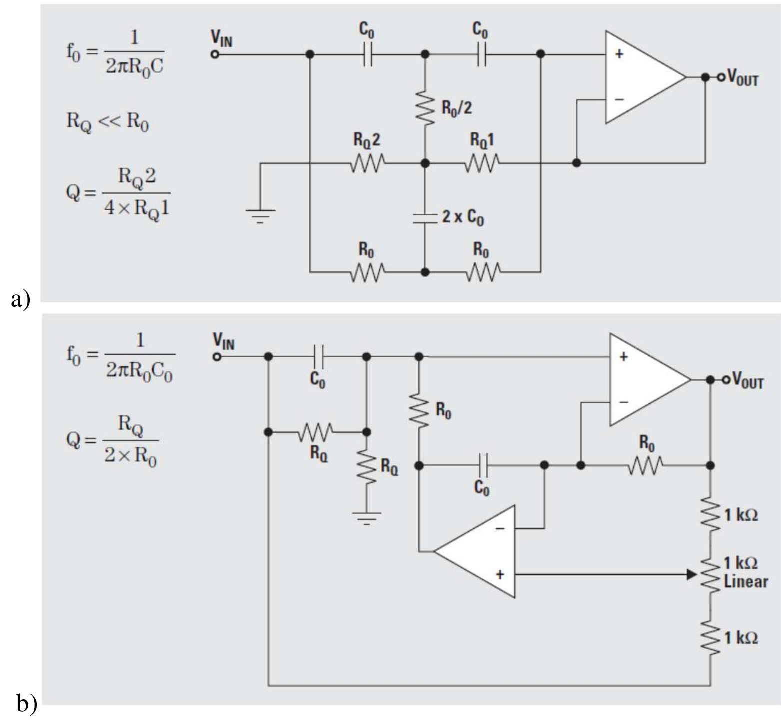

Figure 4. Band-reject filter scheme: a - double T filter; b - Fliege notch filter [3]

A scheme of Fliege notch filter is shown in Fig. 4, b. The advantages of this scheme comparing with the double-T filter are the following:

- only four precision components – two Rs and two Cs are required to set the central frequency
- key feature of this scheme is that in case of small deviations of components only the central frequency will be shifted while the degree of suppression will remain the same
- the quality of the filter can be adjusted independently from the central frequency using two noncritical resistors of the same value
- filter central frequency can be adjusted within a narrow range without significantly blurring the depth of cut
- the possibility of implementing a filter on operational amplifier with unipolar power supply

Unfortunately, this scheme uses two OAs instead of one, but owing to previously mentioned advantages, it would be reasonable to use a control device for TSL.

3.1. Notch Filter in the structure of the TSL device control

If the capacity of telephone lines constitutes one of the frequency-changeable elements of notch filters, its capacity changes caused by the unauthorized connections will change the central frequency of the filter. As is generally known [3], while passing the central frequency with a 180° jump, the phase of notch filter changes. However, the main drawback of the application of this undisguised feature in performance of a detector of devices of establishment on subscriber public-call lines is the difficulty of implementation as there is a need for a smooth change of frequency in small steps.

Therefore, the authors have developed a simple structure of the device of TSL unauthorized connections detection based on notch filter (Fig. 5).

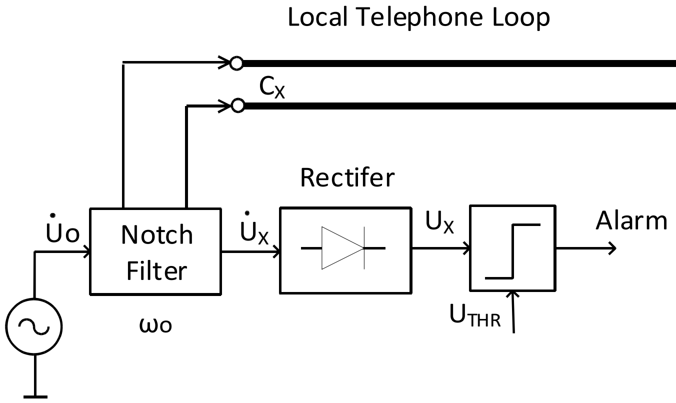

Figure 5. The structure of the device to detect unauthorized connections TSL

The structure of the control device includes a sinusoidal signal generator, notch filter, rectifier, low pass filter and comparator. Notch filter serves as a phone adapter, moreover, to improve the reliability of test results it is advisable to turn the final section of TSL off TSS (telephone subscriber station) at the distribution board. This will help eliminate the destabilizing effect from the shunt influence of the extensive urban cable. The control device itself is connected to the line where the telephone is placed.

As is well known [3], in a simplified form a "clean line" can be provided by the capacity C_K between two cores of a telephone wire. Connecting a parallel devices of establishment on subscriber public-call lines with the capacity of C_{TI} increases the total capacity of the line $C_X = C_K + C_{TI}$.

The device settings run on a "clean line" $C_K = C_O$ and provide the establishment of the resonance frequency ω0. Under these conditions, transmitting characteristic has the form

$$H_0=[1-(\omega_0 C_0 R_0)^2]/(1+j\omega_0 C_0 R_0+(\omega_0 C_0 R_0)^2) \quad (1)$$

3.2. Study of the Model of a telephone adapter based on notch filter

Studies have shown that increasing the capacity of one of the components of the notch filter causes a shift of a resonance frequency without significantly changing the shape of the frequency characteristics of the tuned filter shown in Fig. 6.

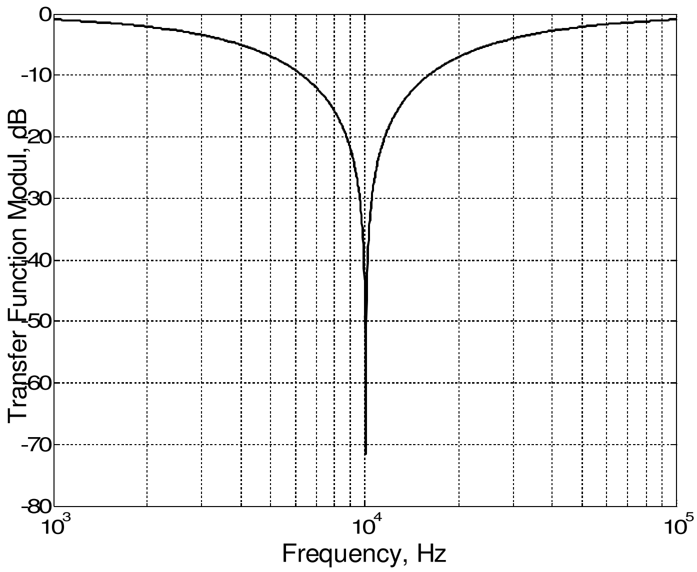

Figure 6. Frequency characteristics of the notch filter

During the studies was determined the capacity of line as 5 nF which corresponds to the cable length of approximately 100 m. The capacity of devices of establishment on subscriber public-call lines varied in the range of 5 pF to 100 pF, which stands for 0.1% - 2.0% of line capacity. Table 1 shows the results of studies of a sensitivity phone adapter according to the developed method.

Table 1.

№	Changing the line capacity, %	Line capacityCx, nF	Input voltage comparator, V
1.	0	5.000	0,01
2.	0,1	5.005	0,69
3.	0,2	5.010	1,4
4.	0.5	5.025	3,5
5.	1,0	5.050	7,0
6.	2,0	5.100	14,0

4. Conclusion

The article analyzes the main aspects that should be considered while implementing a telephone channel protection and also some basic methods of access to a telephone line, taking into account the principles of designing technical intelligence tools that are used in telephone lines.

The paper presents a new approach to designing a device to detect the TSL unauthorized connections. Its key feature is the use of notch filter which acts as a sensor that indicates the line capacity deviation from the nominal value. Despite its simplicity, the simulation results have shown the high sensitivity of the device.

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DEVELOPMENT OF THE CHARACTER RECOGNITION SOFTWARE ON THE BASE OF CELLULAR AUTOMATA

Summary: The description solution for allocation of structural features of the text character representation is considered, which directly affect the quality of recognition. The paper proposes to use a set of labelled cellular automata state labels. Mealy transition graphs for every type of cellular automata are built to determine endings, crossings and cycles in symbols. The work simulation program is observed.

Keywords: text characters recognition, competing cellular automata, probabilistic Mealy machine

ZAAWANSOWANE OPROGRAMOWANIE DO ROZPOZNAWANIA PISMA Z ZASTOSOWANIEM AUTOMATÓW KOMÓRKOWYCH

Streszczenie: W niniejszej pracy, opisano rozwiązania odnoszące się do alokacji cech strukturalnych służących do reprezentowania znaków tekstowych. Zaproponowane ujęcie wpływa istotnie na jakość dokonywanego rozpoznania tekstu. W artykule zaproponowano użycie zbioru etykiet w specjalnym automacie komórkowym. Grafy przejść Mealy'go zostały opracowane dla każdego typu stosowanych automatów komórkowych. Na podstawie tychże grafów można określić stany wyjściowe, stany wewnętrzne, przejścia oraz cykle symboli. Poprawność modelu sprawdzano za pomocą oprogramowanie symulacyjnego.

Słowa kluczowe: rozpoznawanie znaków tekstowych, automat komórkowy, probabilistyczna maszyna Mealy'ego

1. Introduction

The task of OCR (Optical Character Recognition) is important in the modern intelligent systems. OCR systems are used in the analysis of documents, translation

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of book archives into electronic form, analysis of questionnaire test results and in many other areas [1-4].
Most works on solving problems in the recognition systems offer a modular approach; individual modules solve the issues of filtering, segmentation, feature extraction and classification of images. The accuracy of the results of each module often greatly affects the overall result of the OCR [1]. Development of advanced methods underlying the recognition modules and, in particular, the base of module of character feature extraction from images - allows to improve the overall quality of recognition and to find new alternative solutions to the issue.
It is worth noting that today there are many solutions to the task of character feature extraction. These include the allocation of character's skeletons [2,3], feature extraction from converting functions [4] and others. Modern methods of character recognition are used to address both common tasks as OCR and specialized tasks oriented to character information recognition, deposited on the surface of various objects. Currently, there is quite a large number of programs designed to recognize a text (e.g. FineReader [12], Readiris [13], CuneiForm [14] and others). Each of these programs offers its own implementation of solution of image processing and recognition. Most of these programs are commercial, so the methods of solving issues are put into them and known only to their developers, and it is almost impossible to determine which tasks are too much for them and which ones they can do.
Currently there are three main approaches for solving the formulated issue: structural, feature and template. Each method has its own advantages and disadvantages [5]. The solution proposed in this paper determines the way to search and identify character features from their images. An approach based on competing cellular automata and Mealy transitions graphs built for each [6], allows the use of simple mathematical tools in the OCR. Cellular automata have obvious advantages, such as the possibility of parallel computing, ease and simplicity of the rules on which they are built, the possibility of implementing many complex algorithms for image processing [7].

2. Cellular automata with the state labels

A cellular automaton is a powerful tool in performing the tasks of modeling. By clearly defining all its components (metrics of the field, cell state, machine policy, etc.) we can solve a huge number of issues, many of which have non-trivial solutions [8]. To broaden the concept of the cellular automaton a cellular automaton with state labels can be used. The principle of cellular system with labels lies in the association of each cell of the cellular automaton with one or more labels on a Mealy transitions graph. One label or more can be inserted for the cell as well. They act as markers and are used in the policy of cellular automaton. Example of the policy of the cellular automaton with labels is shown in the following Figure 1 (normally white cell is repainted in red (the color of the cellular automaton) if the four adjacent cells in transitions graph contain labels).

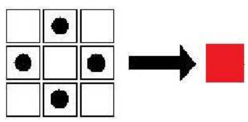


Figure 1. The rules of cellular automaton transition with state labels.

Formally the cellular automaton with labels can be described as follows. Cellular automaton with labels - a set {G, M, Z, N, f}, where G - the final set of discrete metric that indicates the distance between cells; M - the ultimate set of labels defined for each cell; Z - finite set of states of cells; N - end set that defines the neighborhood of the cell so that each element of the set to determine the neighbor for each cell (| N | - the number of neighboring cells that influence the state of the cell); f - a cellular automata rule corresponding mathematical transitions function $Z \times G \times Z^{|N|} \times G^{|N|} \to Z \times G, G \subset M$ [12].

It should be noted that a cellular automaton with labels can be interpreted as an extension of the concepts of mobile cellular automaton [9], in which one active cell is defined. Transition rules apply only for the cell that contains the label corresponding to the label on its transitions graph (for mobile cellular automaton only one single label is defined), cellular automaton with labels does not contain this restriction.

Cellular automata with state labels can be used in systems with complex logic, where cells must store information in the process of the machine functioning.

These signs may be the presence and position of characters` endings, number of loops, the positions of sections segments in the symbol. These features are enough for processing the symbol images in most cases.

Figure 2 shows these features of Mealy transitions labelled for cellular automata of English alphabet characters.

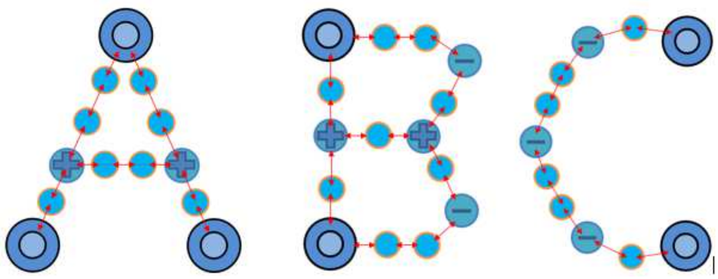


Figure 2. Cellular automata transitions graphs with the state labels for large classes of characters ABC

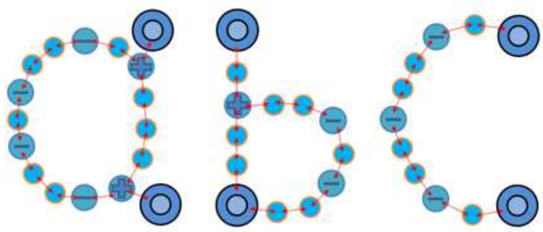
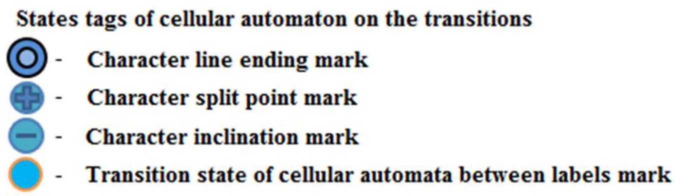


Figure 3. Cellular automata transitions graphs with state labels for small classes of characters abc

Here the incoming signal (the transition to another state of the automaton) is either a cell reaching the end of the line of the character or being cellular automaton at the point of branching, which occurs in characters: A, B and others. Herewith automaton transits into one of the equally probable states of the set (according to the transitions graph).

The initial reaction of cellular automaton is a signal of the direction of movement of the cells at a given time (shown by arrows at the states at column transitions: → - move to the right, ← - move to the left, ↓ - downward movement, ↑ - move up), and check the angle between the states of cellular automaton transition. These cellular automata can move only within the cells corresponding to the cell characters.



It is quite clear that cellular automata, defined by graph shown in Fig. 2,3, will describe the large characters "A, B, C" and small characters "a, b, c". The transitions graphs of cellular automata are constructed similarly, which will describe the rest of the characters.

On the other hand, the problem of recognition does not provide a priori information about the relation of characters to the corresponding class. For solving the problem of recognition in our research work [10], an algorithm was proposed that provides accumulation of the automata of a specific type on the appropriate characters and forcing competition between them, which leads to the high-quality recognition of text characters, what we shall see further.

3. Architecture of the developed software

For the experiments on the use of cellular automata for character recognition process, an algorithm-based software in the programming language Java has been developed. Each entity in the program is based on the principle of object-oriented design and is represented as a set of classes with properties and actions carried out by it.

A class diagram of cellular automaton block is shown in Fig. 4.

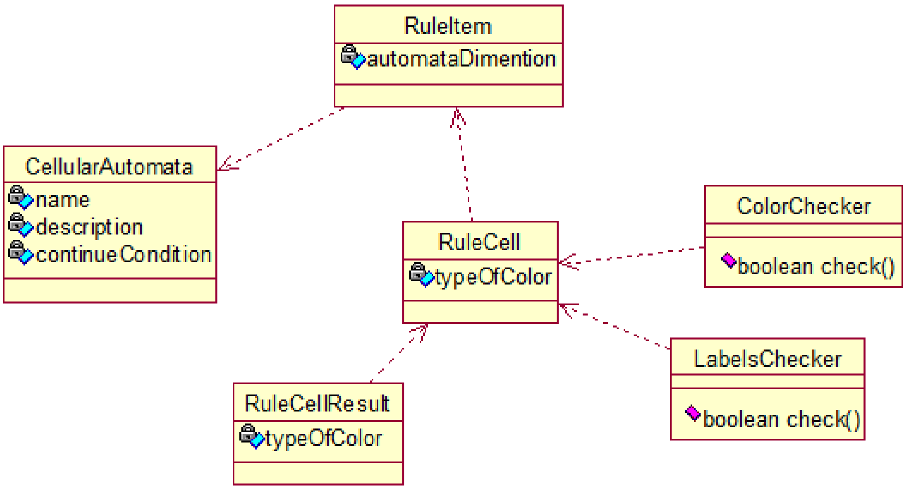


Figure 4. Class diagram of cellular automaton of the developed software

Table 1. The block classes of cellular automaton

Class	**Description**
CellularAutomata	The base class describing the work of cellular automaton
RuleItem	The class that describes the rule of cellular automata in the transitions graph
RuleCell	The class that describes a condition, imposing a cell within the rule of cellular automata
ColorChecker	An abstract class that checks the color of the cell
LabelChecker	An abstract class that checks the cell labels in transitions graph
RuleCellResult	The class that describes the events as determined by the color and cell labels within the cellular automaton rule

Cellular automaton can be defined as a set of certain rules, and at least one rule should be defined in each cellular automaton. Therefore, the automaton contains the default rule, which allows it to move within the transitions graph with its states test and possibly some additional rules based on the description of the algorithm.

Each rule is a combination of state test of a cell and neighboring cells and determination of the new state of the cell. If local radius, in which neighboring cells influence the state of the cell, is determined, the rule will contain transitions in the neighboring cells that must be checked to meet the conditions of the rules.

Cell test to meet the terms of the rule splits into the check of the state of the cell - its color, and check of the presence or absence of labels defined in the Mealy transitions graph. Checking the color of cell is to check an exactly defined color that should contain the cell. In a similar manner, the check of labels in the Mealy transitions graph is set by the presence inspection of all or one of the defined labels or absence of all or specific labels.

Defining a new state of the cell means identifying the color and labels to be determined for the cell as a result of the rule. Color of the cell may be left or clearly specified. Likewise, labels can be kept the same or new ones can be added. In addition, the labels found in the cell during inspections under this rule may be removed.

4. Implementation of the cellular automata interaction

In a cell and automaton interaction such items are included: item of text image separation to image of individual characters, item of checking the conditions in transition graph and transition for this condition to another item of the sequence.

Class diagram of cellular automata sequence is shown in Fig. 5.

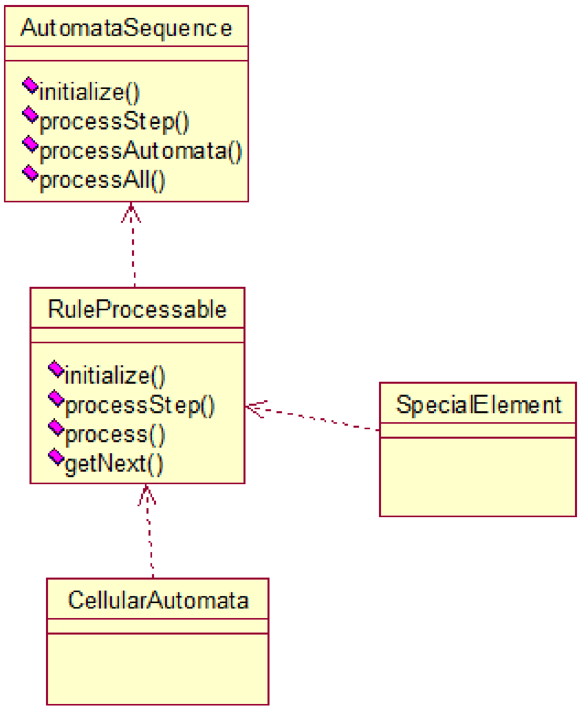


Figure 5. Class diagram of the sequence of cellular automata

Table 2. describes the block classes of the sequence of cellular automata.

Class	Description
AutomataSequence	The base class that describes the work of the sequence of cellular automata and the check of its competition
RuleProcessable	An abstract class that describes the work of a sequence item
SpecialElement	An abstract class that describes work of a special item of the sequence
CellularAutomata	Cellular Automata Class

5. Description of the interface of the developed software

GUI of the developed software consists of two forms, the first of which is used to display an image that needs to be recognized, the second is used to display the result of a sequence of cellular automata in the OCR.

The recognition process uses the built Mealy transitions graphs with labels showing signs of the characters for each cellular automaton that describes a particular character.

Figure 6 shows the software interface of the text character recognition with the following features:

- Font «Times New Roman»;
- Size 14;
- Image size 230x200;

Figure 6. Software interface for text character recognition of «Times New Roman» font ;

Figure 7 presents software interface for handwriting character recognition with overlay and distortion of symbols.

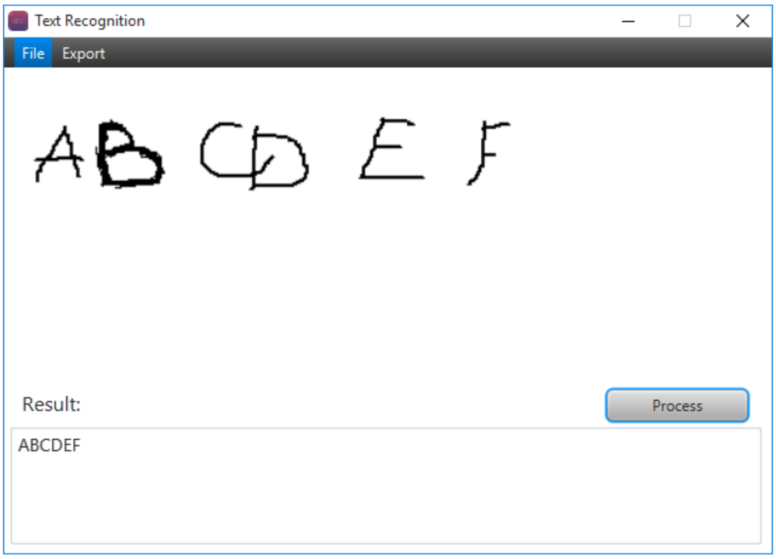


Figure 7. Software interface for handwriting character recognition

6. The results of the recognition quality testing of the developed software

Using the developed software the comparative study of recognition quality of commercial OCR software FineReader was carried out. Text generators were used for the generation of images [15]. The research results are presented in Tables 3 and 4. Table 3 presents the results of our software recognition of different pieces of the text, table 4 shows comparison results of the FineReader software.

Table 3. Characteristics of quality of text character recognition

Font	**Image size**	**Number of characters**	**Recognition result**
Times New Roman	760x276	1,000	98%
Arial	760x276	1,000	98%
Handwriting	760x276	100	84
Handwriting characters overlay	456x58	100	56
Distortion of characters	456x58	100	68

Table 4. Comparative characteristics of OCR of the FineReader product

Test values	Developed Software		FineReader	
	Hours of work in sec.	Errors percentage	Hours of work in sec.	Errors percentage
Rendering the words «Hello World!» Size 236x30 Font «Time New Roman»	1	0%	1	0%
Images of text characters (78 characters), 561x56 size, font "Arial"	3	1%	3	1%
Page of the text rendering (784 characters)	9	3%	7	3%
Handwritten characters image (10 characters) Size 230x50	1	2	1	2%
Image of characters with a certain degree of deformation (10 characters) Size 230x50	2	3%	1	5%
Images of characters that overlap (10 characters) Size 230x50	2	40%	1	50%

On the basis of the given information in the table 4 some conclusions can be made:

- Characteristics of the quality of character recognition with some degree of deformation and characters that partially overlap is higher in the developed software versus commercial product of FineReader.
- Certainly, the commercial program of FineReader surpasses by performance.

High levels of accuracy and speed character recognition for the existing fonts by the commercial product of FineReader are determined by using the complex means of recognition, including extensive use of dictionaries [11]. It can also be added that FineReader is a complete product that is developed by ABBYY over the years. However, the software based on the algorithm built by competing cellular automata with state labels showed certain benefits in recognition of characters with a certain degree of deformation and characters that are partially overlaid. The algorithm optimization will greatly increase the performance and to some extent - the percentage of quality recognition.

7. Conclusions

As it was shown in the investigation, modification of recognition algorithm developed in the paper [10], allowed to achieve high recognition quality and provided tools for future research:

- The algorithm may facilitate its use in parallel computing.
- The algorithm identifies unique features of characters and allows realizing its further classification.
- The algorithm is resistant to the size of the characters, certain degree of distortion and characters overlay.
- The algorithm is designed on simple rules and does not contain complex calculations, particularly with floating point.
- The developed software has demonstrated a high degree of text characters recognition even in comparison with the commercial leader of FineReader.

The algorithm can be involved in complex problem solving of OCR, where the part of the algorithm is based on a different principle. It is also implemented and tested in the developed modeling program where it showed its up state and the possibility of further improvement.

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STEGANOGRAFIA SIECIOWA Z ZASTOSOWANIEM KODU HUFFMANA DO KOMPRESJI STEGANOGRAMU ORAZ MODYFIKACJI NAGŁÓWKA TCP

Streszczenie: Artykuł poświęcono steganografii sieciowej. Przeprowadzono analizę osadzania danych we wszystkich warstwach modelu OSI. Wymieniono metody steganograficzne. Opisano w skrócie strukturę pakietu TCP i technikę osadzania danych z wykorzystaniem protokołu TCP. Zaprezentowano implementację steganografii sieciowej stosując modyfikację pola "Numer sekwencji" nagłówka TCP. Podano przykład transmisji większej ilości danych w polu " Numer sekwencji" z użyciem kodowania Huffmana.

Słowa kluczowe: steganografia sieciowa, TCP, kodowanie Huffmana, modyfikacja pól nagłówka

NETWORK STEGANOGRAPHY USING HUFFMAN CODING FOR STEGANOGRAM COMPRESSION AND MODIFICATION OF TCP HEADER

Summary: The article is devoted to the network steganography. Data embedding in all OSI levels is analyzed. Steganographic methods are listed. The structure of TCP packet and techniques of data embedding using TCP protocol are described. Implementation of network steganography using modification of "Sequence number" field of TCP header is presented. The example of bigger amount of data transmission in "Sequence number" field using Huffman coding is given.

Keywords: network steganography, TCP, Huffman coding, modification of header fields

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1. Introduction

New research areas, which deals with packet data security, came into existence due to the evolution of computer networks and possibility of long distance data transmission. These also influenced the development of cryptography and steganography. The difference between them is that cryptography provides data confidentiality (usually using encryption), while steganography conceals the fact of data transmission. If message, protected by steganographic techniques, was not detected, the sender and receiver will stay unknown. The steganography and cryptography are often used simultaneously to ensure stronger data security [1]. The main aim of network steganography is to hide secret data in legitimate transmissions of users without destroying the hidden data carrier used [2]. In network steganography this carrier is represented by a protocol.

Steven J. Murdoch and Stephen Lewis analyzed the data embedding in each layer of the OSI Model. Authors state, that covert data transmission in the Physical and Data-Link layers requires low-level control of the hardware, which is not always possible. Also both sender and receiver should be on the same LAN. Otherwise the secret message can be stripped out by any intermediate high-level device (e.g. IP router). It is also mentioned that data embedding in the Application or Presentation layers requires prediction of the applications, which are likely to be used on the computer. Then they can be modified to carry secret messages in the traffic they generate. However, it can be hardly done without arousing significant suspicions. Thereby, protocols of Network, Transport and Session levels of OSI model are appropriate for the network steganography [3].

Network packets can be modified in two ways: modification of application data or modification of protocol headers. Alteration of applications data requires deep understanding of the type and characteristics of data sent by a wide variety of applications. Care must be taken to ensure that the modified data could have been generated by a legitimate application, and it should be guessed what sort of applications the receiver considers innocuous. Considering these issues, it is easier to modify the protocol headers. Due to well-defined protocol structure, it is possible to predict what the modification of header fields will result into [8]. In the header of IP-protocol secret data can be embedded into Identification or Source address fields; in UDP header – into Source port, Data length and Checksum [5]. In the TCP-header Timestamp, ISN and Options fields can be used for this purpose.

TCP is “connection-oriented” protocol, which means that connection is established before sending data, while UDP provides “best-effort” service, which gives no guarantees for packet delivery. Unlike TCP, UDP does not send acknowledgements, consequently sender cannot know whether the steganogram was received. Both UDP and TCP protocols can be used for packet length network steganography, but UDP protocol is more suitable for this as the distribution of packet length is variable [4]. However in computer networks UDP is usually considered as service protocol, so large amount of sent UDP-packets on network can be suspicious. Regarding the fact that UDP-protocol consists of considerably smaller amount of fields than TCP, the steganogram discovery in UDP-header is relatively easy. Comparing UDP and TCP, we came to the conclusion that TCP is more appropriate to be used as stegocontainer. Due to the rapid development of Internet technology and computer literacy of users, network steganography can become means of communication of criminals or terrorists. Data transmitted by steganographic techniques is usually embedded in service protocol fields. This allows to bypass those security policies, which are based on verification of the data field of the protocol. So an attacker can send secret data without being detected. In view of the aforesaid, network steganography research is topical and relevant, as this can help to detect and eliminate covert channels on the network.

2. Steganography methods

Methods of network steganography can be divided into three main groups [6]:

- Steganographic methods that modify packets;
- Steganographic methods that modify the structure of packet streams;
- Hybrid steganographic methods, which include features of both previous methods.

Steganographic methods that modify packets are implemented by the modification of IP, TCP and UDP headers fields; affecting packet payload including watermarking algorithms or speech coded steganographic techniques; methods of mixed techniques.
Steganographic methods that modify the structure of packet streams include techniques that affect the sequence order of packets or inter-packet delay and methods that introduce intentional losses by skipping sequence numbers at the sender.
Hybrid methods are LACK (Lost Audio PaCKets Steganography) and RSTEG (packets retransmission) [6].
In this paper methods based on modification of header fields are considered. Its implementation consists in the steganogram embedding into the unused bits of the header fields. This becomes possible due to redundancy in fields. This method provides relatively high steganographic capacity and quite easy implementation. Drawbacks include potential loss of protocol functionality [6].
Method will be implemented using TCP-protocol. Figure 1 represents the structure of TCP-packet.

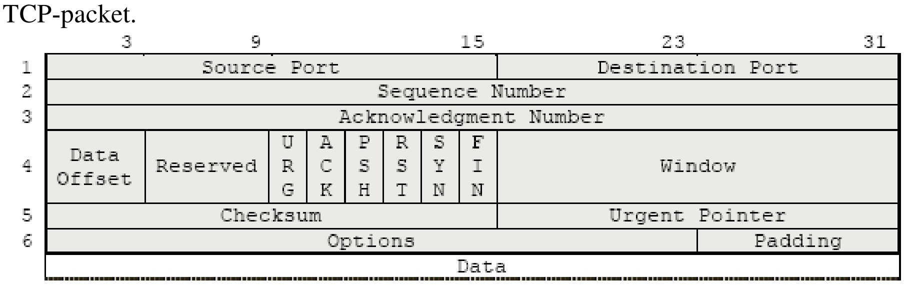

Figure 1. Structure of TCP-packet

One of the methods of the steganogram embedding in header fields is described by Kamran Ahsan. The author suggests using 6-bit of Flags field (URG, ACK, PSH, RST, SYN, FIN). Different bit combinations tell a network node how to interpret other fields in the header. There are 64 possible combinations for these six bits, out of which 29 combinations are considered to be valid. The idea of the method is to use those combinations, which make some fields insignificant, thus they will be not processed by the host of receiver. These fields become redundant and are able to contain the steganogram. The author gives an example of the redundancy conditions by setting

ACK, PSH and FIN-bit to “1”. This combination can be interpreted in the way that, one of the communication participants intends to terminate the connection (FIN-bit) and sends an acknowledgement. The participant also asks to push the buffered data to the receiving application (PSH-bit). As far as the URG bit is not set, the Urgent pointer field (16 bit) of the TCP header becomes redundant and therefore can be used to have a storage covert channel [7].

Another method takes advantage of Timestamp filed (TCP Options). The technique is based on imposing slight delays on the processing of selected TCP packet. Since TCP timestamps are based purely on internal timings of the host, on a slow connection their low bits are randomly distributed. This makes it possible to modify the low order bits of their timestamps, thus create covert channel [8].

Steven J. Murdoch and Stephen Lewis consider method of steganogram embedding in Initial Sequence Number field of TCP packet. ISN is a unique 32-bit number, which is assigned to every new connection. The ISN can be any number from 0 to 2^{32}. In TCP, a connection defined by a pair of sockets can be reused. Consequently it is necessary to determine whether the segment belongs to the current or previous session. This is possible by assigning ISN. The ISN represents the number for the first byte of data transmitted in a new TCP connection, also the SYN-flag is set to “1”. Then user sends acknowledgement and the filed Sequence Number is increased by 1. When SYN equals “0”, then this is the accumulated sequence number of the first data byte of this segment for the current session.

In terms of security, ISN is suggested to be randomly chosen. According to RFC 793 ISN should be incremented by adding a number every four seconds until the limit is exhausted. Indeed, ISN is determined by each operating system differently, but generally ISN depends on machine time value. Once this dependency exists, ISN can be determined as follows: $ISN=F(t_{mcsec})$. Thereby, ISN seems to be random and its substitution, on the face of it, cannot arouse suspicion. On the other hand, if the substitution results in the presence of two identical segments on the network, the receiver will get inconsistent data. However the probability of its occurrence is relatively small.

3. Implementation of network steganography using “Sequence Number” field of TCP header and Huffman Coding

One of the possible ways of network steganography implementation by the modification of TCP header fields is presented in this paper. In the example we consider the transmission of the message with the content “secret”. Field “Sequence Number” is used as carrier of steganogram.

By converting text to binary, one letter is represented by 8 bits, consequently it is possible to transmit only 4 letters in “Sequence Number” field. The message will look like «01110011 01100101 01100011 01110010 01100101 01110100» and is 48-bit long. Since the message is too long, it should be divided and transmitted in different packets.

The solution we propose takes advantage of Huffman coding, which is commonly used for lossless data compression. English alphabet encrypted with Huffman coding is illustrated in figure 2. In order to ensure the equal code length for each letter, number "0" is added at the beginning of the code for the following letters: «V», «Y», «X», «Z», «A» i «C».

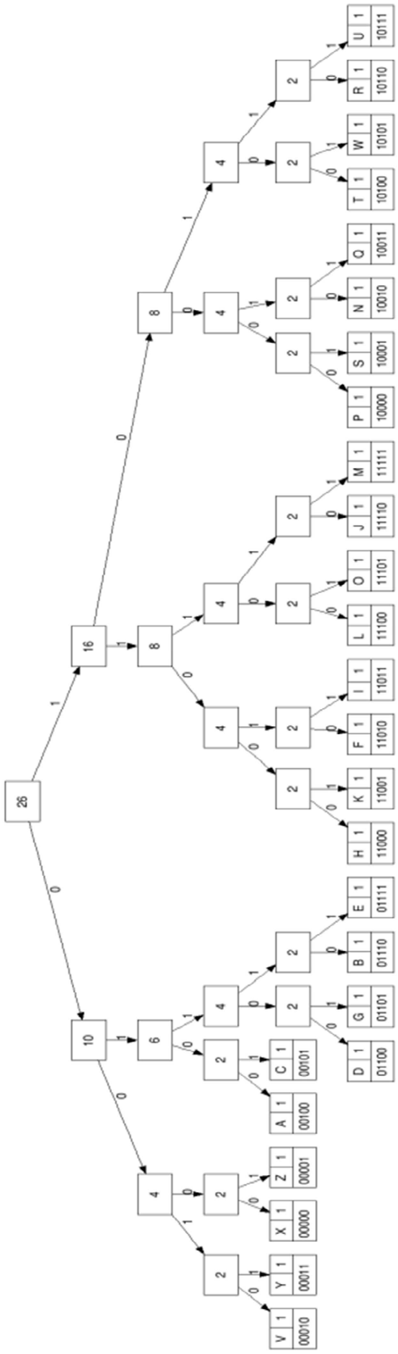

Figure 2. English alphabet representation using Huffman coding

By using such algorithm of encoding, one letter requires 5 bits. Now it is possible to transmit two more letters and leave 2 bits unused. Hence, the message “secret” is 30-bits long and can be presented as follows: «10001 01111 00101 10110 01111 10100».
We propose to use any network packet crafting tool in order to send needed packet on the network. The structure of the TCP header with the modified field «Sequence number» is presented in the figure 3.

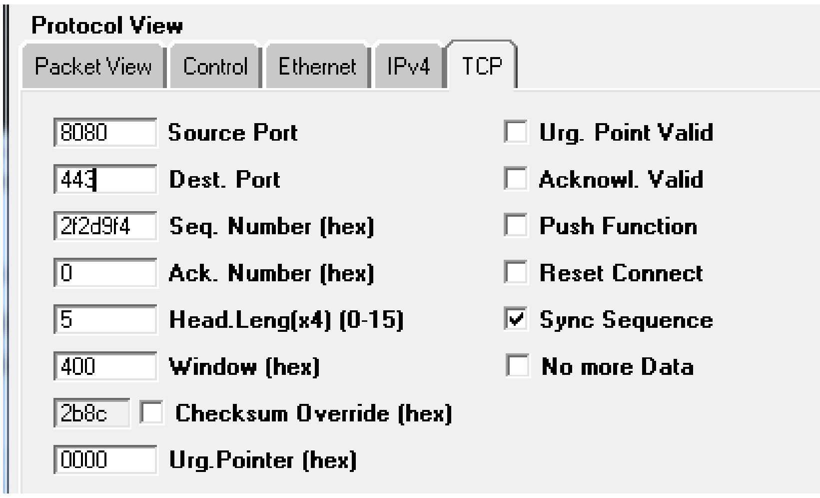

Figure 3. Structure of TCP header with modifier “Sequence number” field

Figure 4 illustrates the captured packet by the receiver host.

```
0000  34 23 87 3c fd 23 00 1f  3c 09 43 99 08 00 45 00   4#.<.#.. <.C...E.
0010  00 2e 26 7e 00 00 ff 06  13 2d c0 a8 00 65 c0 a8   ..&~.... .-...e..
0020  00 69 1f 90 01 bb 02 f2  d9 f4 00 00 00 00 50 02   .i...... ......P.
0030  04 00 2b 8c 00 00 00 00  00 00 00 00               ..+..... ....
```

Figure 4. Captured TCP-packet

Highlighted field denotes the value of Sequence number. The receiver of steganogram should covert the field value in binary notation and decrypt it using Huffman coding.

4. Conclusion

Network steganography is used for concealing the fact of data transmission. It intends to embed secret data in legitimate transmissions of users without destroying the hidden data carrier used. In network stenography protocol is used as a carrier. Data embedding can be done in all OSI levels, however the most appropriate are protocols of Network, Transport and Session levels.
Steganographic methods can be divided into three main groups: those, which deal with modification of packets, modification of the packet streams structure or hybrid techniques. In this paper TCP protocol for data hiding by modification of header fields

was chosen. The advantages of this method are relatively high steganographic capacity and quite easy implementation. On the other hand, it can include potential loss of protocol functionality.

Data embedding in TCP can be implemented by using three methods. The first one is based on finding those combinations of 6 bits of “Flags” field, which makes other fields redundant. Another method takes advantage of Timestamp filed (TCP Options) by imposing slight delays on the processing of selected TCP packet. Thus, it becomes possible to change the low order bits of timestamps and use this modification as covert channel. The last one is based on embedding secret data in “Sequence number” field. ISN, on the face of it, seems to be random and its substitution cannot arouse serious suspicion. Possible drawback is presence of two identical segments on the network. However the probability of its occurrence is relatively small.

For implementation of network steganography using “Sequence Number” field of TCP header, it was proposed to use Huffman coding. Compared to the simple “text to binary” conversion, encoding the message made it practicable to transmit two more letters and leave 2 bits unused. Once the stegonogram is transmitted, the receiver should intercept it and decrypt the “Sequence number” field value using Huffman coding.

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WYKRYWANIE ŚLEDZENIA AKTYWNOŚCI W INTERNECIE PRZEZ ANALIZĘ COOKIE

Streszczenie: W dzisiejszych czasach, naruszanie prywatności dokonywane przez specjalne oprogramowanie stron trzecich występuje coraz częściej. Zwykle opiera się ono za pomocą tworzenia tzw. blacklist. Narzędzie Cookies jest jednym z najbardziej popularnych oraz łatwych do użycia mechanizmów do stwierdzania linków pewnego użytkownika internetu odwiedzającego różne domeny. W artykule analizuje się podejście z wykorzystaniem cookie do automatycznej identyfikacji zapytań typu web-tracking, czyli śledzenia działań użytkownika w sieci.

Słowa kluczowe: cookies, prywatność, śledzenie aktywności w internecie

COOKIE BASED APPROACH FOR WEB TRACKERS DETECTION

Summary: Nowadays, privacy violations caused by third party services are usually addressed with blacklist approaches. Cookies are one of the most popular and easy to use mechanisms to link same user visiting different domains. We investigate cookie based approach for automatic identification of web-tracking requests.

Keywords: cookies, privacy, tracking

1. Introdaction

Dynamic nature of web has been changing rapidly over last few years. Lots of services shifted their vision of static content board to proactive view on dynamic content generation for users. Many websites gain most benefit from targeting particular users and satisfying specific user needs. That is why it's very important to be able to recommend users with the content they like. It can be achieved with website visitors tracking which is the activity aimed to analyze user behavior on a website and build user-specific profiles of typical action, topics of interest, list of visited websites, demographic information etc.
Target websites (called first-party services) quite often embed third-party services like content delivery networks (cdn), social media widgets, advertisement services, third

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party plugins. Those services usually included as javascript code, iframe elements or flash applications and may use various techniques for user tracking.
Privacy violation caused by such services has become a major threat and serious problem. **Considerable** amount of research efforts has been made to develop counter measures and protect users' privacy rights against online tracking mechanisms.
Number of commercial black-list based approaches were developed with focus on blocking malicious tracking content while target website remains working as expected (DoNotTrackMe, Ghostery, Adblock) [1-2]. In this approaches black list of forbidden resources is generated offline and deploy to every instance of application. They would block request to URLs listed in non-trusted database. Main disadvantage of such approach is regular need to keep them up to date which is usually difficult to maintain and requires dedicated efforts. Meaning that black list are not able learn and detect new threats. Many research papers focused on overcoming maintainability issue by presenting algorithms to automatically generate black lists [3-5].
This paper focuses on discovering distinguishing features of tracking cookies. The goal of this study is to improve tracking services detection in general by creating **meaningful** features out of web tracking and cookies study.

2. Data collection metodology

In this study, we wish to simulate real users browsing over a period of time to detect creating of tracking marks. Summary of methodology presented below.
To automate process of data collection we developed web crawler **application** which used depth first search approach and recursively follows each link on target website with defined depth of search. Websites for study were selected from Alexa TOP 500 [6] list of most popular websites. For each website under study we created user account or logged in with social networks profile if possible. Custom web crawler gives full control over mining process and allow to leave fingerprint on multiple web resource. We used Firefox's API modules (NSPR_LOG_MODULES) to collect generated traffic logs and cookies sent between referrer and host. Data mining was done on separate virtual machine with full access which allowed to collect not only HTTP traffic but HTTPS as well.
During data collection, developed crawler made nearly 2,000,000 HTTP request to 1500 distinct domains. We processed 850,000 cookies and found that there are multiple cookie pieces, which are used in multiple cross-domains requests. They are usually set under third party domains and accessed within embedded iframe to avoid security restrictions. For each host and referrer domain in collected data we obtained category of this domain from IBM Xforce [7].

3. Detecting user tracking cookies

Identification marks can be stored in multiple locations (HTTP cookie, Flash cookiej, Evercookie). We focus on HTTP cookie as widespreaded mechanism which is popular target of multiple attacks [8]. In presented study we focus on host and referrer domains as communication agents, cookie key:value pairs as tracking identifiers, multiple cookie params (expiration date, is http only) as tracking **hints**.
To investigate and use those cookies as tracking feature for domain we defined criteria meeting which cookie considered tracking-alike:

- Cookie set by third party domain should be unique for different users.
- Cookie value should be used on multiple domains
- Cookie lifetime more than 1 month
- Cookie value should have high entropy and potentially by unique for large number of users

Setting empirical entropy threshold allows to filter service cookies. For example linux epoch timestamps: 'ts', u'1471811358' , 'tuuid_last_update', u'1471811368', UIDR', u'1471811403', cookie for possible A.B testing and user preferences: 'wsjregion', u'europe', 'marketPref', u'en-us', cd', u'false', 'SSE_price_test_2_20160825', u'price_b'. Identifying cookie with high entropy A6', u'02fdwOlm4W000cnd000010000', 'id2', u'57ba2239001Es0002003ys0002001Cs0002' are kept. In additional high entropy cookie keys:domain pairs are verified on Cookiepedia [9].

4. Results

Before training classifier, we labeled request from training and validation sets. For each request, we investigated category of host and referrer and transmitted cookie. Requests where sender or receiver are marked as advertisement, tracking or malicious beacon and cookie is tracking alike were marked as tracking-positive.

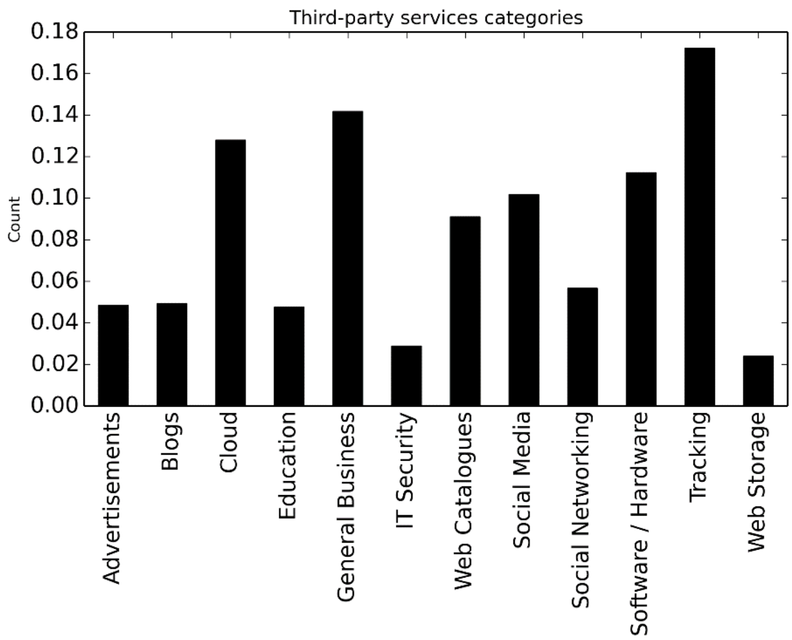

Figure 1. Categories distribution for dataset

Categories were taken from black list of ghostery, handcrafted reputation dictionary from IBM® X-Force Exchange. Only advertising / tracking domains that set third party cookie were labeled as such.

With every parsed tiple of (host, referrer) and cookie pairs we build graph of transitions in dataset. Where vertices are domains from collected data and each edge is associated with weighted (statistical characteristics) cookie importance score.
We investigated in- and out-degree for vertices in possible ads and tracking categories (Auctions / Classified Ads, Banner Advertisements etc) and found significant difference between two distributions.

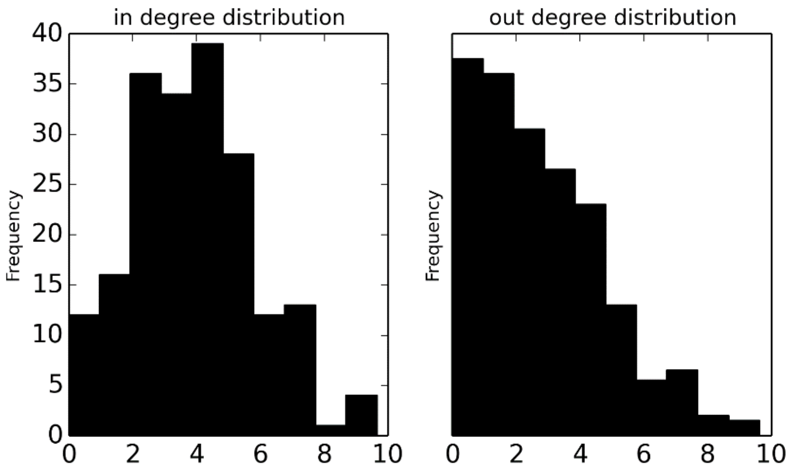

Figure 2. In-out degree distribution for tracking domains

RankSum test introduced by Mann-Whitney-Wilcoxon was selected for significance testing as it does not assume that data is normally distributed and potentially providing a more accurate assessment of the data sets.
P value for calculated statistics is 1.09046514588e-10 implying significant difference between distributions. It can be used as prediction feature for machine learning classifier of tracking requests.

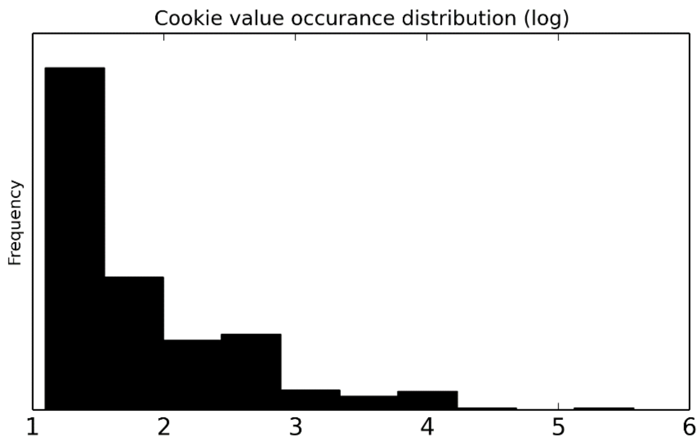

Figure 3. Cookie value occurance distribution (log scaled)

Cookie exchange identification showed highly connected structure of the web which arises with advertizement services inclusion on target pages. Same service included on many pages will share same cookie id value acrross the web.

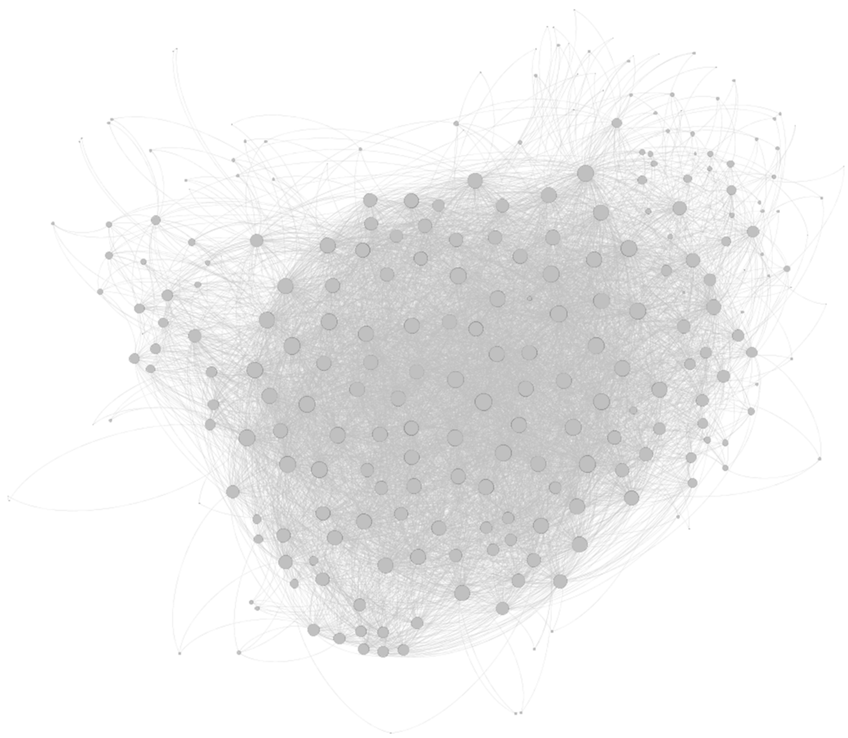

Figure 4. Connected componens for cookie's cross requests graph

We observed that top cookie setter domains would share cookie value with other adverisement domains.

5. Conclusions

We believe that cookies usage data information and distiribution characterysctics as well as cookie matching and domain connectivity information presented pottentially can impove web tracking services identification and blocking which would lead to privacy information leackage reductio. One way to achive this is to develop an automated self-learning system that uses presented methodology to crawl web pages, analyses cookie and creates rule based framework to identify such activity.

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SECURITY AMPLIFICATION METHODS OF QUANTUM CRYPTOGRAPHY PROTOCOLS

Summary: In this paper, the comparing of security amplification methods to the ping-pong protocol use XOR-encryption and inverse transformation algorithm with LUP-decomposition is proposed.

Keywords: security amplification, ping-pong protocol, quantum direct secure communications, XOR encryption, eavesdropper, LUP-decomposition, mean generation time, inverse transformation

METODY ZWIĘKSZANIA BEZPIECZEŃSTWA DLA PROTOKOŁÓW KRYPTOGRAFII KWANTOWEJ

Streszczenie: W niniejszym artykule, porównano metody zwiększania bezpieczeństwa dla różnych działań w sieciach komputerowych. Analizy dotyczą użycia protokołu typu ping-pong z zastosowaniem kodowania XOR oraz algorytmu transformacji odwrotnej z dekompozycją typu LUP.

Słowa kluczowe: bezpieczeństwo, protokół ping-pong, kodowanie, dekompozycja, transformacja odwrotna

1. Introduction

In modern world transmission of confidential data between multiple parties in different communications networks can not only bring to loss of transmitted

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information, or to it compromising, that is, disclosure of information, which has become known to any person who does not have access rights to it.
During the last decade, new direction of information security has been developing actively - quantum cryptography. One of the quantum cryptography approaches is quantum secure direct communications (QSDC), which allow you to send confidential messages directly by quantum channel, without encryption.
Currently, a large number of different purposes QSDC protocols are proposed [1-7]. One of such protocols, not requiring a large amount of quantum memory, but requiring entangled states of photons, is ping-pong protocol, that allows to send one or more bits of classical information within a single cycle of the protocol [1,6,7].
Another recently performed protocol [8, 9] uses single photons instead of entangled states and allows detecting eavesdropper's attack within a short time. The ping-pong protocol and protocol [8,9], as well as many other protocols QSDC is designed for security transfer of classical information by quantum communication channels (using classic methods of information security for security amplification of QSDC).
Currently, there are several security amplification classical methods of quantum communication protocols to protect data from attack. One of the most impressing and cryptographically guaranteed security methods is XOR-encryption. However, though reliability assessing and efficiency of XOR-encryption for ping-pong protocol with entangled pairs of qutrits partially had been performed before [10], but the same assessment but for other kinds of protocols had not been conducted.
In this paper, security amplification method of quantum secure communication ping-pong protocols against passive attacks of eavesdroppers, based on XOR- encryption of plaintext blocks' is performed, and it is also offered to modify inverse transformation method [7, 11] with the using of LUP-decomposition for matrix inversion.

2. XOR-encryption and inverse transformation of plaintext's blocks in Ping-Pong Protocol

The idea of method based on XOR-encryption is:
The message splits on l blocks a_i predetermined length r.
Block length is determined, if probability of attack detecting after one block transfer does not exceed 10^{-k} [7]:

$$r \geq I = \frac{-kI_0}{\lg((1-q)/(1-q\cdot(1-d)))}, \tag{1}$$

where I − is the amount of information gained by eavesdroppers within transmission of one block; I_0 − the amount of information gained by eavesdroppers per round of protocol;
q − probability of transition for eavesdropping "control mode"; d − level of errors made by attack of eavesdroppers.
Generate random block of binary gamma γ_i size r is carried out and the addition of this block of binary gamma with the appropriate block $b_i = a_i + \gamma_i$ (XOR encryption). Thereafter, the transmission messages by ping-pong protocol is carried out. When

legitimate users verified in absence of eavesdropping, transfer block of binary gamma is performed by data channel. The next step is producing of reconstruction of original data block a_i (the addition of the resulting block b_i with the corresponding block of binary gamma γ_i).

According to the foregoing algorithm, in integrated development environment (IDE) C++ MS Visual 2010 simulation model ”message mode” in ping-pong protocol with entangled pairs of qubits using XOR-encryption by quantum channel and an additional module for the calculation of the average generation time block of gamma is developed. Simulation results, the average time estimate required for block of gamma generating have been presented in the table. 1.

The method using inverse transformation having been modified with using LUP-decomposition for performance improvement is as follows.

The message splits on *l* blocks a_i predetermined length *r*.

Then generation is carried out of a random invertible binary matrix L_i of size *r* and multiplying this matrix by a corresponding block $b_i = L_i a_i$ (perform direct transformation), and execution of “message mode” of ping-pong protocol with pairs of entangled qubits.

When legitimate users verified in the absence of eavesdropping, matrix L_i transmission occurs in the data channel. Further the original data block a_i is being restored that is obtained by multiplying the block b_i on corresponding matrix L_i^{-1} (inverse transformation) [11].

For a comparative analysis of these two methods of security amplification of the ping-pong protocol using developed software 1000 pseudo-random binary matrix of size *r* using a random number generator was performed, to check them on the invertibility and timing necessary to generate a inverse matrix and 1000 pseudo-din were generated as well.

For each matrix of size and gamma’s block the described procedure was carried out 1000 times with average value calculation, the results are given in table. 1. Moreover, the percentage of invertible binary matrix in GF (2) is 0.289 of the total number of matrices (if $r \geq 16$).

According to the data in table. 1, generation time of a random block of binary gamma is insignificant for small blocks of binary gamma. Thus, for the block of binary gamma of size 500 bits for generating of one blocks of gamma it takes approximately 0.106 seconds and block of binary gamma of size 2000 bits - 1.763 seconds. Generation of one invertible random binary matrix size of 500×500 using LUP-decomposition is performed in about 6.6 seconds, and for matrices 1000×1000 - 55.1 seconds.

Generation time of the Gauss–Jordan elimination method for generating one invertible random binary matrix is about 6 minutes. Moreover, this term is increasing rapidly with increasing matrix size for both methods.

Thus, using the method LUP-decomposition for inverse of binary matrices, the computational complexity is equal to O(N^3), and for Gauss–Jordan elimination method implemented in IDE Mathworks Matlab R 2013 – is equal to also O(N^3).

But at the same time the speed of the latter algorithm is much lower due to the complex implementation in IDE Mathworks Matlab R 2013. Generator blocks of binary gamma function - rand () is used, which works by the constant time, that is, the computational complexity is O (1).

Table 1. Assessments of generation time blocks of binary gamma of size r and random inverse binary matrices r x r

r	Mean generation time of one random inverse binary matrix (Gauss-Jordan Elimination), second	Mean generation time of one random inverse binary matrix (LUP-decomposition), second	Mean generation time of one block of random binary gamma, second
50	0,2176	0,0122	0,0009
100	0,8580	0,0728	0,0046
150	2,0748	0,2094	0,0095
200	3,8658	0,4429	0,0169
250	6,2025	0,9184	0,0254
300	10,5532	1,6102	0,0371
350	15,5273	2,5682	0,0502
400	21,7585	3,8923	0,0671
450	28,5148	5,3113	0,0836
500	39,3564	6,6705	0,1057
550	48,5743	8,5056	0,1314
600	67,3453	11,395	0,1578
650	87,669	14,610	0,1856
700	109,282	18,214	0,2145
750	134,31	22,385	0,2460
800	170,712	28,452	0,2788
850	189,582	31,597	0,3113
900	220,446	36,741	0,3557
950	264,162	44,027	0,3955
1000	330,45	55,075	0,4381
1250	594,889	99,148	0,6911
1500	1120,5	186,75	0,9972
1750	1139,08	323,18	1,3517
2000	2629,38	438,23	1,7635
Computational complexity			
	$O(N^3)$	$O(N^3)$	O(1)

Thus, XOR-encryption method has lower security amplification because to restore the original data block of inverse transformation, an eavesdropper has to gain the whole transformation of matrix. Thus, using XOR-encryption because present possibility to

restore immediately that part of the data block for which block of binary gamma has been intercepted by eavesdropper.
It should be noted that the proposed security amplification methods can be used not only for the ping-pong protocol, but are completely suitable for the protocol is proposed, in [8,9].

3. Conclusions

The method of security amplification QDCP based on XOR-encryption, and modified method of inverse transformation with using LUP-decomposition is proposed.
These methods allow a high level of security protocols against non-coherent passive attacks. The number of operations necessary for selection of the matrix brute-force search is equal to the average 2^{n^2-1}, and for selection of block of binary gamma - 2^{n-1}.
Assessment of time pseudorandom binary matrices for generating the blocks of transformation message and pseudo-random blocks of binary gamma was performed.
It is shown that by using the elimination Gauss-Jordan method for generating an inverse random binary matrix 1000×1000 is about 6 minutes, and in the generation of matrices with using LUP-decomposition size 1000×1000 is about a minute and for the size block of gamma is equal 1000 - 0.44 seconds when using low speed computing, that is quite acceptable.
Thus, the method of security amplification of the quantum protocols direct secure communication based on XOR-encryption, requires much less time for preparatory operations - the generation of one block of random binary gamma of a given size than the method that uses an inverse transformation with LUP-decomposition.
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MODELOWANIE 3D SYSTEMÓW BEZPIECZEŃSTWA W LOTNICTWIE

Streszczenie: Ocena efektywności technologii jest silnym oraz stałym czynnikiem sprzyjającym odniesieniu sukcesu w projektowaniu i późniejszym użytkowaniu. W odniesieniu do lotnictwa poprawna ocena oznacza zabezpieczenie życia ludzi oraz zapobieganie wypadkom. Modelowanie 3D może stanowić istotną część omawianego podejścia jeżeli posługują się nim prawdziwi profesjonaliści. W celu uniknięcia ryzyka, autorzy sugerują przeprowadzanie przewidywania czy oceniania nie tylko na ujęciu ilościowym (liczbowym) ale także jakościowym w odniesieniu do bezpośrednio uzyskiwanych informacji przez eksperta używającego Zaawansowanego modelowania 3D.

Słow kluczowe: bezpieczeńtwo, modelowanie 3D

3D-MODELING FLIGHT SAFETY IN AVIATION

Summary: Evaluation of the effectiveness of the technology is a strong and stable factor of success which results human lives preservation and accidents prevention. 3D-modelling can take an essential part in technology if they are used by true professionals. To prevent risks authors suggest the usage of prediction based on the work of not only quantitative but also qualitative information obtained directly from the experts with sophisticated 3D-models.

Key words: safety, 3D modelling

Introduction

Information model is a handy and a powerful analytical tool. Storing and integration of data, reflection the process of operation of the 3D-models are available with its help. Neural networks allow you to analyze and predict the future trajectory of the movement for a large number of obstacles in airline sector.

Widespread use with neural network algorithms generate random sequences and chaos. Neurocomputers in the identification of anomalies in switching devices and data lines are essential. Routing and distribution channels in mobile radio communication systems is the scope of the task at traffic control. In military

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communication systems, data problems have increased importance due to the need of ordered message with high priority, provided a radical change in environmental conditions and bi direction of channels.

The main means of 3D-modeling in this study are the methods of artificial intelligence, expert systems; neural networks; fuzzy logic techniques; genetic algorithms.

In order to conduct 3D-modeling used combined model of method of expert systems and fuzzy logic methods that are implemented in the system MatLab. These methods allowed performing system analysis developed in this study of electronic knowledge base and intuitive data node technology [2].

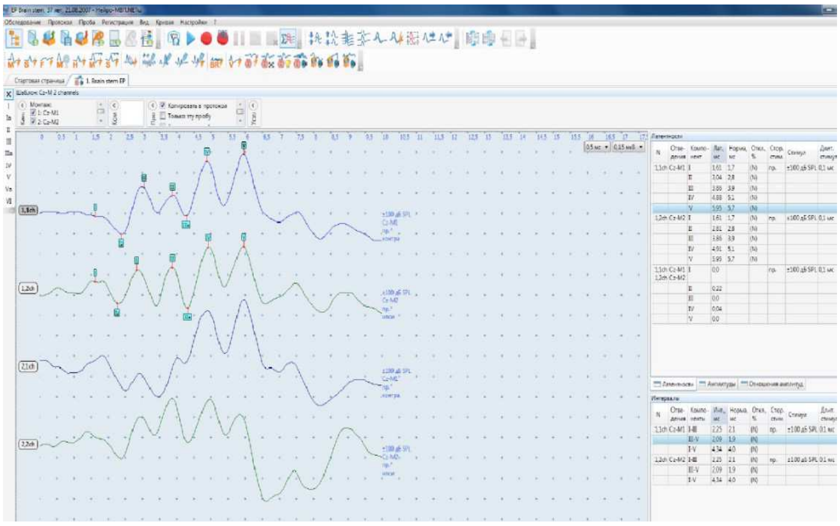


Figure 1. The trajectories of the information in the 3D-model obtained by the neural network Note: created by authors

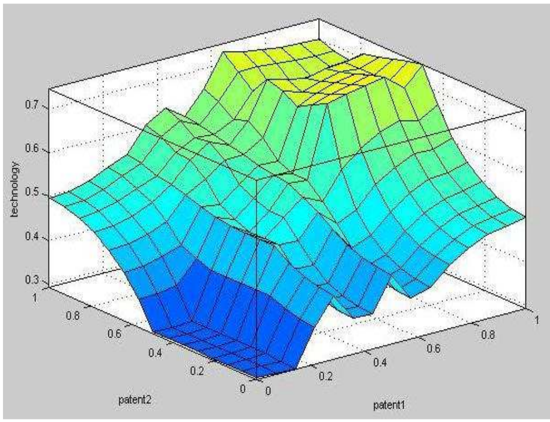


Figure 2. Surface development of node technologies due to the results of expert assessment of patent statistics data Note: created by authors

In the spatial form set of available in an electronic database node technologies presented in the form of surface (Fig. 2), where the axes delayed evaluation according to the patent statistics, time selection decision), vertical axis is point technology options.

As shown in Fig. 3 In the lower region are unpromising technology. The top area has «high technology» that implement the most innovative and original innovative solutions. Between these areas, there are intermediate technology.

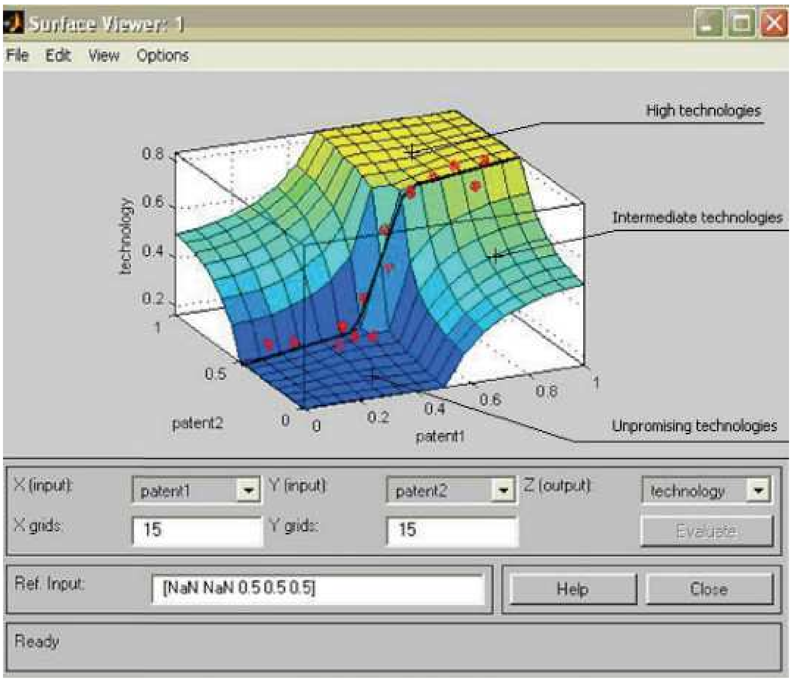


Figure 3. Theoretical surface development of node technologies Note: created by authors

Multinode graph of technology development is core for possible construction design as well as and technological solutions (in the form of design, perspective and policy processes) for structural optimization of node technologies. Multistructural optimization technologies on network graphs is made using the theory of stochastic decision and game theory, dynamic programming, use of artificial neural networks and other methods of system analysis technology.

Neural network is adaptive systems for processing and analyzing data, which is mathematical structure that mimics some aspects of the human brain and demonstrate such its features as the ability to non-formal learning, the ability to generalize and cluster unclassified information, the ability to build their own forecasts based on lodged on time series [4]. Their main difference from other methods, such as expert systems, is the neural network does not require formerly known model and build it by itself through the provided information. Therefore, neural networks and genetic algorithms included in the practices wherever necessary to solve problems of prediction, classification, management – in other words, in the area of human activity, which is bad for algorithmization. Neural networks are adaptive systems of automation to solve immediate problems or for continuous work of qualified expert group.

The neural network receives incoming information and analyzes it in a manner analogous to human brain. When analyzing network learns (acquires experience and knowledge) and gives background information based on experience.

The main task of the analyst that uses neural network to solve any problem is to create the most efficient architecture of the neural network means to choose its form, its learning algorithm, the number and types of neuronal connections between them. This work has formalized procedures, it requires a deep understanding of the different types of architecture of neural networks, includes many research and analysis activities, and can take a lot of time to prepare. Thus, in the shortest time the neural network is able to give many the most effective solutions for a given time and the particular situation. Neural network models can exceed the performance of traditional methods informal tasks in several times.

Neural networks present themselves in the best way where there are a large number of inputs, among which are implicit relationships and patterns. In this case, the neural network helps you automatically consider various nonlinear dependence, hidden in databases. This is particularly important in decision support and forecasting systems.

It should be noted that since the economic, financial and social systems are very complex and are the result of actions and reactions of different people, it is very difficult (if not impossible) to create a full mathematical model with all the possible actions and reactions. Almost impossible to detail the approximate model based on traditional parameters such as maximizing utility or profit maximization [7].

The criteria for selecting the most suitable network that delivers better classification error control are the value of the training and test subsets and summary statistics window «Classification Statistics». Network demonstrated best results has hidden layer that includes seven items that neural network architecture has the form: 6-7-1 (Fig. 4).

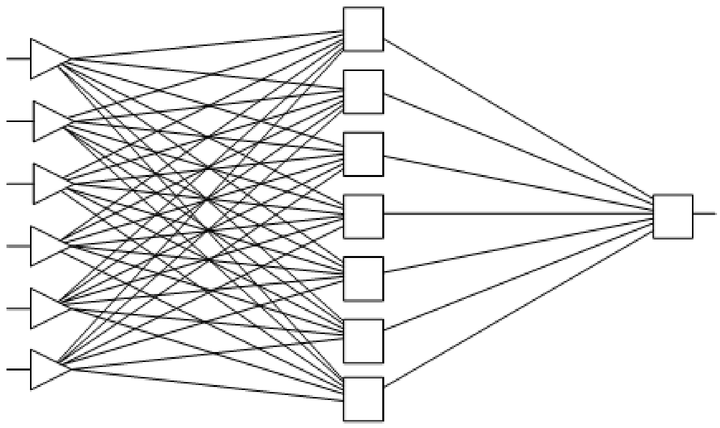


Figure 4. Neural network architecture: 6-7-1 Note: created by authors

The value of the control error is 0,016 for the training subset and 0,018 for the test. The network shows the highest number among the networks that correctly classified observations taken the training and test sets.
The results obtained via the 6-7-1 are shown in Tab. 1.

Table 1.

Net-work archi-tecture	The value of the control error (the mean square error on training and testing subsets)	The number of classified observations on the test subset (valid observation class is the class assigned to the INS)					
		priori dangerous = potentially stable	priori dangerous = potentially stable	potentially stable = priori dangerous	potentially stable = priori dangerous	priori dangerous = potentially stable	potentially stable = priori dangerous
6–7–1	0,016; 0,018	99	–	96	–	1	4

Tab. 1 shows that neural network solved classification task, put successful flights into two groups: potentially stable and a priori dangerous. Network accurately classified 96 potentially stable among a hundred experiments; among the same amount, 99 a priori dangerous were identified correctly. Network classified correctly all surveillances, which can be attributed to too tight confidence levels.
Fig. 5 shows Training Error Graph of the network.

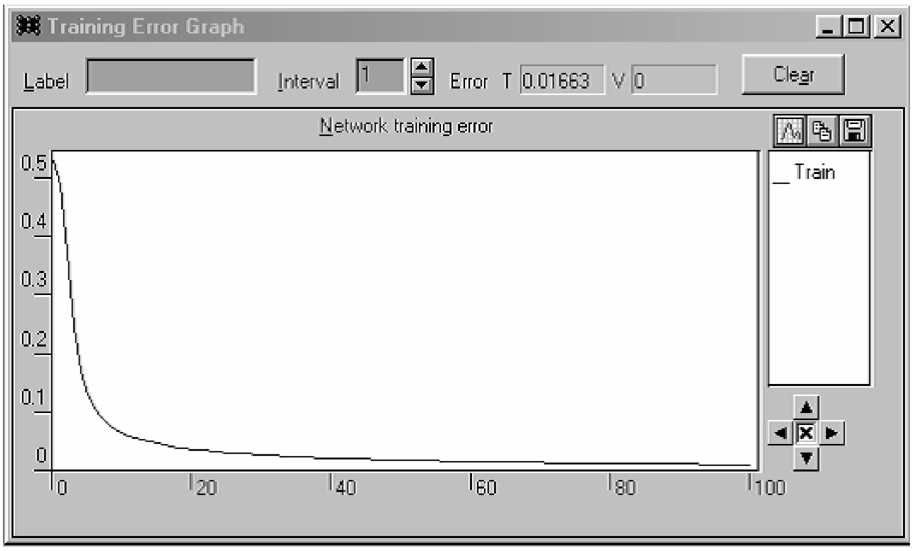
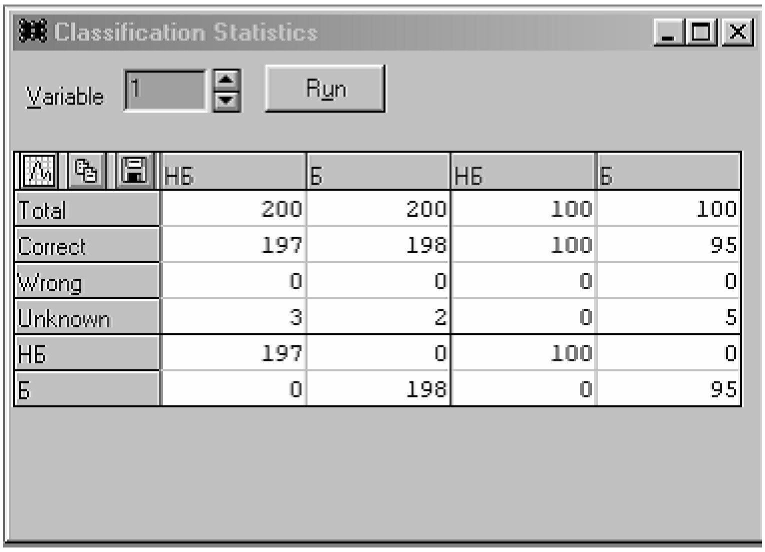


Figure 5. Training Error Graph Note: created by authors

«Classification Statistics» contains very helpful information for analyzing the results, quality of classification and the choice of thresholds of acceptance/rejection, shown in Fig. 6.



	НБ	Б	НБ	Б
Total	200	200	100	100
Correct	197	198	100	95
Wrong	0	0	0	0
Unknown	3	2	0	5
НБ	197	0	100	0
Б	0	198	0	95

Figure 6. Classification Statistics Note: created by authors

Columns correspond classes; each column is divided into two parts: the summary statistics and statistics assignment. All data is displayed for each set (learning or test). Summary statistics include total number of observations in this data set; observations of this class, which network correctly classified; observations of this class, which network classified incorrectly, belonging to another class; observations from this class that the network could not classify. Assignment statistics shows how each set of observations were attributed to each of the possible classes, including correct (vague observation not shown). From the above table follows the conclusion of high quality training and work neural network.

The resulting neural network model aims to classify new secure flights for which there are known values of the above parameters. Work model was tested on a test set data that did not participate in the training network and has shown good results, indicating broad practical application of this approach.

The study examined various modifications of multilayer architecture of perceptron (settings Temporary window – Steps and Horizon – Lookahead, the number of items in the hidden layers), configuration of training options (training speed, inertia, and the number of periods). As a learning networks algorithm method RFP was used. Logarithmic activation function in the output layer was replaced with linear to improve the quality of extrapolation, which does not change the level of activation and thus, unlike logarithmic, is not fulfilled, so is better predictable. Possibility of automatic design a network that is implemented in the package Statistical Neural Networks was used during searching for a better alternative network. To solve the problem of forecasting flight safety indicator K1 the best option was network of five centers of input, one hidden layer, consisting of ten neurons and extrapolating unit, resulting in the type of network architecture 5-10-1.

The value of the control error is 0,18 for educational subset and to 0,21 – for control. Time series projection of flight safety (Fig. 7) can perform with the help of trained network.

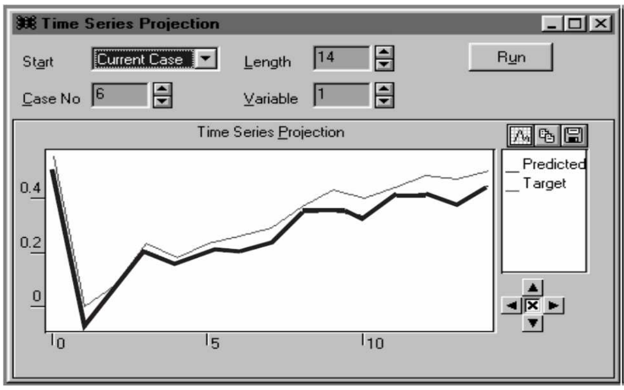


Figure 7. Time series projection of flight safety Note: created by authors

The graph shows that the estimated number approximates well the original sequence and as a result, gives a reliable estimate forecast for the two periods (19 and 20) forward.

This search goals and means to conduct a wide range of environments technology based on the simulation of linear operations of intelligence and nonlinear laws of intuition. It is generated by the study of the human brain, as aimed at building a logical functioning system with a large number of simple elements, to identify mutually conjugated as well as branched connections without a priori knowledge.

In the process of determining the effectiveness, neural networks can solve problems related to the technical diagnosis aircraft using the methods of nondestructive testing in real time. Moreover, mechanical damage to the aircraft is evaluated, both on Earth and in flight. The method of high-frequency ultrasound scans can achieve nearly 100% accuracy. Network predict the reliability of systems that are used both in aircraft and in ground traffic control flight [1].

Neurocomputers are used to recognize the types of aircrafts. Observations on the image allow profiles turns, movement, zooming, reduce high noise levels.

Neural network algorithms and neurocontroller quality management used in teaching of beginners helicopter pilots. Training takes place automatically without human intervention: the system actively control helicopter, makes beginner to increase degree of control over the flight for a particular skill. In fighter aircraft neurocomputers accounts external conditions, are responsible for the precise maneuver against the goals, adjust pilot mistake, noise, etc. [10].

The results of the analysis based on patent statistics selected list of the most promising technologies for new design solutions of the new generation, development of the previous set of technical documentation and design policy processes.

As Hero of the Soviet Union Colonel-General M. M. Gromov wrote: «In order to fly safely, it is necessary to know how to control the aircraft, but even more important is to know how to control himself. My success in the aviation industry is often explained by excellent knowledge of technology. That's true ... but at 1%, while the remaining 99% relate to the ability to learn, to explore myself and the ability to improve myself. This improvement should start with learning the basics of psychology.» [5].

This method can be automated, namely to build a structure that can be used by the pilot during a medical control before the flight. The main part of this design will be the «helmet», which is connected to the computer.

«Helm» comprises a magnet coil which can be moved mechanically, depending on the areas that need to be activated. The principle of operation is exactly the same coil as in the manual. It generates an alternating magnetic field and an electric field; because of this neurons begin to generate action potentials, which are further transmitted to the appropriate locations along nerve pathways in the nervous tissue [9]. The path of movement of the coil is determined by the computer. There is a database with medical conditions and symptoms of the pilot, his medical map and the volume of the head. The program builds a model of the brain based on these data. Also, using different algorithms movement trajectory and the power coil stimulus are calculated. Usage of this machine can diagnose a variety of characteristics of the pilots, which may affect the quality and safety of the flight or can be cause of the crash.

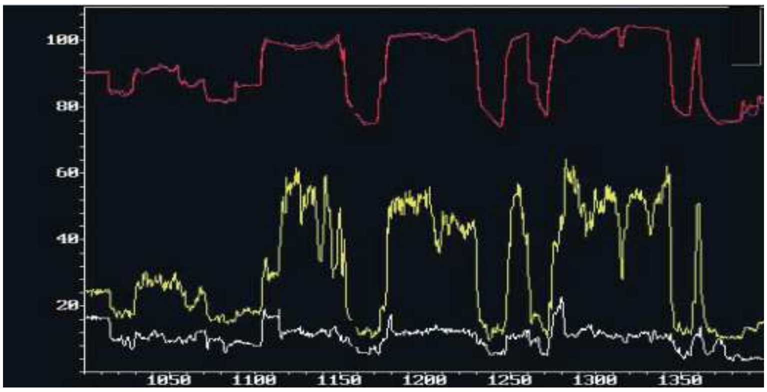


Figure 8. 3D-modeling of flight safety characteristics, obtained by the neural network Note: created by authors

In addition to this function of the human brain as the only channel information have natural limits. Information overload occurs in flight practice is much more common than is commonly believed. For many decades, the share of «human factor» is estimated to range from 55 to 80 percent [12] of the causes of accidents. And this figure only applies to certified flight personnel. In view of the flight training process, departmental, private aviation share of the HR on average increased by four percent. With the addition of «human reasons» from the manager, maintenance overall proportion of the human factor is equal with the traditional classifications and methods about 87%.

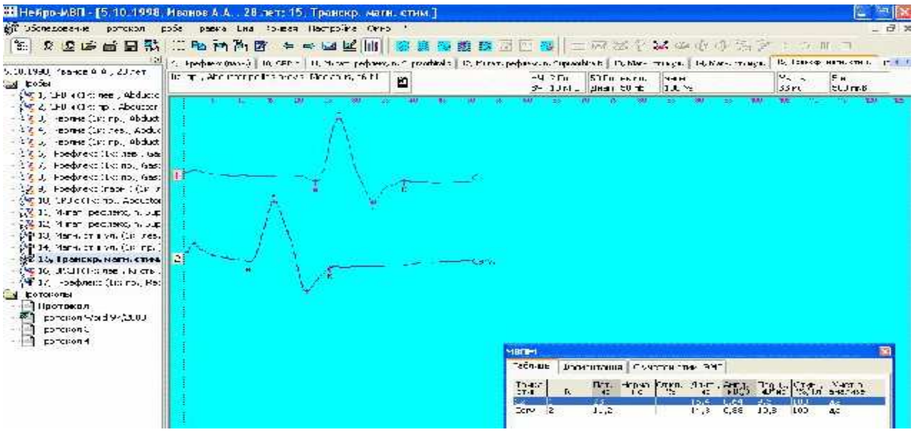


Figure 9. 3D-modeling of information channels Note: created by authors

While engineers have created a kind of helmet, which a person needs for mechanisms manipulation. However, in the future, these technologies will become more advanced and compact that will issue commands of various tasks without attracting undesired attention, focusing exclusively on the power of their mind. Human brain is still a mystery part of the body for scientists. This is why active study of brain activity, technology understanding and ideas origin, imagination are processes that help make robots more human-like and autonomous. Nevertheless, these technologies are unavailable to modern man now.

Nowadays devices with the help of which people could operate aircraft and cars by thought became very active in designing.

Researchers at the Technical University in Munich launched a project named «Brainflight», to demonstrate the possibility of using Mission Control opinions. According to scientists, with the help of this even people with no experience of piloting are able to cope with it.

In the experiment, the virtual simulator involved seven people with different levels of experience. Helmet with electrodes was put on heads of the participants, and information about brain activity was transferred to the computer.

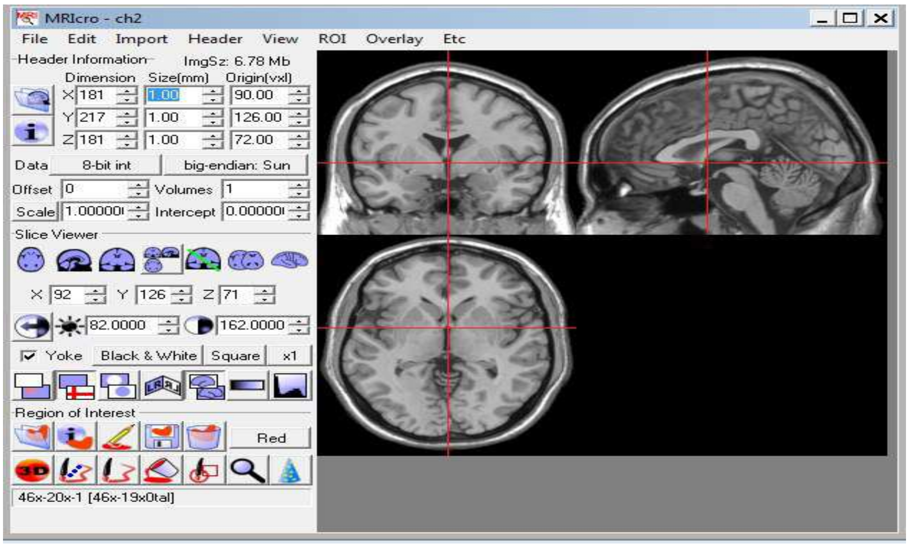


Figure 10. Information about activity of the brain Note: created by authors

As Gagadget explained, scientists developed an algorithm that converts the electrical signals of the EEG into commands, as a result, all handles and steering wheel in the cockpit simulator is moving due to pilot's thoughts.

There was one man in the experimental group who was never associated with the management of aircraft, but eventually he was able to perform eight tasks out of ten – with deviation from the course of just 10 degrees. Several people under test were able to land the plane in conditions of poor visibility.

New technologies will help to control the aircraft using thoughts.

Experiments under supervising of German experts proved: control the plane using thoughts may be as effective as manual control. Plane can be easily controlled by thoughts. German researchers came to this conclusion, following a series of tests of flight simulation.

Figure 11. The using of helmet into an airplane

Participants followed exactly preset course using only their thoughts. According to scientists, the results of such experiment shown: volunteers could get pilots licenses.
Helmet with sensors was worn on the head of participants, which retreated cables, transmitting information about brain activity to the computer.
The participants were in a copy of the aircraft; while the steering wheel and handles moved independently, basing on the «pilots» thoughts.
The project «Brainflight» was organized by a group of researchers led by Florian Holtsapfel in Munich Technical University. For the first time, American scientists proved the theoretical possibility of managing aircraft a year ago. In their experiment, the subjects managed miniature helicopters using thoughts.
Munich experts made the next step: using real simulator for mental control. Scientists believe that their study may have a great future in aviation. After all, if the pilot will be able to mental respond quickly to unusual situations, he will have great freedom of movement.

Figure 12. The using of helmet on the simulator

Man-machine communication became possible by a complex algorithm that deciphered electrical signals obtained by EEG, into the specific commands to the onboard computer. This program allocated only those thoughts in the flow of ideas, which belonged to the management of plane.
Researchers want to do next step – to establish a feedback between the plane and pilot. For example, if a particular maneuver requires machine to overcome very large resistance, the pilot has to make a lot of physical effort to hold it. Scientists want that onboard computer gives information about the complexity of the commands to future «mindpilots».

Machines are already an integral part of our lives. In the future, when the cities become bigger, cars – faster, we will need a new way to drive.
Experiments with machines are still quite frequent. Scientists create machines that are able to fly, swim underwater, cars of the future, after all. The new development is something innovative, something that had not been.

Figure 13. The using of helmet into a car

AUTONOMOS Laboratory, which is located in Berlin, presented a new invention. The main breakthrough was the ability to control the car through the power of thought. To create this device was much easier as previously required devices parts were invented. One exception they use a computer instead of machine. This principle is the same.
In words, this project is quite simple, unlike its implementation. Man has special device that reads information from the brain and sends it to the computer. The computer, in turn, writes EEG.
So people can mentally give commands like «deceleration», «right», «left», «accelerate» and so on. As mentioned earlier, the computer recognizes the information as pulses and depending on what type of information, it changes into the command and executes it.
The car has passed all tests Tempelhof airport in Berlin.
German scientists showed that driving with power of thought is realistic. The main task now is to teach people the right to give commands, so the computer can recognize and fulfill it.
Particularly promising areas are related to navigational robotic systems that allow autonomous navigation with full respect to external influences, such as its own speed and speed changes in the environment, rotation, direction of travel and so on.
This information is automatically assessed without human intervention. In addition, there are possible solutions to the most difficult task – instead of the human operator, computer-operators of air (or underwater) ships can control movement in three areas

simultaneously: along the front, up and down, around the axis. Network error is less than 1.2%, which is unattainable to the human operator. Interesting land robots-loaders can be used in extreme environments and on other planets, small-sized aircraft with autonomous piloting etc. [8].

Increasing the effectiveness promotes the use of neurocomputers, due primarily, with the ability to signal processing at high noise levels. Handling images in two ways: recognition and allocation of moving target on stationary or moving background – opens tremendous opportunities in the implementation of tactical tasks. Being the most efficient algorithm for selection of moving targets on the background – neural networks open the way to fully automatic combat operations with conventional weapons. Building systems compatible with human biological vision will increase the productivity of operations tenfold. The ability to restore the original picture by the following data will create significant market security. It is now obvious advantages of neural networks over human in the allocation of targets on the image even in the optical range. Networks have been used for systems of robots that move in an environment with obstacles.

Also, increasing the effectiveness contributes in transputers market, creating three-dimensional paintings and using for radars. They use three-dimensional (3D) model of radio sources. Networks allow qualitatively solving problems of goal in any of the signal/noise ratio by removing obstacles and simulation purpose. Solved the problem of information processing in a wide area view of the presence of large numbers of objects, task-tracking goals, identifying goals maneuver in the area of deliberate interference, etc. Before, all of this caused great difficulties in real time mode and in the ability of the human operator. Experienced dispatchers cope with simultaneous support of 25-26 goals. In real situations, such as in the area of the airport, the number of targets can reach several dozen. Joint activities of several controllers that communicate with each other goals; reduce airport capacity due to the human factor. Neural networks allow you to analyze and predict the future trajectory of the movement for a large number of obstacles. The creation of tracking the trajectories of many targets based on neural networks engaged in several companies in China and Singapore [3].

Conclusion. The performed analysis of the capabilities 3D-modeling and the concepts of «new engineering» showed that the modern knowledge in technics is fundamentally changing the traditional principles, approaches and models. There is an intelligent value of the role of modeling. The intellectualization of technics activity requires the creation of intellectual automated systems, that contribute to more active use of modern intellectual, geoinformational communications, corporate integrated systems and technologies, and will improve the quality process and stimulate the development of intellectual capital.

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THE PECULIARITIES OF CONSTRUCTION THE FORECASTING ALGORITHMS OF UNAUTHORIZED ACCESS TO THE STATE INFORMATIONAL NETWORKS IN CASE OF PARALLEL DATA PROCESSING

Summary: In this work is carried out an analysis of construction the forecasting algorithms of unauthorized access. On base of proposed structures of algorithms of unauthorized access forecasting, using one parameter and group of parameters, is presented a structure of algorithm of forecasting a state of controlled parameter during parallel procedure of information processing.

Keywords: unauthorized access, State informational networks, control, a priori information, algorithm

ALGORYTMY PRZEWIDYWANIA NIEAUTORYZOWANEGO DOSTĘPU DO SIECI INFORMACYJNYCH PAŃSTWA W PRZYPADKU PRZETWARZANIA RÓWNOLEGŁEGO

Streszczenie: W artykule przeprowadzono analizę budowy algorytmów przewidywania dostępu nieautoryzowanego. Na podstawie zaproponowanych struktur algorytmów przewidywania nieautoryzowanego dostępu, przez ustawienia jednego parametru i grupy parametrów, zaprezentowano strukturę algorytmu prognozowania stanu kontrolowanego parametru w procedurze przetwarzania równoległego.

Słowa kluczowe: nieautoryzowany dostęp, sieci informacyjne Państwa, kontrola, informacja aprioryczna, algorytm

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1. Introduction

The forecast of unauthorized access to the State informational networks (SIN) must be undoubtedly based on tendencies researching, that are observed in changes of their current state under the influence of unauthorized access. In theory of automatic control is expected, that this state can be presented by the range of values of some controlled parameters. Then, obviously, the reason that causes changes of SIN state, must be changes of values of these parameters. Thus, the forecast of unauthorized access in SIN must be based on forecasting the values of controlled parameters state. This can be carried out on base of mathematical instrument of process extrapolation, that describes regularities of changes in parameters. In its turn the usage of extrapolation instrument needs certain processes formalization of changes in controlled parameters, i.e. it needs creating a certain mathematical model of SIN parameters measurements under the influence of unauthorized access.

1.1. Main part

The main reasons of imperfection of mathematical analysis, that is used today, consist in difficulties of formalization the tasks of showing and unauthorized access concerning information, threats and its protection, which are connected with the processes, that are formalized hard and change their parameters throughout SIN functioning, as a part of SIN. As a result, a requirement for compensatory analysis of functioning of the Complex system of information protection is not carried out, that leads to reducing of its effectiveness and complicating the designing of perspective systems on its base. The tasks of forecasting the unauthorized access are closely connected with the tasks of control of current SIN state, which are solved automatically and are characterized by the following: first – big amount of processing information and second – large homogeneity of rather small amount of the main operations. As the experience proves, the programs of control and forecasting have in some cases thousands of commands, and their executing is turned into repeated memory and sub-program requests (a program of control and forecast).

The enumerated peculiarities have decisive influence on question of rational placement of output data, programs of control and forecast in computer memory and on organization of program structure. But nevertheless, despite heterogeneity of controlled parameters, is reasonable designing a typical program for most of them.

This universal program of control and forecasting is reasonable to arrange in type of standard sub-program. One of the criterion of reasonableness of organization the standard sub-programs is a multiplicity of usage of program during processing of large amount of output data.

During carrying out a procedure of forecasting the unauthorized access, as output information is used the aggregate of measurements of controlled parameters, a priori information, a value of interval of notice and dispersion of chance components of investigative parameter. Thus, a compound part of procedure is control performing of characteristic parameter. On the one hand, this operation is inherent in procedure of forecasting and it can be examined as a compound part of the algorithm and accordingly, a part of standard forecasting sub-program. On the other hand, performing the controlled measurements can have independent importance, because the aggregate of controlled parameters and forecasting the unauthorized access cross

only partly. That's why is reasonable to accept such organization of mathematical support, in which a control of parameters is picked out into separate standard sub-program, same as the tasks of individual unauthorized access forecasting.
Let's examine possible variants of data processing from point of view of arrangement a procedure of forecasting.
The 1st case. The procedure of control the SIN parameters provides for time intervals between controlled measurements of parameters exceed or are equal to the time of unauthorized access forecasting. A block-diagram of algorithm of processing the information for the first case is presented on the picture no. 1.
The procedure of forecasting the unauthorized access is performed at once after usual control of investigative parameter. During this, the output information is presented by results of control of last n results of investigative parameter. Also is specified anticipatory moment of time, concerning which must be performed calculations and a priori information according to the parameter. The forecast of unauthorized access according to the parameter consists of 2 stages. On the first stage is performed forecasting the parameter state at the anticipatory moment of time. On the second – is found a probability of unauthorized access for the anticipatory moment of time.

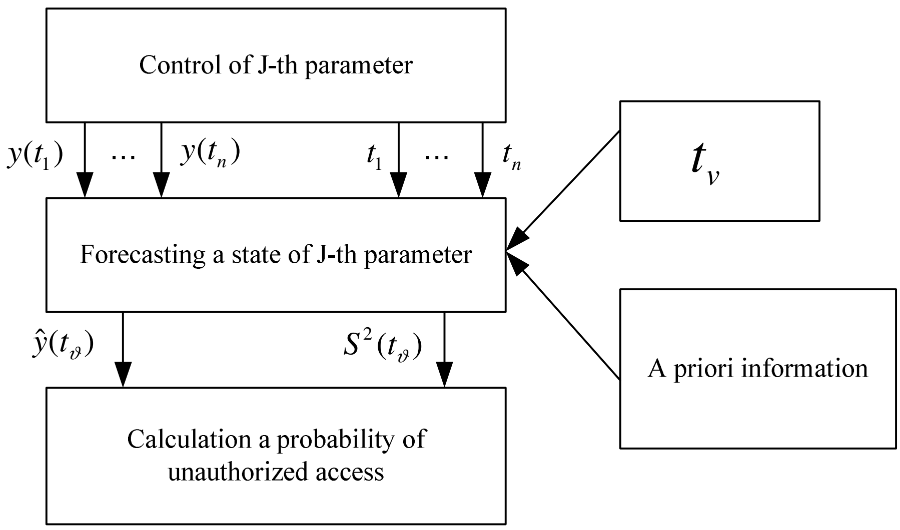

Figure 1. A structure of unauthorized access forecasting algorithm using one parameter

The 2nd case. A structure of SIN control program provides for probability of performing a procedure of forecasting only after performing control on group of forecasting parameters. Having calculated a probability of unauthorized access out of group parameters, the control system automatically continues to control the network parameters. If there is "free" time, bigger or equal time of performing forecasting, the system switches from information processing for the purpose of forecasting a probability of unauthorized access of new group of parameters etc. Extended block-diagram of information processing for the second case is shown on the picture no. 2.

As in the first case, the unauthorized access forecasting consists of forecasting stages of parameter state with estimating accuracy of forecasting, and calculation a probability of unauthorized access by every group parameter.

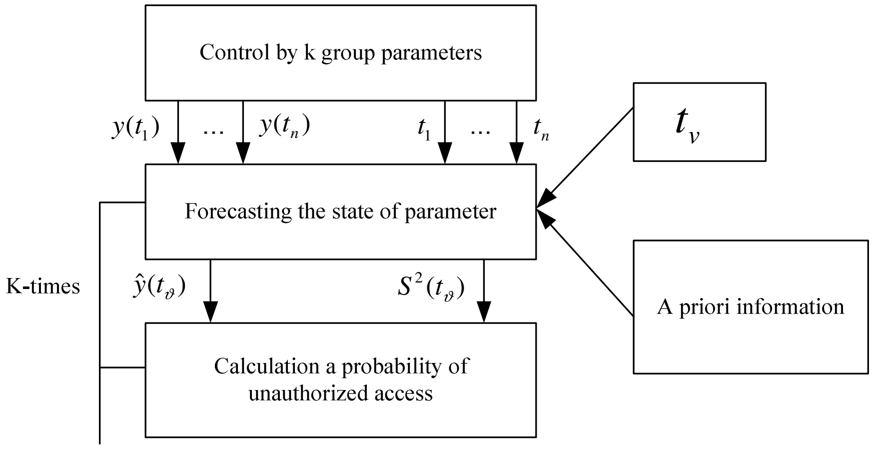

Figure 2. A structure of unauthorized access forecasting algorithm using group of parameters

A discrepancy between the second variant of processing algorithm and the first, consists in the following: standard stages of processing repeat as many times as there are forecasting parameters in group. The output information during processing is the same as in the first case.

The 3rd case. The aim of information processing is forecasting a probability of unauthorized access. It is possible to do only after performing control of parameters and finding probabilities of unauthorized access by all forecasting parameters separately. A block-diagram of information processing is shown on the picture no. 3. A difference of examined case from previous, is a presence of a block, which provides for probability calculation of unauthorized access to network in general.

For examined variants of information processing the block-diagrams consist of typical sections:

1. State forecasting using one parameter
2. Forecasting a probability of unauthorized access using one parameter
3. Forecasting a probability of unauthorized access to network in general

This accepted split of information processing algorithm is easy-to-use from the point of view of shortening the length of program of every section.

Therefore, let's design and analyse the forecasting algorithm of unauthorized access in case of parallel data processing. The algorithm is designed for forecasting the network state, represented from control elements of chance sequence, including a priori information. In addition, algorithm provides for simultaneity of processing the existing a priori information and the aggregate of control results of forecasting parameter.

A mathematical model of deterministic component of chance sequence, which represents a forecasting parameter is a polynomial of degree 2, coefficients of which are chance values, with known mathematical expected value $\|\Theta_k\|$ and a covariance matrix $\|\sigma_{kl}\|$.

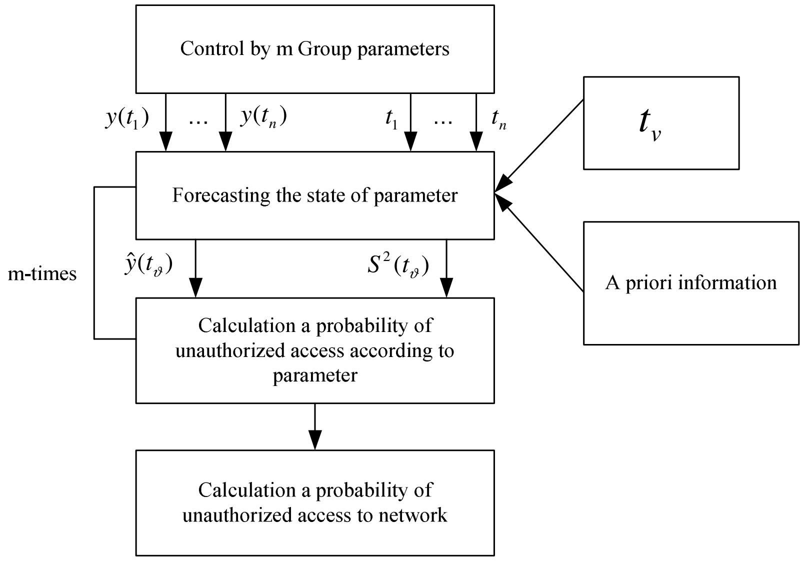

Figure 3. A structure of forecasting algorithm of unauthorized access in SIN

The output data of forecasting algorithm of parameter is:

1. A priori information, that is specified in view of column of mathematical limitations and coefficients of covariance matrixes (always 9 values)
2. Controlled information, that is specified by the aggregate of controlled measurements $y(t_1)$, $y(t_2)$, … , t_n (n values)
3. The value of moment of time of performing control t_1, t_2, … , t_n (n values)
4. A dispersion of chance component of sequence and error D_n.
5. The value of time moment of prediction t.

As a result, the output data using one parameter is represented by Q_n+11 values.
The processing algorithm we will separate into 4 consecutively performing stages:

1. A preparation of a priori information
2. A preparation of controlled information
3. A calculation of auxiliary values
4. A calculation of the first 2 moments of distribution law of probability of parameter value in specific moment of time including shifts.

The first stage, that ensures a preparation a priori information, includes:

a) covariance matrix inversion $\|\sigma_{kl}\|$;

b) finding a left informational matrix

$$B_I = D_n \bullet \left\|\sigma_{kl}^{-1}\right\| = \left\|D_n \sigma_{kl}^{-1}\right\|. \quad (1)$$

c) finding a right informational matrix

$$C_I = \left\| D_n \sigma_{kl}^{-1} \right\| \bullet \left\| \theta_k \right\| = \left\| \sum_{k=1}^{m} \theta_k D_n \sigma_{kl}^{-1} \right. . \qquad (2)$$

The second stage, ensures preparation of controlled information, includes:

a) a calculation of left controlled matrix B_y, its elements are calculated using a formula

$$B_{kl} = \sum_{i=1}^{n} t_i^{k+l-2}; \qquad (3)$$

b) a calculation of left parts of controlled matrixes C_i, their elements are calculated using a formula

$$C_{il} = t_i^{l-1}, 1 \le i \le n. \qquad (4)$$

The third stage, that ensures a calculation of auxiliary values, includes:

a) creating a full left matrix

$$B = B_y + B_I = \left\| \sum_{i=1}^{n} t_i^{k+l-2} + D_n \right. . \qquad (5)$$

b) a calculation of Θ_{ki} value by solving a system of equations

$$B \left\| v_{k0} \right\| = C \qquad (6)$$

$$B \left\| v_{ki} \right\| = C_i , 1 \le i \le n; \qquad (7)$$

c) a calculation of coefficients (h_i, $0 \le i \le n$) that have weighty values

$$\sum_{k=1}^{m} \vartheta_{k0} t_{\vartheta}^{k-1} = h_0 y_0 ; \qquad (8)$$

$$\sum_{k=1}^{m} \vartheta_{ki} t_{\vartheta}^{k-1} = h_i ; \qquad (9)$$

d) Finding the estimations of coefficients of model of deterministic component

$$\vartheta_k = \vartheta_{k0} + \sum \vartheta_{ki} y_i \qquad (10)$$

The fourth stage ensures a calculation of concrete value of parameter and estimates the accuracy of prediction, includes:

a) A calculation of anticipatory value using formulas:

$$\hat{y}(t_{\vartheta}) = \sum_{i=0}^{n} h_i y(t_i), \qquad (11)$$

or

$$\hat{y}(t_{\vartheta}) = \sum_{k=0}^{m} \hat{\vartheta}_k t_{\vartheta}^{k-1}; \qquad (12)$$

b) An estimation of error rate using shift

$$\delta^2 y = [\sum_{k=1}^{m} \Delta \vartheta_k (\sum_{i=1}^{n} h_i t_i^{k-1} - t_{\vartheta}^{k-1})]^2 , \qquad (13)$$

where $\Delta\vartheta = \hat{\vartheta}_k - \vartheta_k$;

c) An estimation of error rate using a chance component of sequence and control error

$$D_n \sum_{i=1}^{n} h_i^2; \tag{14}$$

d) A calculation of general error of forecasting the parameter state

$$S^2(t_\vartheta) = (\delta^2 y + D_n \sum_{i=1}^{n} h_i^2), \tag{15}$$

The output values of algorithm are an estimation of mathematical expected value of parameter at the anticipatory moment of time $\hat{y}(t_\vartheta)$ and estimation of total need of forecasting at the anticipatory moment of time. A block-diagram of algorithm is cited on the picture no. 4.

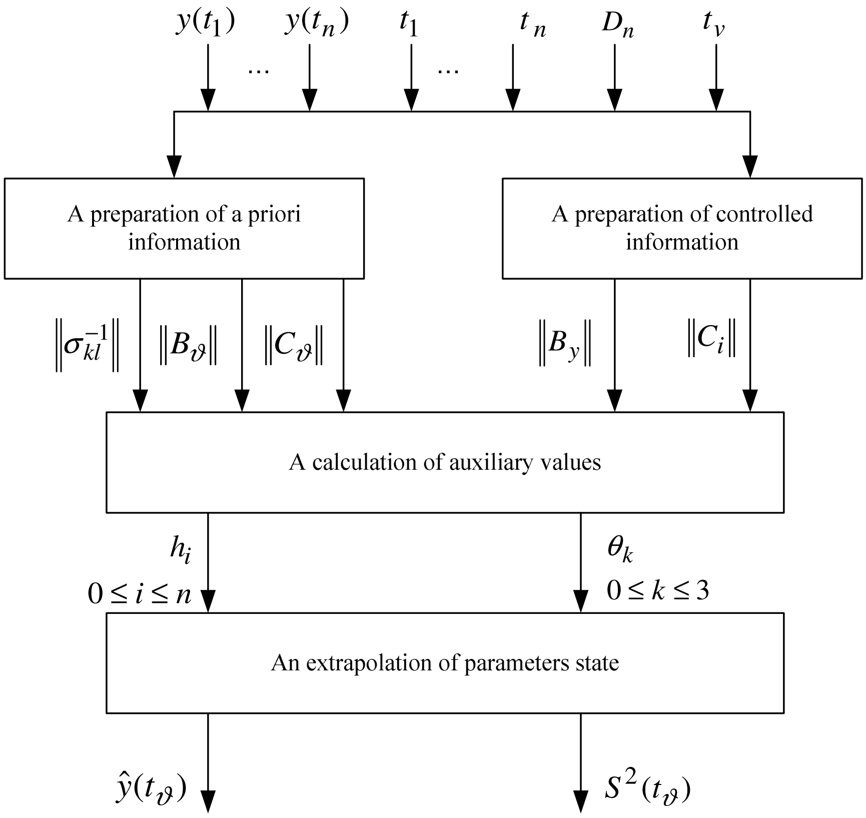

Figure 4. A structure of forecasting algorithm of controlled parameter state during parallel procedure of information processing

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TESTY MONITORUJĄCE ZDROWIE KOBIET - NARZĘDZIA DO ICH OBSŁUGI KOMPUTEROWEJ

Streszczenie: W niniejszym artykule, omówiono narzędzia komputerowe do rejestracji, archiwizacji i monitoringu wyników badania zdrowia kobiet. Badania te mają na celu klasyfikację, która może pomóc w diagnozie wybranych chorób kobiecych.

Słowa kluczowe: klasyfikacja, hiperpłaszczyzna oddzielająca, mammogram, technologie informacyjne

MODELS TEST IN WOMAN'S HEALTH MONITORING INFORMATION TECHNOLOGY

Review: The results of models test in woman's health monitoring information technology were set forth

Key words: classification, separating hyperplane, mammogram, information technology

1. Introduction

Transformation and analysis of information resulting from medical research, in particular from X-ray films, make it possible to determine the patient's health status. The more detailed information concerning the «problem» image areas can be received after solving the problem of pattern recognition and hyperplane search.

Pattern recognition is currently one of the burning problems. The development of modern information technologies, used for pattern recognition problem solving, gives the possibility to reach the completely different level in many spheres, for example,

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in criminalistics (fingerprint identification), medicine (diagnostics and diagnosis making) etc.
Though numerous research papers in different spheres of human activity, in particular, in medical diagnostic (X-ray films recognition), were dedicated to this problem, the latter is still very burning and should be further investigated.

1.1. Framing the Article Objectives

This research paper aims to solve the following problems: 1) marking and classifying the mammogram's problem areas; 2) determining the separating surface by models' teaching, evaluating and testing; 3) experimental studies of taught models' output and selection of the best of them, able to identify the problem area at the highest recognition rate.

1.2. The Research Paper Body Description

Every image is a set of numbers, describing its properties and being called features. The ordered feature set is called the feature vector. The feature vector is the point in the feature space. It uniquely determines the position of separating plane in the feature space, so the problem of separating plane construction is reduced to the search of vector values.
To construct the separating surface, it is necessary to choose the decision rule (a function which associates the image feature vector with a class to which it belongs) specified by a set of linear decision rules as follows:

$$F(x,\alpha) = \theta\left(\sum_{i=1}^{n} \alpha_i \gamma_i(x)\right) \tag{1}$$

To choose the function out of this class means to find the corresponding α (to construct the corresponding separating plane)

$$\sum_{i=1}^{n} \alpha_i \gamma_i(x) = 0 \tag{2}$$

Two finite sets of vectors $X = \{x_1, ..., x_a\}$ and the set $\overline{X} = \{x_1, \ldots, x_b\}$, separated by hyperplane, if there exist such vector γ and such number α, so that for any vector $x_i \in X$ the equation holds true,

$$(x_i, \gamma) > c,$$

and for any vector $\overline{x_j} \in \overline{X}$ – the equation

$$(x_j, \gamma) < c$$

When both these conditions are met, this means, that the X set is separated from the $\overline{X}$ set by a hyperplane (separating surface)

$$\left(x,\gamma\right)=c$$

Let's define for any single vector φ two values $c_2\left(\gamma\right)$:

$$c_1\left(\gamma\right)=\frac{\min}{x_i\in \mathrm{X}}(x_i,\gamma), \tag{3}$$

$$c_2\left(\gamma\right)=\frac{\max}{\bar{x}_j\in \overline{\mathrm{X}}}(\bar{x}_j,\gamma) \tag{4}$$

According to determination of values $c_1(\gamma)$ and $c_2\left(\gamma\right)$ the inequalities always hold true:

$$\left(x_i,\gamma\right)\geq c_1\left(\gamma\right)\ \left(i=1,2,...,a\right)$$

$$\left(x_j,\gamma\right)\leq c_2\left(\gamma\right)\ \left(i=1,2,...,b\right).$$

It is obvious that if

$$c_1\left(\gamma\right)>c_2\left(\gamma\right),$$

then the pair $\gamma,\dfrac{c_1(\gamma)+c_2(\gamma)}{2}$ determines the hypersurface

$$\left(x,\gamma\right)=\frac{c_1(\gamma)+c_2(\gamma)}{2}, \tag{5}$$

separating the X set from the $\overline{\mathrm{X}}$ set.

The functions $c_1(\gamma)$ and $c_2(\gamma)$ are continuous ones, that is why the existence of one hyperplane, separating two finite sets of vectors X and $\overline{\mathrm{X}}$, implies the existence of multitude of hyperplanes, separating X and $\overline{\mathrm{X}}$ [1].

So, the search of hyperplane and the models' test in the developed information technology occur by applying the multilevel system of information transformation [2]. In this case the data received at the preceding level are used for research at the next level.

At the first stage the image is loaded, it can be of arbitrary size, the image is loaded without preprocessing. Fig.1 displays the mammogram with pathology. The problem area is circled red.

Figure 1. Mammogram image

The images are chosen for program teaching; in order to teach the model two areas are marked on the film: the problem one (highlighted areas) and the sound one (gradation of grey or black colors), then the samples of these two areas are taken and the program is teaching, constructing the model and entering it into the model knowledge base.

The next stage after teaching is selection of models through test sampling (images which were not included into teaching), when the percentage of correctly recognized problem' and sound areas is checked.

In course of analysis the models are loaded from the knowledge model base. Each model contains in its structure the size of window on which it taught. The analysis is performed by window displacement method and goes through the whole image. The window width is set according to the saved parameter in the model knowledge base. Each window is given in the form of a matrix, which is the part of general image. Accordingly, each row of this matrix is the observation. The image properties – brightness and pixel saturation – are fed to the model's input.

The mammogram areas with signs of disease were marked as «Self» by numerical value n_{max}. Other areas were marked by numerical value ($-n_{max}$), meaning «Nonself». Then the modeling results were interpreted. Those mammogram areas, for which modeling results were within the range from n_1 to n_2 were marked green and considered as problem-free. Those mammogram areas, for which modeling results'

values were within the range from n_2 to n_3 were marked yellow, from n_3 to n_4 – were marked orange, from n_4 to n_5 – were marked with light-red shades, changes in breast structure, indicating the pathology, were marked red (range from n_5 to n_6), the pathology itself (problem area) was marked blue (range from n_7 to n_{max}). The modeling result values n_1, n_2…, n_{max} were determined by expertise by a qualified breast specialist.
Fig. 2 shows the test results of model knowledge base. 20 images were tested and it was determined that the number of correctly classified areas reached 86,2%.

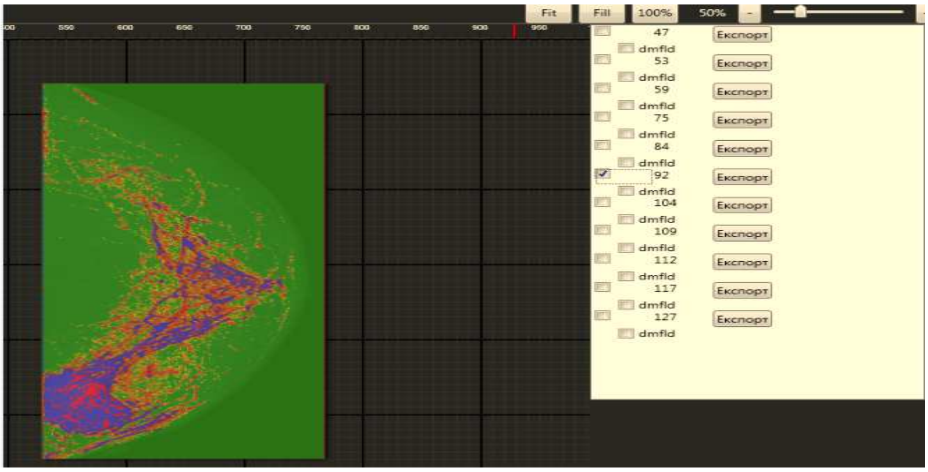

Figure 2 Mammogram areas classification results

2. Conclusions

The research resulted in testing the women's health monitoring information technology. The models were tested and the best of them were selected. In order to search the separating surface, the system of marking the sound and problem areas of mammography images was proposed. It was proved by experiments, that the percentage of correctly classified images reached 86,2 %.

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ANALIZA METODY DRZEW DECYZYJNYCH

Streszczenie: Data Mining – tzw. eksploracja danych – to proces odkrywania w surowych, nieznanych wcześniej danych niebanalnej i praktycznie użytecznej wiedzy niezbędnej do podejmowania decyzji w różnych dziedzinach działalności człowieka. Data Mining jest jednym z etapów odkrywania wiedzy w bazach danych. Informacje znalezione przy stosowaniu technik Data Mining, muszą być nietrywialne i wcześniej nieznane, na przykład, średnia sprzedaż nie są niczym nadzwyczajnym.

Słowa kluczowe: drzewo decyzyjne, data mining, losowe drzewa, algorytm

ANALYSIS OF DECISION TREES METHODS

Summary: Data Mining - is the process of discovery in the raw data previously unknown non-trivial and practically useful interpretations of the available knowledge necessary for decision-making in the various spheres of human activity. Data Mining is one of the steps of Knowledge Discovery in Databases. The information found in the application of Data Mining techniques, must be non-trivial and previously unknown, for example, the average sales are not.

Keywords: decision tree, data mining, random tree, algorithm

1. Introduction

One of the commonly used automated data analysis methods are decision trees. The first idea of creating decision trees go back to work Hovlenda (Hoveland) and Hunt (Hunt) end of the 50-ies of XX century [1]. However, the underlying work, which gave impetus to the development of this direction, was the book Hunt (Hunt, E.B.), Marin (Marin J.) and Stone (Stone, P.J) "Experiments in Induction" saw the light in 1966 [1].

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Decision trees - this is a way of representing rules in a hierarchical, coherent structure, where each object corresponds to a single node, giving the decision [1]. Under the rule refers to a logical structure, presented in the form of "if ... then ...". Fig.1 shows an example of a decision tree for the problem of issuance of bank loans [1].

Figure 1. Sample decision tree for the problem of issuance of bank loans

Scope of decision trees is now wide, but the problems solved by this machine can be combined into the following three classes:

- Data Description: Decision trees allow you to store information about the data in a compact form, instead you can store a decision tree that contains an exact description of the objects.
- Classification: Decision Trees excellent job with classification tasks, ie assigning objects to one of the previously known classes. The target variable must be discrete values.
- Regression: If the target variable is continuous values, decision trees allow us to establish the dependence of the target variable of independent (input) variables. For example, this class contains numerical forecasting tasks (prediction target variable values) [3].

Decision trees are a wonderful tool for decision support systems, data mining (data mining). The structure of many packages for data mining methods have included the construction of decision trees. In areas where the cost of failure is high, they will serve as an excellent tool analyst or supervisor [7].
Decision trees have been successfully used to solve practical problems in the following areas:

- Banking. Assessment of the creditworthiness of the bank's clients for loans;

The advantages of the use of decision trees are:

- quick learning process;
- Removing rules in natural language;
- intuitive classification model;

- high prediction accuracy, comparable with other methods (statistics, neural networks);
- construction of non-parametric models.

1.1. The formulation of the purpose of Article

The aim of the article is to study the decision tree algorithm and the choice of building a decision tree to solve the problem of regression.

1.2. Basic material

An algorithm for constructing a decision tree
The idea of building a decision tree from a variety of T, for the first time expressed Hunt, here on Kuinlenu R. (R. Quinlan) [3]. Let there be given a training set T, containing objects (examples), each of which is characterized by m attributes, one of which points to an object belonging to a class.
Let by {C1, C2, ... Ck} are designated classes (value class label), then there are three situations [4]:

6. The set T contains one or more examples of the same class Ck (then a decision tree for T - is a sheet that defines class Ck);
7. The set T does not contain a single example, that empty set (if this sheet again, and a class associated with a sheet selected from another set of distinct T, say, from the set associated with a parent);
8. The set T contains examples belonging to different classes.

In the latter case it is necessary to split the set T to some subset. For this purpose one of the symptoms is selected, having two or more distinct values O1, O2, ... On. T is partitioned into subsets T1, T2, ... Tn, where each subset contains all examples Ti having Oi value for the selected characteristic [5]. This procedure will continue until recursively until the final set will consist of the examples pertaining to the same class.
The above procedure is the basis of many modern algorithms for constructing decision trees, this method is still known under the name of separation and capture (divide and conquer). Obviously, when using this technique, the construction of the decision tree will be upside down. Since all objects have been pre-assigned to certain classes nam, the process of building a decision tree called learning with the teacher (supervised learning) [6]. The learning process is also called inductive learning or induction of trees (tree induction).
Today there are a significant number of algorithms that implement decision trees: CART, C4.5, NewId, ITrule, CHAID, CN2, etc. [6]. But the most widely popular and received the following two:

- CART (Classification and Regression Tree) - is an algorithm for constructing a binary decision tree - dichotomous classification model. Each node of the tree in the division has only two children. As the name of the algorithm, it solves the problems of classification and regression.
- C4.5 - algorithm for constructing a decision tree in which it is assumed that the number of children of a node is not limited. C4.5 algorithm can not work with a continuous target field and, therefore, only solves the problem of classification.

Most of the known algorithms are "greedy algorithms". If once the attribute has been selected, and splitting into subsets was made on it, the algorithm can not go back and select another attribute, which would give a better partition. Thus, if in step construction will not be selected attribute say eventually optimal partition.

When building a decision tree focuses on the following issues: the selection criteria attribute for which will partition, stop training and the cut-off branches.

To build the tree on each internal node is necessary to find such a condition (check), which divides the set would be associated with this node in the subset. As such a checking one of the attributes to be selected [6]. The general rule for selecting an attribute can be summarized as follows: The selected attribute should partition the set so that the result obtained in the subset composed of objects belonging to the same class, or were as close as possible to it, ie, the number of objects of other classes ("impurities") in each of these sets as small as possible.

C4.5 algorithm (an upgraded version of ID3 algorithm, Iterative Dichotomize) using information-theoretic approach. To select the most appropriate attribute, the following information-theoretic criteria:

$$Gain(X)=Info(T)-Infox(T), \tag{1}$$

Where: $Info(T)$ – a plurality of entropy T, and

$$Infox(T)=\sum i=1n|Ti||T|*Info(Ti), \tag{2}$$

The sets T1, T2, ... Tn obtained by the original partition of T on X. Select this check attribute that gives the maximum value for the criterion (1). For the first time the measure was proposed by R. Kuinlenom developed them in the ID3 algorithm [6]. Apart from the above algorithm C4.5, there is a class of algorithms that use this attribute selection criteria.

CART algorithm uses statistical test (the so-called index of Gini, named after the Italian economist Corrado Gini), which evaluates the "distance" between the distributions of the classes.

$$Gini(c)=1-\sum jp2j, \tag{3}$$

where c - the current node, and pj - the probability of class j at node c.

In addition to the basic method of decision trees the following rules have been proposed:

- The use of statistical methods to assess the feasibility of further decomposition, the so-called "early stop" (prepruning). Ultimately "early stop" building process is attractive in terms of cost of training time, but it is appropriate to make one important caveat: this approach builds less accurate classification models and therefore stop early is highly undesirable. A recognized authority in the field Breyman L. and R. Quinlan advised as follows: "Instead of stopping, use the cut-off."
- Limit the depth of the tree. To stop further construction if a partition leads to the tree with a depth greater than a predetermined value.
- The partition must be a non-trivial, ie, the resultant components must be at least a predetermined number of examples.

Very often the algorithms for constructing decision trees provide complex trees that are "filled with the data" have a lot of nodes and branches. Such "branching" trees are very difficult to understand. In addition, green tree, which has a lot of knots, splits the training set on a growing number of subsets, consisting of all the smaller number of objects [7]. It is much better to have a tree consisting of a small number of nodes, which would correspond to a large number of objects from the training set. The most obvious solution would be to build all possible trees, the corresponding training set, and one to choose a tree with the lowest depth. However, this problem is NP-complete, which was shown Hayfilem L. (L. Hyafill) and R. Rivest (R. Rivest). As is known, this class of problems is not effective methods to solve. To solve the above problem is often used so-called cut-off branches (pruning) [7]. Let a precision (recognition) of the decision tree is the ratio of correctly classified objects at training the total number of objects from the training set, and a mistake - the number of misclassified. Assuming that we know the tree error estimation method, branches and leaves. Then perhaps use the following simple rule:

- build a tree;
- subtree cut or replace those branches that do not lead to an increase in errors.

In contrast to the build process, cutting off branches going from the bottom up, moving from tree leaves, marking nodes as leaves or replacing them subtree [7]. Although pruning is not a panacea, but in most practical tasks gives good results, which is indicative of the lawfulness of the use of such techniques.

Let us consider in more detail the algorithms CART, Random forest and Stochastic Gradient Boosting.

CART (. English Classification and regression trees - Classification and Regression Trees) was the first method, invented in 1983 by four renowned scholars in the field of data analysis: Leo Breiman, Jerome Friedman, Richard Olshen and Stone. The essence of this algorithm is to construct a decision tree [8]. On the first iteration construct all possible (in a discrete sense) hyperplane that would divide space into two. For each such partition the space is considered to be the number of observations in each of the spaces of different classes. As a result, such a partition is selected that best allocated in one of the spaces of observation of one of the classes. Accordingly, this partition is the root of a decision tree, and the leaves on this iteration will have two partitions. In the next iteration takes one the worst (in the sense of the number of observations of different classes) sheet and carried out the same operation on his partition. As a result, the sheet becomes a node with some decomposition, and two sheets of [8]. The process continues until you have reached the limit on the number of nodes, or from one iteration common mistake fails to improve to the other (the number of misclassified cases over the tree). However, the resulting tree is "retrained" (to be tailored to the training set) and, accordingly, will not give results in other normal data. In order to avoid "re-education", using the test sample (or cross-validation) and inverse analysis is carried out, respectively, (the so-called pruning), when the tree is reduced depending on the result on the test sample. [8]

CART - a relatively simple algorithm, which is obtained as a result of one decision tree. The CART algorithm, each node of the tree of decisions has two children. At each step of the construction of the tree usually formed in a node divides a given set of examples (the training set) into two parts - the part in which the following rule (child - right) and a portion in which a rule is not met (child - left). To select the optimal rules are used as the evaluation function of the partition. Due to this, it is convenient for the primary data analysis, for example, that would check for the existence of links between the variables [8]. The advantages of this algorithm are:

- rapid construction of the model;
- easily interpretable (because of the simplicity model, you can easily display the tree and follow all the tree nodes).

The disadvantage CART algorithm is that it often converges to a local decision (for example, the first step has been selected hyperplane which divides the space as much as possible in this step, but it will not lead to the optimal solution). [8]

The method devised after CART Leo Breiman in collaboration with Adele Cutler - Random forest (Random Forest), which is based on the use of the committee (ensemble) decision tree [8]. The essence of the algorithm is that at each iteration variable is a random sample, and then, this new start sample decision tree construction. This is done "bagging" - random sample of two-thirds of the observations for the training, and the remaining third is used to evaluate the results. This operation is doing a hundreds or thousands of time [8]. The resulting model will be the result of "voting" a set obtained in the simulation tree.

Advantages of the method Random forest:

1. High quality results, especially for data with a large number of variables and the small number of observations.
2. The possibility of using parallel processing.
3. Do not test the sample is required.
4. The disadvantages of this method are:
5. Each of the huge trees, resulting in a huge model is obtained.
6. For a long construction of the model, to achieve good results.
7. The complex interpretation models (hundreds or thousands of large trees are difficult to interpret).

Analysis of the literature showed that currently there was a contradiction between the rapidly increased the amount of data that must be analyzed and opportunities for their handling experts. With this in recent years, much attention is paid to developing methods for the automatic study (analysis) of data. One of the widely used automatic data analysis methods are decision trees. Analysis of the basic algorithms for constructing decision tree C4.5, CART, Random forest and Stochastic Gradient Boosting allowed the authors to identify their strengths and weaknesses and identify ways of further research.

Is currently under development and research of new mathematical apparatus structures semantic-numerical specification (ESS), which is a means of formal specification of static and transient objects of synthesis and analysis of parallel computer systems: the original problems / algorithms, parallel temporal process models, serial, parallel programs, parallel hardware, complex information processing and control systems and their complex algorithms and models of their time on the functioning of the different levels of detail. The authors conducted the study of the possibility of applying the mathematical apparatus for construction of decision trees.

ESS algebra unit contains the following functional parts:

- static and temporal semantic-numerical semantic structure arrays, numeric, static, temporal and spatial characteristics of the object specifiable synthesis / analysis ("basic carrier set of the M, the foundation");
- set of operations that provide static, temporal and spatial transformation of semantic-numerical structures and objects they represent the synthesis and analysis of parallel hardware and software and parallel computing systems as a whole ("signature");
- «generative procedure", which provides a formal synthesis of semantic-numerical structures on C source code programs.

Consider the composition, function and design of static and temporal semantic-numerical structures ESS unit ("main bearing set of M»).

The basic structure of the composition of BF operators and the base structure CF telecom operators provide (for a variety of specifications of the objects listed above), the formal description of the composition, types of components and their relations scheme.

The basic structure of the operators BF ESS unit has the following organization:

BF = (J, MET, TYP, NSJ, SJD, BJ, NWJ, WJD, MP1, MP2, VH, VIH, RES).

We explain the different semantics of arrays in the case C-ESS software specifications:

- J- array indices j operators Pj (data and transactions considered by operators and are numbered successively from j = 0 to j = n - 1; n - the number of operators);
- MET- operators array of labels (label comprises asked in a C program text and tags are automatically entered into the process of synthesis of structures ESS);
- TYR- array types ESS format statements in C programs;
- NSJ- nsj array of pointers (j) the number of i-th row structure of CF bonds, which begins the chain of conjugated Pi Pj operators for the operator;
- SJD- array sjd values (j) capacity conjugate sets Sj operators Pi to Pj operators;
- BJ- array of numbers of natural pieces (fragments) a C program, bj element value (j) specifies the number of the natural, to which belongs the operator Pj;
- NWJ- array of pointers nwj (j) the number of i-th row structure of CF bonds, which begins the chain of external operators Pi to Pj operator;
- WJD- array wjd values (j) capacity external sets Wj operators Pi to Pj operator;
- MP1- array of labels operator unconditional transfer and conditional branch by value "true" C-program ("0" means no labels);
- MP2- array tags operators conditional branch by value "false" C-program ("0" means no labels);
- VH- array whose elements vh (j) Pj operator specify the number of inputs (it is assumed that the operators Pj for interpreting the raw data inputs names (a_in, b_in, ...), the variables (a, b, c, ...) vh (j) = 0; vih (j) = 1, value vh (j) for the operators - operations / functions equals the number of operands corresponding operation, the operator has a stop vh (stop)> = 1);

- VIH- array whose elements vih (j) Pj operator specify the number of outputs (it is assumed that the operators Pj for interpreting output names (x_out, y_out) vih (j) = 1; stop vih operator has no output (j) = 0) ;
- RES- array containing the names of the input data (eg, a_in, b_in), the names of the original variables, constants, symbols of the C language operations, the names of the intermediate and final results of the solution of the problem, output names (for example, x_out, y_out), as well as the name of the operator stop .

The basic structure of CF telecommunications operator has the following organization:

CF = (K, JSD, SPJD, SWIH, SWHO, JWD, WPJD, WWHO, WWIH).

In the case of C-ESS program specification array structure CF telecom operators have the following semantics:

- K- array numbers k rows structure CF links;
- JSD- array of pointers jsd (k) on the set of numbers Pi adjoint operators for the operator Pj, starting with jsd pointer (k) = nsj (j) row with k = nsj number (j) and ending SPJD array k-th row of the array JSD, having jsd (k) = -1 (where each index jsd (k) ▪ -1 indicates an element SPJD array that specifies the number of the next Pi operator conjugate to Pj);
- SPJD- array specifying for each operator Pj (j = 0, 1, 2, ..., n-1) its conjugate set Sj (ie number of operators i Pi, the outputs of which are inputs to Pj), pointers to the elements of the set Sj are the values of the corresponding elements of the chain of pointers jsd (k) array JSD, beginning with the k-th row with the index jsd (k) = nsj (j) of the array structure NSJ BF);
- SWIH- array specifying for each pair Pi operators Pj (regarded respectively as an adjoint operators and external) and communication connection from the data connection management, and / or communication of news (or some combination of these types of relationships), the output number of the adjoint operator Pi, appropriate consideration, "conjugate connection";
- SWHO- array that specifies the operators for each pair Pi, Pj (regarded respectively as an adjoint operators and external) communication connection for data communication management and / or communication of news (or some combination of these types of connections), the entry number of the external operator Pi, appropriate consideration, "conjugate connection";
- JWD- array of pointers jwd (k) on the set of numbers of foreign operators for the operator Pj Pi, beginning with the k-th row with the index jwd (k) = nwj (j) and ending WPJD array k-th row of the array JWD, having jwd (k) = -1 (where each index jwd (k) ▪ -1 indicates an element WPJD array that specifies the number of the next Pi Pj external to the operator;
- WPJD- array specifying for each operator Pj (j = 0, 1, 2, ..., n - 1) its external set Wj (ie operators of Pi number i, for which the inputs are the outputs of the operator Pj), pointers to the elements sets Wj are the values of the corresponding elements of the chain of pointers jwd (k) array JWD, beginning with the line number k = nwj (j), (nwj (j) - pointer of array structures nWJ BF);
- WNHO- array specifying for each pair Pi operators Pj (regarded respectively as an external and adjoint operators), communication connection for data

communication management and / or communication of news (or some combination of these types of connections), the entry number of the external operator Pi, considered appropriate "external communication";

- WWIH- array specifying for each pair Pi operators Pj (regarded respectively as an external and adjoint operators), communication connection for data communication management and / or communication of news (or some combination of these types of relationships), the output number of the adjoint operator Pj, considered appropriate "external communication".

Signature algebra structures ESS defines the set of "base of operations" transformation ESS structures as a basis for solving the problems of the formal synthesis and analysis of hardware and software facilities of parallel Sun submitted the relevant structures of the space-time algebra of discrete mathematics.

As shown previously, the main structural elements ESS structures are the "semantic-numerical elements': their particular type and structure completely determines the functionality and structure of the ESS. Therefore, as a basic or "core" operations transformation ESS structures useful to define the operation of the "elements", the totality of these operations is the signature of the algebra ESS structures.

"Basic" operations on ESS structures have as operands the individual (viewed as indivisible) and the numerical semantic "elements» Fd () (Field, Fd) of various structures ESS, (nsr), = 0,1, ... -1. The main parameters of semantic - numeric number of elements are specific ESS structures considered structure ESS line number, item number in a particular row of the selected structure, semantics, and the numerical value of the element.

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MONITOROWANIE AKTYWNOŚCI BAZY DANYCH

Streszczenie: Studium zakładało trzy podstawowe sposoby monitoringu funkcjonowania bazy danych. Dzięki zastosowaniu analizy porównawczej podstawowych kryteriów, wybrane zostało optymalne rozwiązanie.

Słowa kluczowe: monitorowania, bazy danych, wyciek danych,sieci, monitoring, audyt baz danych, incydent

MONITORING OF DATABASE ACTIVITY

Summary: The study examined three basic ways of monitoring the database activity. Through a comparative analysis on the basis of criteria was chosen the most optimal solution.

Keywords: monitoring, database, data leakage,network monitoring, auditing databases incident

1. Introduction

Currently, for business to be more profitable it is necessaryy to protect all resources and company's assets from internal and external threats. The most critical asset is information-if it lost, results will be like reducing the company's reputation, harming profits and hindered business continuity.
The situation shows that for hacking and penetration in the system minutes and days are enough, but the response to the incident often takes weeks and even months [1]. Therefore, in any business environment is the urgent task of the operational monitoring database activity the solution of which is, unfortunately, not enough attention .
Currently, there are three methods of monitoring database activity[2]:
• own audit;
• audit through the centralized agent;
• network monitoring.

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2. Own audit

It is an audit without installing any additional software. However, the use of own auditing decreases the productivity of the database.
The use of own audit increases the cost of information storage, and this increase may be significant because the audit process produces substantial quantities of logs. If organization have requirements for data retention, the presence of logs will increase the cost of backup storage because of their large size.
There are additional problems with the logs of the own audit, when due to the fall in the productivity own audit becomes unsuitable for use. The fact that in large-scale use and control own audit is very problematic. Finally, logs of their own audit does not provide much useful information, like logs of network monitoring. Consequently, tracking the relationship between the database and the rest of the infrastructure is very time-consuming. If the logs show that the network committed the attack, it is difficult to track the response, and the content of the query logs of the own audit. During the investigation of the incident, information about the response to the request may help to determine the extent of the hacking and the liabilities of the company for the consequences of hacking.
If the company can prove the breach of confidentiality only of a certain number of records, it will be able to assess more accurately the financial damage from the attack. If users access the database via a service account, the log would not reflect specific user, only that act was done under a service account. Mapping a database connection with the user only through the own audit logs is not possible. Due to the productivity deterioration and other problems mentioned above, before using a private audit companies should weigh the pros and cons.

3. Audit through the centralized agent

Agents are programs installed on the database server and run in a privileged mode as a service or daemon (depending on platform). Agents usually have hooks inside the kernel that allows them to intercept the SQL traffic and forward it to the monitoring program. Since agents work on the database server, they can record all actions with the database, including users that are connected directly to the server.
Centralized agents can track all processes in the database because they are memory-resident programs running on the server. At first glance, it seems that centralized agents are the ideal solution, however, they have some drawbacks. Since these agents run in privileged mode and directly interact with the kernel, due to the possible presence of the agents of vulnerabilities there is an additional risk to the server. Centralized agents can close the joint with a malicious nature, functioning as a centralized intrusion prevention system for databases. The main problem is that agents require continuous prophylaxis. Because agents tied to the kernel and the version of the database, changing database version or operating system may require upgrading the agent. If infrastructure database is large – it can take a long time to update the agents on each server. If the server or database problems occur, the database agents will be the first suspects.
Currently, there are many solutions and tools of centralized monitoring of databases, which have special databases agents. So to fulfill the basic purpose of monitoring the

DBMS ,company can use a number of *Oracle tools*. The most obvious way of monitoring Oracle database-using SQL queries[4].
Technology *IBM* monitoring database *Database Activity Monitoring* (DAM) helps to prevent external attacks, such as the introduction of malicious SQL code (SQL Injection), and provides a comprehensive multi-layered protection through the use of proactive security policies that are controlled in real time[5].
The solution *InfoWatch Traffic Monitor* has technologies that protect the database and prevent data leakage using the technology "Detector of extracts from the database"[6]. «Detector of extracts from the database " allows detecting a reference extracted from the databases in the network traffic and text documents. Technology makes possible to respond quickly to the transmission of information copied from the database to identify the offender, to prevent the release of the data outside the organization and use of digital evidence at the incident, if necessary, investigate or prosecute.
"Garda" DB from the company MFI Soft - hardware and software complex class DAM (Database Activity Monitoring - audit network access to databases), which detects possible information leakage and improves the reliability of protection of databases. The system monitors requests to the database in real time and identify [7].
Dell ChangeAuditor for Active Directory real-time and without the expense of a private audit, operational monitors and checks important configuration changes and generates reports and notifications. You receive the ability to know who, where, when and at which workstation made any changes. You can compare original and current values for Troubleshooting problems. The decision ChangeAuditor for AD performs the intelligent detailed analysis for auditors and managers and reduces the risks associated with daily modifications [8].

4. Network audit

Network monitoring monitors the network for problems caused by overloaded and/or servers, other devices or network connections. This decision allows corporations to improve the analysis of database traffic without creating additional load on the server. For network monitoring it is necessary to use special equipment or feature SPAN (Switched Port Analyzer) on the switch. SPAN mirrors all traffic on a specific port, which then can be analyzed. For network monitoring you can also use a special device (for example, from the company Gigamon) that allow to aggregate, switch, replicate, and filter traffic. In addition, the traffic monitor allows you to find new (or maliciously) connect to database that gives better integration with corporate change management and security policies.
As network monitoring tools, it should be noted the decision of the company *Gigamon*. Company Gigamon Networks is one of the leading manufacturers of data access (Data Access Network). The company's solutions provide service IB complete vision of traffic in any segment of the network, effectively performing the role of a bridge between the network and all media monitoring, analytics and protection. This solution eases the connection of any means of protection, monitoring and Analytics lowers the impact on network performance, minimizing the performance degradation. In addition, Gigamon solution can significantly reduce capital and operating costs to support the network[9].

5. Conclusion

In conclusion ,it was conducted the comparative analyses of the types of monitoring by their possibilities to implement the basic requirements : monitoring inconsistent add and modify user accounts, control of the multiple failed attempts to access the database, tracking user activity, detection of fraudulent connections, detecting known types of attacks, saving time and improving the efficiency of DBMS. The analysis showed that among three considered methods of monitoring database activity a number of advantages has network monitoring, which is the most beneficial and effective solution .

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ANALIZA WPŁYWU CYBERATAKÓW NA BEZPIECZEŃSTWA ZASOBÓW INFORMACJACH TYPU WIDEO

Streszczenie: W artykule przeprowadzono analizę aktualnych zagrożeń systemów informatycznych i telekomunikacyjnych. Podkreślono pilną potrzebę ochrony informacji w wideo-zasobach. Ponadto, opisano przejawy najważniejszych rodzajów ataków, w tym np."Distributed Denial of Service" (DDoS). W artykule przedstawiono podstawowe wymagania dotyczące technologii kodowania, które zapewniają odpowiednią ochronę.

Słowa kluczowe: informacje o bezpieczeństwie, dystrybuowane ataki takie jak "odmowa usługi", kodowanie wideo, wideo informacje zasobów

THE ANALYSIS OF IMPACT OF CYBER ATTACKS ON THE SECURITY VIDEO INFORMATION RESOURCE

Summary: The analysis of current threats of information and telecommunication systems. The urgency of the protection of video information resource. The manifestation of the most important types of attacks "Distributed Denial of Service" was describe. In the article the basic requirements for the encoding technologies that offer adequate protection.

Keywords: information security, distributed attack such as "denial of service", video encoding, video information resource

1. Introduction

Prompt development of information technology has led to wide spread of multimedia data on information and telecommunications networks. The use of multimedia data can increase the quality of perception of the information, as a person gets the most attention of the visual information. Currently, the transfer of multimedia files in a single direction are used in video monitoring systems, and bidirectional transmission

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is used in videoconferencing systems in the interests of departmental organizations and the relevant ministries. At the moment these systems are widely used in government departmental structures to improve the quality control on relevant activities. Practice shows that in normal conditions, especially in crisis situations, increased threat of cyber attacks by hackers. At the same time, issues relating to research the relevance and significance of the impact of various cyber attacks on characteristics of the integrity t and the efficiency of video information resource of the telecommunications system, received a limited review.
Therefore it is necessary to consider the impact of cyber attacks on the video information resource based on existing mechanisms functioning of telecommunication system.
The goal of the paper was suggest ways of encoding methods to ensure the required protection of information security.

2. The description video processing and delivery of video information resource in a telecommunication system.

The processing and delivery of video data in a telecommunication system consists of the following stages (Fig. 1).

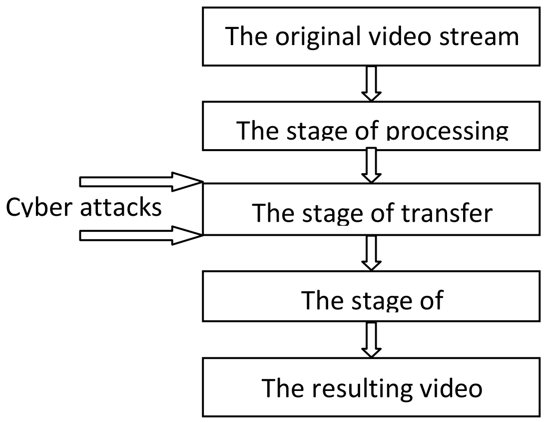

Figure 1. The processing and delivery of video data in a telecommunications system

Let us describe each stage of the process.

1. *The stage of processing*. At this stage, the image prepare for transmission in a telecommunications system to provide the required quality at the receiving end.
2. *The stage of transfer*. At this stage, the transfer of the video stream from the source to the consumer uses of telecommunication technologies.
3. *The stage of reconstruction*. At this stage there is decoding of information and the image output to the consumer.

To assess the quality of video playback when decoding significant are the following parameters:

- T_{pd} – packet delay;

- δ – packet jitter;
- ν_{lp} – the number of lost packets.

According to the recommendations of the International Telecommunication Union (ITU) [1] for system of video communication package delay should be less than $T_{pd} \le 150\ m\sec$, for the video stream package delay should be less than $T_{pd} \le 10\ m\sec$, packet jitter should be less than $\delta \le 80 m\sec$, the number of lost packets should be less than $\nu_{lp} \le 1\%$.

These parameters depend on the dynamic characteristics of the environment data and the operator information and telecommunication systems, and even under normal conditions (in the absence of any interference in the work from outside the system) operation of telecommunication devices possible loss of video information resource. For example, the probability of loss of information bits in the transmission under normal conditions in wireline systems is approximately 10^{-8} and is approximately 10^{-3} for wireless systems [2].

Now look at how to change the parameters of evaluating the quality of video playback in the case of cyber attacks.

3. The description the impact of DDoS attacks on information and telecommunications system

The attackers may affect in the information-telecommunication system. The objective of cyber malicious attack is breach of information security properties of both the integrity and availability of video information resource.

During 2014 CERT-UA were adopted measures to 216 computer incidents [3]. Statistics on the types of threats and the emergence of sectors shown in the tables №1 – 2. Note that the data are presented in relation to the incidents about which the CERT-UA was duly reported.

Table 1. Correlation of threats

Types of threats	Number	Share %
DDoS	51	24
Unauthorized access	39	18
Fishing	30	14
Malware	25	12
Advanced Persistent Threat (APT)	25	12
Others	46	21
Total	216	100

Table 2. Distribution of threats by sector

Types of threats	Affiliation				
	UAGOV	UACOM	FGOV	FCOM	UACTZ
DDoS	43	2	3	3	0
Unauthorized access	33	3	3	0	0
Fishing	0	6	1	23	0
Malware	7	10	0	1	7
Advanced Persistent Threat (APT)	21	3	1	0	0
Botnets	5	6	2	2	1
Vulnerability	13	1	1	0	2
Fraud	2	6	0	0	0
Information leak	0	3	0	0	0
Others	0	2	0	0	0
Total	124	42	11	29	10

As can be seen from the above table, the most common types of cyber attacks (43 for the Ukrainian state sector, 2 for Ukrainian commercial sector, 3 for the foreign state sector, 3 for the foreign business sector) are the type of attack DDoS-attack. This is due, primarily, to ease the implementation of this type of attack.

At the moment there are many different types of attacks on the failure, each of which uses a specific feature of the construction of a network or software vulnerability.

These attacks can be carried out by direct transfer of a large number of packets (UDP, ICMP flood), the use of attacks on intermediate nodes (Smurf, Fraggle), too long transmission packet (Ping of Death), malformed packets (Land) or a large number of labor-intensive queries [4]. Note that in recent times is the development of this activity and the appearance of new types and methods of attack. From the latest trendscan note the appearance of Quality Reduction Attack and Low Rated Attack and, of course, this process will continue, requiring new research and development of new methods of counteraction.

The depletion of network resources is sending a large number of packets in the victim's network. They reduce its capacity to legitimate users. Depletion of resources node is sending time-consuming or incorrect queries to the victim.

Enough effective form of reflection attack is the use Domain Name System (DNS) servers. A schematic this attack is shown in Fig. 2.

These servers need to store and at the request of different records (Resource records (RR)) with the names of Internet domains. The most important function of DNS servers is translation of domain names into IP addresses. Dimensions request and response may differ materially. Usually, the response contains the original request and the response. This means that the answer is always more request. Moreover, the response can comprise various types of RR data and some of them may have a significant amount. Theoretically, the initial traffic capacity of 140 Mb/s with a botnet may result in DNS responses flow capacity of 10 Gb/s.

As apparent from the above that the existing model of processing and delivery of video information resource telecommunication device will handle the large flow of information. With the existing mechanisms of its work takes place packet delay with the possibility of dropping. The main result of DDoS-attacks on the telecommunications device is to change the time of passage and the total number of data packets for video information resource.

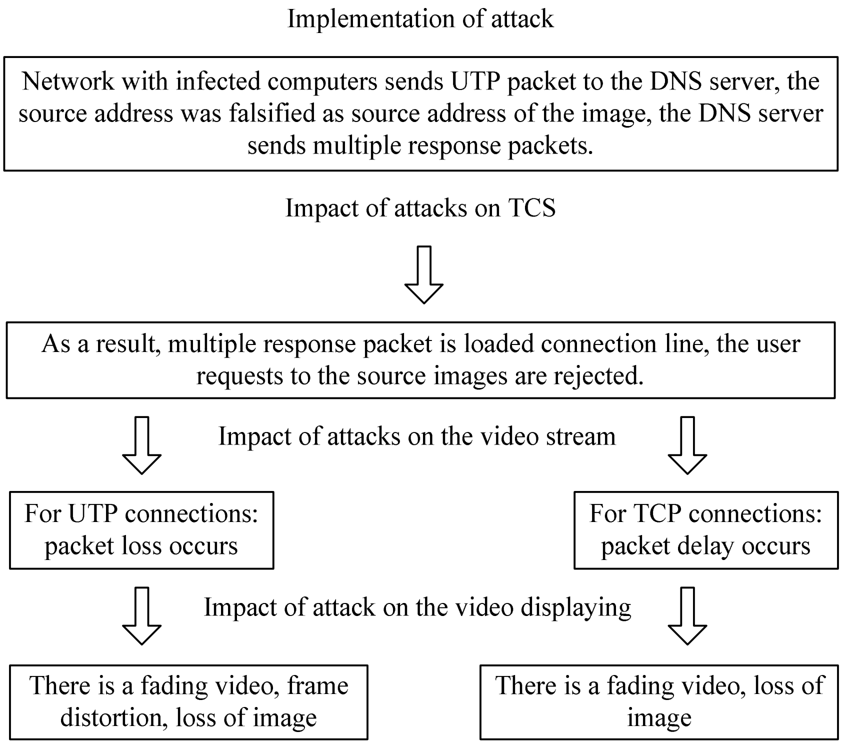

Figure 2. Effect of the type of attack "DNS Amplification Attacks" to transfer video information resource in the information and telecommunications system

To prevent the occurrence of attacks such as DDoS-attack can be used detection systems and intrusion prevention, managed switches with ACLs and backup communication lines between different nodes [5].

The disadvantages of these methods are introduced through the packet processing delays, and as a result of the restriction signal transmission rate in the network, increased the cost of equipment and subscriptions to the signature, these methods do not protect against camouflaged virus attacks. Existing methods of processing video information resources involve the use of correlation between image frames. Therefore, the distortion of keyframes leads to violation the information security of video information resource.

It follows that it is necessary to develop a new method of localization effects attacks that allows source encoding step provides the necessary degree of compliance information received class of service parameters in the initial stages of application DDoS attacks when possible packet delay with the possibility of dropping.

4. Conclusions

- The analysis of the impact of cyber attacks on security video information resource in the telecommunications system. Develop approaches to the creation of a new method of localization of the attacks, which take into account the stage of source encoding and provides the necessary degree of compliance received information to indicators of the class of service.
- It is proved that the DDoS attacks affect transmission in the information and telecommunications system. This leads to a loss of integrity and availability of video information resource.
- According to ITU recommendations [1] for system of video communication package delay should be less than $T_{pd} \le 150 \text{ m sec}$, for the video stream package delay should be less than $T_{pd} \le 10 \text{ m sec}$, packet jitter should be less than $\delta \le 80 \text{msec}$, the number of lost packets should be less than $\nu_{lp} \le 1\%$.
- It is shown that the existing counter DDoS attacks technology do not provide their full localization and prevention (ie they work with delay, after the recognition of the fact of the use of attack). It is also not without significance that in the case of existing systems to counter cyber attacks DDoS attacks cut off the incoming data stream, which is why there is a loss of "useful" information, ie deteriorating security features such video information resource as integrity and availability.

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WIZUALIZACJA WYBRANYCH OPERACJI GRAFOWYCH

Streszczenie: W pracy omówiono wizualizację prostych operacji grafowych. W tym celu napisano program komputerowy. W jego okienkach można wyświetlać wybrane grafy źródłowe oraz grafy wynikowe. Przykładowe operacje to suma, różnica, iloczyn kartezjański i inne.

Słowa kluczowe: rysowanie grafów, operacje grafowe, dydaktyka

VISUALIZATION OF CHOSEN GRAPH OPERATION

Summary: In the present paper, visualization of simple graph operations is discussed. A computer program was written for this purpose. In the windows of the program, the chosen source graphs as well as the resultant ones can be presented, The exemplary operations are as follows: sum, subtraction and Cartesian product of graphs and other.

Keywords: graph drawing, operation on graphs, didactics

1. Introduction

Graphs theory is a branch of mathematics having mutual and reciprocal connections to computer science and many other fields of knowledge. Graphs model various practical problems. Additionally, graphs with weights assigned to their edges are called network, where edges could be considered as directed i.e. arcs. Therefore graphs in the broad sense are models of communication networks - especially railway, road and Aeronautical Telecommunication Network (ATN) as well as many others. All other types of networks, such as: Grids or social networks are described using graphs to store them in computer resources and software. However, there is not any standard software for graphical presentation of graphs and the existing programs are difficult to adapt to the needs of the individual user. Moreover, they are very general (Matematica, Pajak). The aim of this work is to write a program for visualization

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of graphs - simplified, with a limited range of possibilities, used for teaching purposes, namely to perform and present selected graph operation.
Changing the graphical form of a graph, conversion of graphs, operations on graphs are the basic concepts of graph theory. These notions are the basics for the more advanced sub-disciplines of graph theory as e.g. graph transformations and graph grammars. Annually hosts international conferences in this field, eg .:

a) "The 8th International Conference on Graph Transformation (ICGT 2015)" in the city of L'Aquila in Italy in 2015,
b) "The 9th International Conference on Graph Transformation (ICGT 2016)", which will be held in Vienna in July 2016.

Grammar graph is another subdomain of graph theory, which is intensively developed in recent years, and which is used, for example in the automatic editing computer programs or analysis of the distribution of elements in the schemes of construction and architectural.
Discussed in this work operations on graphs are widely used in theoretical considerations and practical analysis of all types of networks, eg. Road, rail, power, media: gas, water, electricity and others. For example - the removal of edges in the graph representing the road network maps and situation when a certain section of the road is completely closed as a result of a road accident for a short time or much longer because of the damage to the bridge by the flood.
Therefore, understanding simple operations through their visualization will be facilitated through the use of a computer program, which was created as part of this work.

2. Selected graph operations

The aim of the work is to develop a computer program to draw certain types of graphs. In particular, the aim is to visualize the selected operations on graphs. Operations that can be performed on a single graph:

1) removal of the vertex,
2) addition of the vertex,
3) removal of the edge,
4) addition of the edge,
5) calculation of the complementary graph,
6) calculation of the edge graph.
7) calculation of the square of the graph.

In the case of operations on the two graphs, developed in the program shall be:

1) the simple sum of graphs,
2) the symmetrical difference of graphs,
3) cartesian product of graphs.

3. Basic notions related to graphs

The aim of the work is to develop a computer program to draw certain types of graphs. In work.

4. Program description

The Each utility allows a dialogue with the user. Fig. 3.1 shows the window of the program.

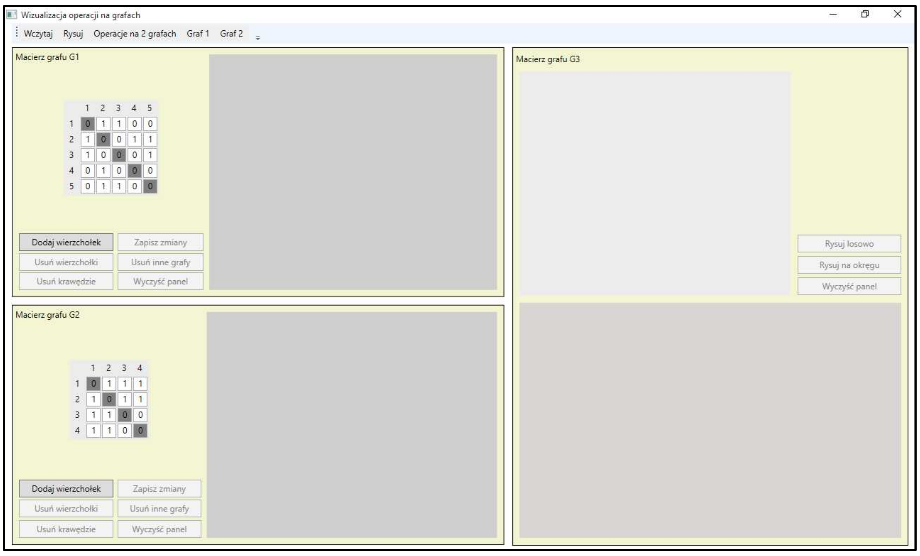

Figure 1. The interface of the program after starting

After starting the eyes of the user appears in the program window divided into three segments. Two of them (on the left) are used to present the arrays and graphs drawing, and the third segment (right part of the window) shows the matrix and graph drawing after the operation. The interface is scalable, ie. That when you change the window size segments decrease or increase in size to fill the entire window.

a) Loading neighborhood matrix

By default, when you start the program loaded are two examples of graphs from program memory. On panel graph G1 is loaded matrix graph with five vertices, and on panel graph G2 - with four vertices. However, you can load other matrices (Fig. 2).
It features a five graphs sample contained in the program memory, but it can also load the matrix from your own text file with a .txt extension. However, due to the objective of the program, and the fact that every graph can be modified (add or delete vertices and edges), it was assumed that the option of loading the matrix with your own file will be rarely used.

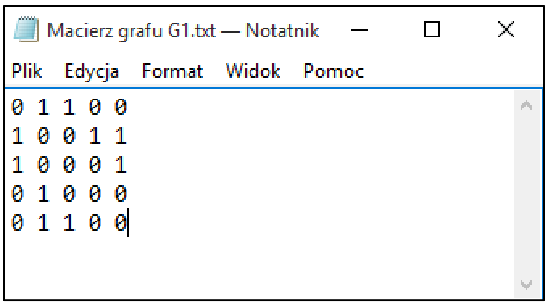

Figure 2. Sample text file with matrix

The correct text file format with the matrix shown in Fig. 3. The characters in all rows should be separated by spaces.

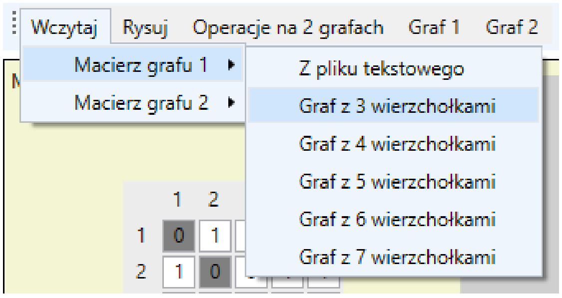

Figure 3. Menu of loading matrix

b) Draw a graph and deployment of vertices

The program lets you draw a graph on the gray panel in accordance with the loaded matrix.

You are offered two options distribution of vertices:

- **In random places**. Each time you select this option, are drawn new coordinates for each vertex.
- **On the circle**. The coordinates of the vertices are calculated, so that when you draw a circle formed. A sample graph drawn on the circle is shown in Fig. 4.

Whichever option you can move vertices using the mouse. To do this, press and hold down the right mouse button on any vertex, and then drag to a different location on the panel.

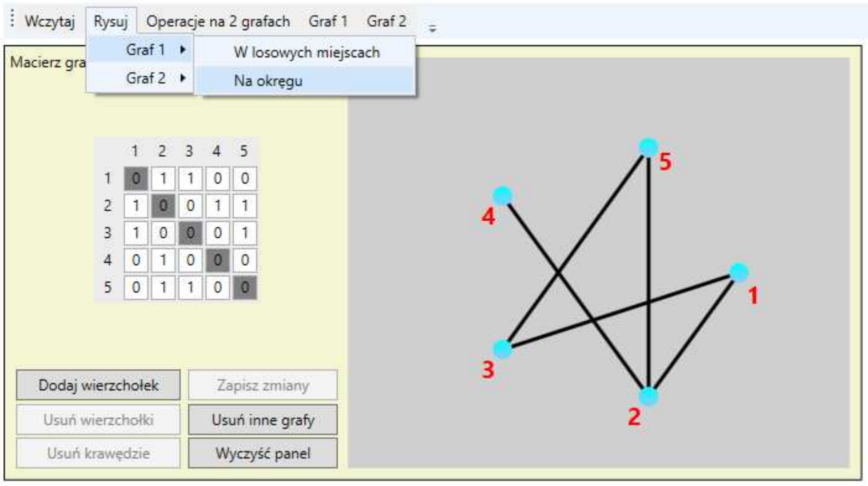

Figure 4. A sample graph drawn on the panel of the graph G1

Next to each vertex is the number. By default, when you draw a graph all of the numbers are arranged slightly below the vertices, but the user can freely move in the same way as vertices (holding down the right mouse button).

c) Selecting vertices and edges

Since the program is a teaching, an important issue should be transparency, and the possibility of present to the user elementary properties of graphs. One such feature is to select in Figure vertices and edges. An example of this function shows Fig. 5.

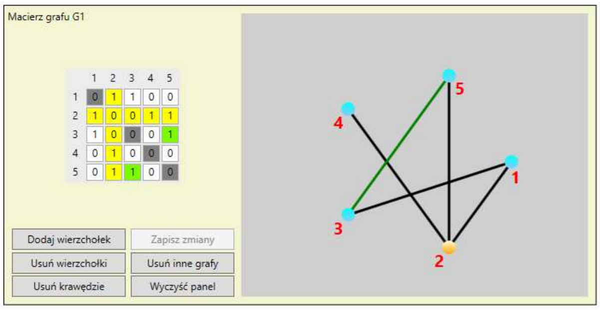

Figure 5. Graph with selected vertex and edge

When you click the left mouse button on the vertex, it changes color to orange-yellow, while the corresponding row and column of the matrix are highlighted in yellow. When you click the vertex again, colors back to the original. Analogous function have edges. When you click the left mouse button, the edge turns green, and the corresponding two fields in the matrix are highlighted in green. When you click again, the colors back to the original. The user can select any number of vertices and edges.

d) Deleting vertices

When you select any number of vertices you can perform surgery to remove by pressing the appropriate button in the segment containing the graph where you want to perform this operation. The matrix will be updated, the corresponding vertices and edges will be removed from the panel, and the other vertices will be renumbered. Fig. 6 shows an example of the matrix before and after surgery to remove vertices 1 and 4.

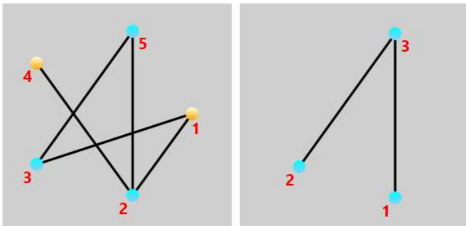

Figure 6. Drawing graph G1 before and after surgery to remove the vertices 1 and 4

Fig. 7 presents a drawing of the graph before and after the operation. A similar operation can be performed for the edge. Select any number of edges, and then press the corresponding button on the selected segment.

	1	2	3	4	5
1	0	1	1	0	0
2	1	0	0	1	1
3	1	0	0	0	1
4	0	1	0	0	0
5	0	1	1	0	0

	1	2	3
1	0	0	1
2	0	0	1
3	1	1	0

Figure 7. Matrix before and after surgery to remove the vertices 1 and 4

e) Complementary graph

One of the operations to a single graph that allows the program is to determine the graph complementary. When you select this option in the menu, drawing on graph source will be marked edges of the blue color (Fig. 9). However, in the third segment will be the newly formed matrix graph with the drawing (Fig. 8). Ultimately, the vertices will have the same coordinates as the vertices in source graph at the time of the operation, however, as in the case of graphs source, and so on, the user can move vertices using the mouse, and redraw them in random places, or on the circle.

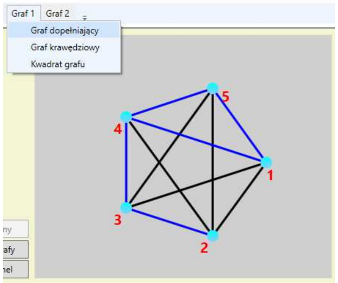

Figure 8. Drawing graph G1 with a graph superimposed complementary

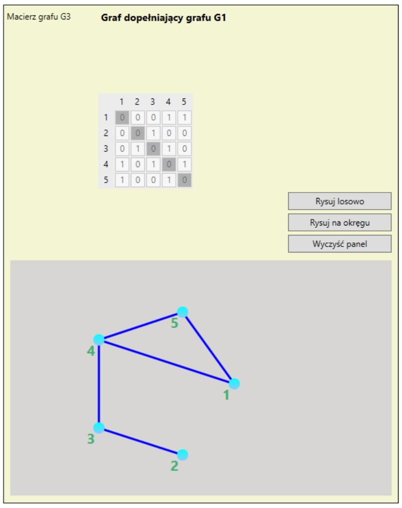

Figure 9. The third segment containing information about the operations carried out, complementary graph matrix, and its drawing

f) Line graph

Another of the available operations on a single graph is the determination of a graph edge. When you select this option from the menu, on the source graph will be plotted the line graph (Fig. 10). To distinguish the vertices will have the color dark red, and the edges - blue. Vertices will be located always in the middle of the edge of the graph of the source (even if you move the vertices of the source using the mouse). The bearing graph is not possible to select edges and vertices, or offset vertices. These functions are available in the third segment, where it is drawn line graph without the graph source.

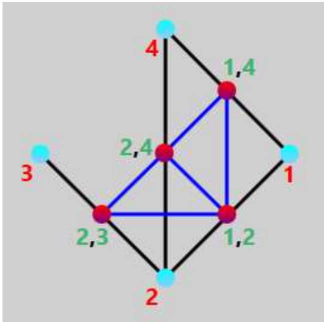

Figure 10. Drawing graph G1 with superimposed line graph

g) Square graph

The last of these operations carried out on one graph is the determination of the square of the graph. In this case, in contrast to the line graph and complementary graph, the resulting graph is not applied to the source, but drawn in the third segment. This is because all the edges of the graph of the source part of the square, so that in case of imposition, the edges overlap each other and the user would not be able to compare the graph before the operation to the resulting graph. Fig. 11 is an exemplary graph, and its square.

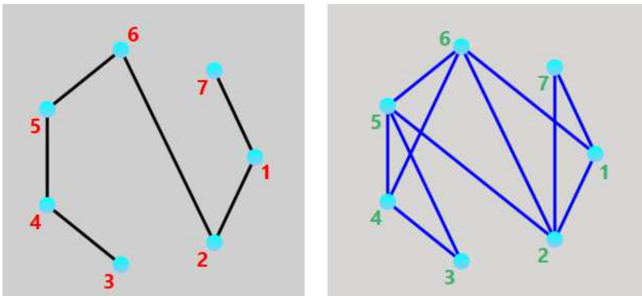

Figure 11. Drawing graph G1 and its square

h) The sum of graphs

In the case of operations carried out on the two graphs, both graphs must first draw. In addition, the operations of addition and subtraction of graphs, both must have the same number of vertices. In the event of failure to comply with these conditions the user will see an appropriate message shown in Fig. 12 and 13, and the operation is not performed.

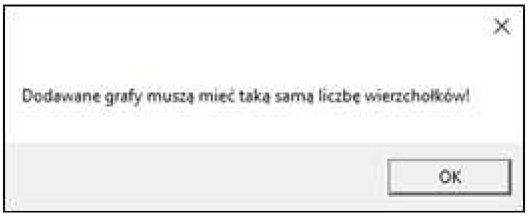

Figure 12. Message with an invalid number of vertices

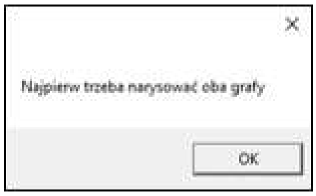

Figure 13. Message about need to draw the two graphs

After the summation graphs in the third segment appears matrix and drawing a graph with the edges of the three possible colors:

- black edges are those that are part of the graph G1, but they are not in the graph G2,
- brown are the ones that are part of the G2, but they are not in the G1,
- blue are those that are common to both graphs.

Fig. 14 shows all three segments after performing the summation of sample graphs.

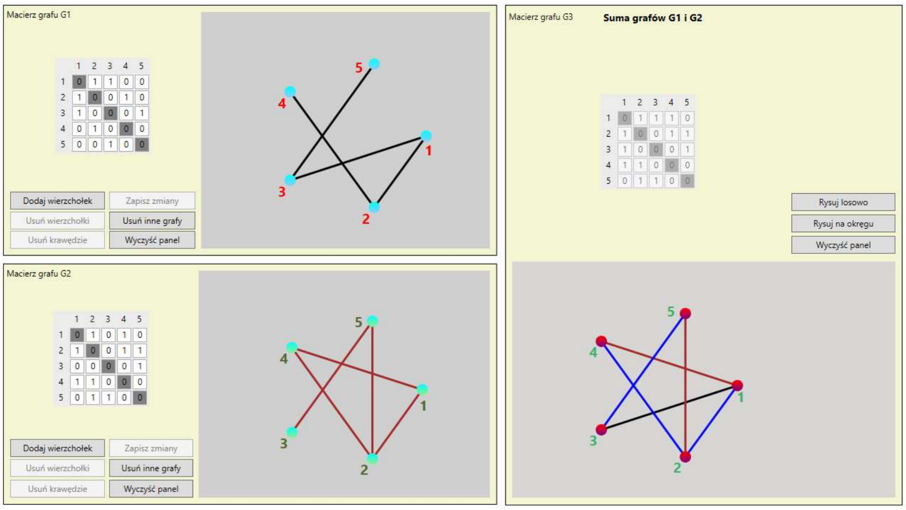

Figure 14. The program window after performing the summation graphs G1 and G2

i) The substraction of graphs

Similarly, to add operation runs the operation subtraction of graphs. Both graphs must be previously drawn and both must have the same number of vertices.
After the operation in the third segment will be released from the resulting graph edges:

- black - for subtraction G1 - G2.
- brown - for subtraction G2 - G1.

In special cases, the resulting graph can not have a single edge. Fig. 15 shows all three segments after the subtraction operation sample graphs.

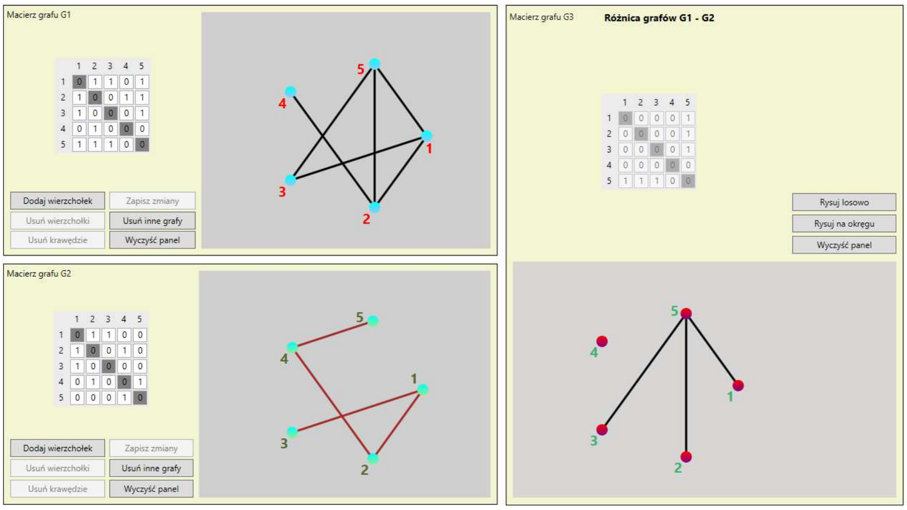

Figure 15. The program window after the subtraction of graphs G1 and G2

j) Cartesian product of graphs

One of the most complex operation that allows the program is designed to calculate the Cartesian product of two graphs. After selecting this option in the menu, in the third segment will be the newly formed matrix graph and drawing the graph vertices spread the circle. The edges that arose from the edge of the graph G1 will be black, while those that have arisen from the edge of the graph G2 - brown color. The situation is similar with the names of vertices. The names of the vertices are formed by the combination of the numbers of the vertices of the two graphs source. To increase transparency and legibility will have colors corresponding to the colors of the numbers in graphs source.

Operation can be performed with Graph of theoretically any size, but since the number of vertex of the graph is the resulting product of the number of vertices of graph source, it is advisable to choose the graphs such that the resulting graph is no higher than 12 vertices. For larger graphs, drawing becomes a little transparent. Fig. 16 shows exemplary results of the operation.

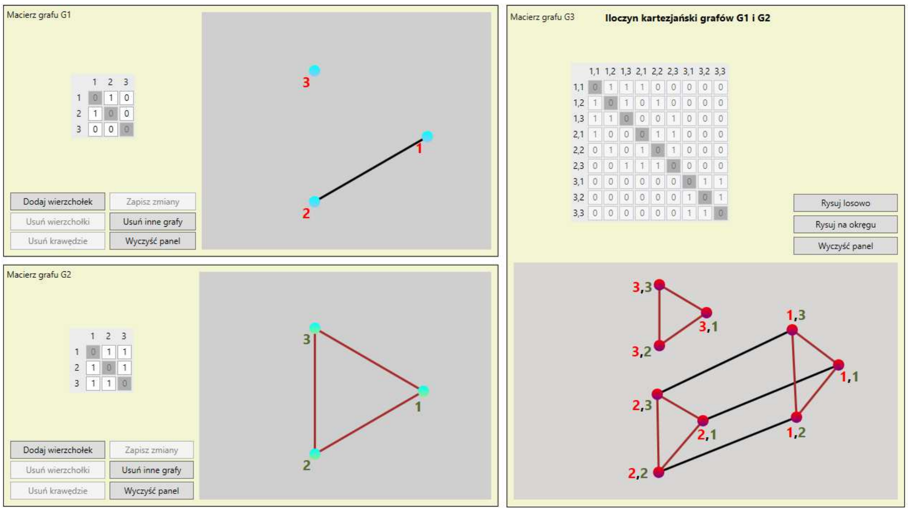

Figure 16. The program window after performing the Cartesian product on graphs with three vertices arranged by the user

5. Conclusions

As part of the bachelor thesis, the computer program for visualization of operations on graphs was written. Operations are performed on a single graph or two graphs. In the visualization windows of the prepared program, drawings of graphs appear as well as their matrices. It was assumed that graphs are small i.e. number of vertices as well as number of edges are relatively small. The aim of the program is its use in teaching. The principles of drawing graphs have been utilized, which are designed to facilitate the performed activities: different edges have different colors depending on their origination. When the user points (by means of a mouse) the top of the selected rows and columns of the matrix – the adequate graph edges are distinguished by changing the color, etc. Available options are: moving the vertices together with the adjacent edges and moving descriptions of the vertices.

The windows are transparent, describes the operations performed, if the operation cannot be done - warning messages are appeared on the screen.

The program will be used to ATH in teaching subjects related to graph theory e.g. ‘Discrete mathematics’ and ‘Algorithmic approach of graph theory’. With the introduction of imaging matrix and graph, the resulting translations of concepts are elegant and fast. The possibility of making repeat the same operation on different examples can promote easy understanding of the concepts and relationships graph theory to algebra.

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BEZPIECZEŃSTWO INFORMACYJNO-PSYCHOLOGICZNE SPOŁECZEŃSTWA W KONTEKŚCIE WOJNY INFORMACYJNEJ

Streszczenie: W pracy przedstawiono analizę definicji i różnych strategii cyber-bezpieczeństwa. Także zalety i wady ukraińskiej narodowej strategii cyber-bezpieczeństwa z punktu widzenia bezpieczeństwa informacji i odczuć psychologicznych zostały zdefiniowane. Dlatego też dokonano klasyfikacji manipulacyjnych metod wpływających na wyżej wymienione czynniki. Poza tym, strukturalne i analityczne modele manipulacyjnego oddziaływania zostały opracowane i zorientowane na ocenę efektywności masowego wpływu mediów. Podsumowując, można stwierdzić, że uzyskane wyniki mają wartości strategiczne dla zapewnienia bezpieczeństwa społeczeństwa ukraińskiego w kontekście wojny informacyjnej.

Słowa kluczowe: bezpieczeństwo informacji, przestrzeń informacyjna, cyber zagrożenia, oddziaływania psychologiczne, strategia bezpieczeństwa cybernetycznego, manipulacja, klasyfikacja

INFORMATION-PSYCHOLOGICAL SECURITY OF SOCIETY IN THE CONTEXT OF INFORMATION WARFARE

Abstract: In this work the analisys of definitions and different cybersecurity strategies were carried out. Also the advantages and disadvantages of Ukrainian national cybersecurity strategy from viewpoint of information and psychological security were defined. That's why the classification of manipulative influence methods was created. Besides, structural and analytical models of manipulative influence were developed and oriented on efficiency evaluation of mass media influence. Given results have strategic values for providing Ukrainian society security in the context of information war.

Keywords: information security, information space , cyberthreats, information and psychological impact, cyber security strategy, manipulation, classification

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1. Introduction

Today, the modern information and communication technologies (ICT) are widely used in public and private structures and in society. However, ICT, except the efficiency increase on processes, in which they are implemented, give rise to a number of new threats and vulnerabilities. In view of this, the information security (IS) and cyber security is a key for the problem decision. A constant aggravation of the cyber security issue , domestic and foreign scientists have studied the basic terms "cyberterrorism" [1], "cybersecurity" [2] "cyberspace" [3] "cyberimpact" [4] "cyber" [5] "cybercrime "[6]" cyberincident "[7]" cyberattacks "[8]" cyberinfrastructure "[9], etc., to give a comprehensive and integrated definitions of these definition. In [1] was structured summary of national cybersecurity strategies in different countries. But in our country cybersecurity strategy was adopted only recently (March 2016) and its provisions have not adopted into life - this creates a number of problems and threats in various kinds.

The main task of this paper is to study important aspects of safety information state space , namely the protection of information and psychological influences (such as analysis methods and models media manipulative influence on people, society and the state).

Cybersecurity Strategy of Ukraine [10] was adopted in March 15, 2016. The aim of the document is to create conditions for the safe cyberspace functioning , its use for the individuals benefit , society and the state. Presented the concept of cyber security definition. Ensuring cyber security based on the following principles: the law rule and respect for human rights and man and citizen freedoms ; Ukraine's national interests; openness, accessibility, stability and cyberspace security; public-private partnerships, broad cooperation with civil society in the cybersecurity and cyberdefense; proportionality and adequacy of the measures cyber real and potential risks; preventive measures priority; punishment for committing cybercrime inevitability; priority development and support of national scientific, technical and productive capacity; international cooperation to strengthen mutual trust in the cyber security and the development of common approaches in combating cyberthreats consolidation efforts in the cybercrime investigation and prevention , prevent the use of cyberspace as illegal and military purposes; ensuring democratic civilian control established under the laws of Ukraine military units and law enforcement agencies operating in the cybersecurity. Defined the priority directions of a secure development , stable and reliable cyberspace, cyber public electronic information resources and information infrastructure intended for processing, protection of which is set by law, cyber critical infrastructure, capacity building security and defense sector in the cybersecurity, cybercrime area.

After analyzing the crucial provisions of cybersecurity strategy it is possible to identify benefits and drawbacks in cybersecurity strategy.

Positive aspects:

1. Forming and providing of functioning the state register in critical infrastructure objects, that must contain in the composition the special subdivisions of specialists attested in information security area, will decrease time of finding out a threat and reacting on her.

2. The strategy involves the creation of the Ukraine armed forces on cyber security and cybercrime at the strategic, operational and tactical levels.

3. Introduction the concept of active cyberdefense - is a possible answer for aggression in a cyberspace, however method of realization it is not known while.

4. Done an accent on the necessity of the use of software and informative products of domestic manufacture.

5. The National Bank of Ukraine, according to the strategy, responsible for cyber security in the financial sector, creates a requirement for critical cyber infrastructure.

6. Creating the independent auditing information security system .

7. Training of judges, investigators and prosecutors to work with the evidence relating to the crime received electronically, allowing for the cybercrime.

8. Introduction of mandatory periodic certification of specialists in the field to ensure compliance with these requirements.

9. Raising awareness and culture of citizens in cyberspace.

Negative aspects:

1. Absent a single conceptual system that eliminates the concrete of strategy.

2. Absent the clear plan of defined terms and performers, as well as the period for which a valid document.

3. Not specified kinds of responsibility for various kinds of offenses and crimes in cyberspace or link to a document in which it is defined.

4. Do not provide periodic updates of the document in accordance with the current situation.

5. In timely of strategy acceptance.

6.Spared not enough attention to the aspects of information-psychological influences (IPI) is spared.

Obviously, cyberspace - is a combination of hardware, software and users interact. The person and his consciousness (the subconscious), which is the object of IPI (actually in information security there is a new facility protection) is an integral component of the any system functioning . In general, the person is an elementary part of society and the state. Providing information and psychological security (IPS) and countermeasures to combat IPI must be enshrine in law. Ukraine cybersecurity strategy includes not only measures of information protection and technical effects, but IPI.

The main methods of special information operations (SIO) include: misinformation, propaganda, public opinion diversification, psychological pressure, spreading rumors [11]. This is to prevent their implementation provides IPS of state.

Also, can conclude that the strategy does not account for all the possible ways IPI per person, society, state and ways and means of protection. This necessitates the creation and adoption of a separate legislation act that would regulate activities relating IPS, especially in the present conditions of temporary occupation of the territory by the Russian Federation, Ukraine, the escalation of conflict in the east of the state, the economic crisis and the subsequent collapse of international image. One of the biggest gaps in the plane IPS in Cybersecurity Strategy Ukraine is manipulating public opinion. For the best coverage of this issue is worth a closer observe the IPS concept.

Harmful information and psychological effects

Under IPS usually understand the security status of citizens, individual groups and social strata, mass organizations and people in general population from the negative IPI [12]. IPS characterized as a security status of the individual, various social groups and people associations from influence which can to change the mental state and psychological human characteristics behavior and modify it to restrict the freedom of choice [13-15].

Today, it is no secret that modern mass media try to "set up" thinking society towards that profit for a prime audience by all way. Only a small part of the population is able to prevent unwanted access to your information. Most people have no such opportunities remain vulnerable in this regard and are victims of so-called "manipulation".

At the moment formulated a lot of definitions the "manipulation" concept , among which highlight the following:

– psychological impact on peoples, which is not always recognized them and forcing them to act in accordance with the objectives of the manipulator [16];

– the process of creating artificial entity illusions about reality (or for yourself), perceived by other actors (or by the illusions creator) [17];

– a particular impact on the subconscious of the person (mostly on emotions, feelings and experiences) to programming motive partner for cooperation [18];

– hidden control person against freedom, which brings initiator unilateral advantages [19];

– kind of psychological impact, skillful execution of which is hidden in the awakening of another person's intentions that do not coincide with its actual desires [20].

Summing up the definition of "manipulation", it is useful to note, that is *the influences process by one individual to another in order to fulfill the will of the first.*

It is worth noting, that each person may have the various subtypes depending on the situation. The person - a social being, it constantly feels the need to communicate, aesthetic pleasure, the employment implementation and so on. Quite often the people social needs are the targets for manipulators. There is a desire to change direction in the person of its development, from the spiritual to improving full social degradation. This change will make it possible to manage people without even thinking about what this administration can be performed resistance [20].

Everyone has weaknesses that can be used for manipulation of consciousness. Point of impact on the minds of all people have in common. As the main points are: stereotypes, feelings and fears. [21] For professional manipulators use these points of human is quite significant part of the manipulation. The "click" on these buttons to receptors is invisible, that allowing the manipulator to realize the goals.

Crucially in the society history stands the freedom problem of choice. People from ancient times fighting for to be able to freely express their views and do what they want. The development and spread of information technology and the media questioned the personal freedom. On the one hand, the Constitution stipulates that the people - the highest social value, and ensuring the rights and freedoms is the main duty of the state. [21] On the other hand, even in a democracy restricted individual freedom, not through the adoption of new laws, and a virtually invisible manipulative effect (ME) on mind. The most active such influence through media.

There is a wide means range by which to control the people behavior, their thoughts and feelings. Quite effectively mass media use influence methods to subconscious person. Common is a situation when a person hypnotized by television, just not able to turn it off. This person is not able to analyze the information as such as direct interpersonal communication. [22]

In addition to the impact on the subconscious are often used unconscious influences . They focused on the subconscious perception and unnoticed by the man steering her thoughts and behavior in a given pointing direction. The main objective of this effect - to create the free choice appearance without actually leaving this [23].

It is worth noting, that today there are a number of methods which used by the mass media to manipulate people's consciousness, it is appropriate partial their presentation followed by classification and description of the algorithm implementation, "silence spiral" [24], "Poison sandwich" [25] "everyday "story [26] myths [27], citing anonymous authority [28], an emotional response [29], the presence effect [26], information reality creation[29], fasting [29]" Hold thief "[30] "talking" [31]" boomerang effect "[32] information blockade [25] comments [33] halo effect [28], the primacy effect [34], classifiers [35] statement fact [35], additional evidence [34] a false analogy [36], feedback [37], stereotyping [29].

Nomination various theories of media awareness is defined as the potential impact of the mass media, as the desire to find out the nature, essence and main characteristics of this complex phenomenon. As a result, the mass media impact on the individual more consistently carried out a sociological, socio-linguistic, semiotic, psycholinguistic, cultural, political, neurophysiological, psychophysiological and cognitive aspects of communication media.

The primary objective in assessing the MI is to understand the main signs of manipulation.

First, the manipulating is a asymmetrical process: there influence subject and influences object. And often to people whose consciousness is manipulated, treated not as individuals, but as objects of some kind of things.

Second, it is - a kind of spiritual, psychological impact (not physical violence or violence threat). The target manipulator actions are mental structures of the human person.

Thirdly, manipulation - a hidden effect, a fact which should not be seen by object manipulation

Fourth, is the impact that requires considerable skill and knowledge. When it comes to public awareness, policy, at least locally, they tend to develop action involved experts, or even the expertise gleaned from literature or instructions. There was a system of training, research institutions, scientific and popular scientific literature.

Fifthly, any manipulation of consciousness is a information exchange product.

2. Classification methods of mass media manipulative influence

Manipulation is carried out in three main areas: ideological (propaganda), economic (advertising), social (education, education, etc.). Manipulation can be done within interpersonal, group and mass communication. Of particular importance in recent years has become the manipulation of mass consciousness and mass behavior.

There are a communication methods to solve problems and achieve MI goals. They are called differently: technology, methods, but the essence remains the same. All of these methods can be classified according to different criteria. Generally meaningful classifications have not yet created. Usually limited to a simple listing of known methods. One of the first such list was formulated in the thirties of last century, the US Institute for Propaganda Analysis. It is known as the "ABC of propaganda."

However, over the years developed a large number of other methods, and there was the problem of this classification. This classification is advisable to build in accordance with the influence mechanisms, to wit influence the human mind.

Mythological influences (manipulation) (MythInfl)

Manipulation by means of updating or creating mental-mythological constructs and impact on people's archetypes and metaprograms [38-39].

This category includes such methods:

1. Name of the method: **myths.** The purpose of the method: the perception people get the information for granted without rational, critical thinking them.

2. The name of the method: **a false analogy**. The purpose - get people to think in analogies and making a false report.

3. Name the method: **stereotyping.** The purpose - building the image of the social world, imposing man stereotypic behavior in any situations.

Manipulative Psychotechnology (PsTechInfl)

This class methods use psychological manipulation automatism, that there is a large set of influence techniques which based on the human perception psychology. Perception - is a mental process that is holistic reflection of objects and phenomena of the world under the direct influence of physical stimuli on the senses receptors . This perception is subjective, because it depends on previous experience and knowledge.

1. Name of the method: **"Poison sandwich."** The purpose - the psychological impact on the individual by deliberate structuring text and to ensure that people do not notice the "unnecessary" truth.

2. The name of the method: **comments.** The purpose - the creation of the context in which the thoughts of a man going in the right direction.

3. Name the method: **classifiers**. The purpose of the method: to convince a person and as a consequence, the company the veracity of information, confuse and convince their views.

4. Name the method **"talking"** The purpose - reduce the urgency of a phenomenon or cause backlash to them.

Manipulation using information management or information environment (InfFlInfl)

The feature of this category is that in the information environment very often operating information that adequately reflects the existing world and deformed, distorted information.

The method consists in managing information flows, that any processing of information. Often the obstacle created the information appearance, filtering information, a special selection and use only those facts that are beneficial to IPI.

1. Name of the method: **the primacy effect**. The purpose of the method: to impose owns views to a wider audience first. Method primacy effect is fully based on the psychological properties of the human brain to favor one of the information received first.

2. The name of the method: **information blockade**. The main goal of this method is to block information, which is dangerous in a sense or can harm of various kinds.

3. Name the method: **information reality creation**. The purpose of the method: get disorientation rights in the information space.

4. Name of the method: **the presence effect.** The purpose of the method: get the audience in faith fabricated information; disorientation people.

Value-emotional manipulation (EmotInfl)

Value-emotional manipulation based on a person's ability to get involved in making sure the message severity and prestige source.

Under the value-emotional manipulation understand the manipulations that are done by updating the value audience perceptions, that suggestion as mental verbal impact or figurative type that is uncritical perception or mastering any information the audience.

1. Name the method "silence spiral ". The purpose - create such conditions that the individual is left unspoken their views, if they are not supported by the majority.

Social control mechanisms (SocCntr)

The essence of this category method is to use a reputable, well-known for the target audience people or groups.

1. Name of the method: **citing anonymous authority**. This method belongs to the so-called "gray propaganda."

The purpose - get from society "blind" faith in the words and facts authenticity which offered by the mass media, using psychological method creation authority to humans. The authority may be significant religious or political figure, scientists and others. Name the authority reported. In this case more convincing to be quoted documents, expert opinions, statements of witnesses and other materials.

2. The name of the method: **additional evidence**.

The purpose of the method: to achieve a "blind" faith in the mass media.

Logical principles. Manipulation rational, convincing arguments (LogicInfl)

Group logical methods based on a conscious violation of basic laws and rules of formal logic or, conversely, their skillful use in order to manipulate not familiar opponent. These techniques are used in negotiations, discussions and disputes.

1. Name of the method**: halo effect**. The purpose of the halo effect to ensure that the person is thinking within the false analogies.

2. The name of the method: **statement fact.** The purpose - get a full public confidence in the veracity of news coverage, the creation of appropriate attitudes in society

3. Name the method: **feedback**. The purpose of the method: subconsciously change thoughts and mood in a positive direction for yourself, to make it "blindly" believe in the information presented veracity.

Emotional sphere control (EmtSphInfl)

Under this category refers to techniques such disputes, discussions, polemics, which are based on the psychological impact on the interlocutor with the aim to introduce them in a state of irritation to play on his feelings of pride, shame.

1. Name of the method: **emotional resonance**. The purpose of the method: creating a mass audience in a particular favorable mood with simultaneous transfer of propaganda information; psychological defense removal, which builds on the mental level man, deliberately trying to protect themselves from propaganda or advertising "brainwashing." And if the propaganda effect on people going on an emotional level, beyond her conscious control, no rational counter-arguments in this case do not work

2. Name an example: **"boomerang effect"** The purpose of the method: cause pity and sympathy to the wider audience of a particular person or phenomenon. Quite often can be traced to the reverse reaction expected.

3. Name the method: **fasting.** The purpose of the method: the impact on the electorate and the psychological pressure on the government.

Thus, a generalized classification of MI methods developed under the mechanisms of influence, that influence the human mind, is presented in Table. 1.

Table 1. Generalized classification of MI methods

Category	**Method's name**
Mythological influences (manipulation) (*MythInfl*)	A false analogy
	Stereotyping
	Myths
Manipulative Psychotechnology (*PsTechInfl*)	"Poison sandwich"
	Comments
	Classifiers
	"Talking"
Manipulation using information management or information environment *(InfFlInfl)*	The primacy effect
	Information blockade
	Information reality creation
	The presence effect
Value-emotional manipulation *(EmotInfl)*	"Silence spiral"
Social control mechanisms *(SocCntr)*	Citing anonymous authority
	Additional evidence.
Logical principles. Manipulation rational, convincing arguments *(LogicInfl)*	Halo effect
	Statement fact
	Feedback
Emotional sphere control *(EmtSphInfl)*	Emotional resonance
	"Boomerang effect"
	Fasting

3. The mass media manipulative influence models on the person and social group

For developing mass media manipulative influence models on person and social groups is important to consider already known models.

In Peleshchyshyn and Huminskiy researches made description the information environment of virtual community on social networks [40]. Developed and detailed models of internal information environment to model virtual community discussions. Based on a formal model of the information environment of virtual community given the information threats index [41-54]. The models dive the opportunity to identify the information threat on social networks and provide information and psychological human security in social networks. However, the disadvantage is the inability to put value the developed models.

In Shiyan researches the analysis of information and psychological factors that are essential for building models of human protection and social groups [55-56] in order to enhance human security of the negative consequences of information-psychological influence. In scientific work presented the method for forming information space problem for human activities and social groups, ie splitting a comprehensive database performance problems on eight classes of information that is given by the tuple [57].

Shiyan presents the model of human rights and joint activities in the information space and development the protection from negative psychological impact of information and features on its base, which based on its activity [58-60], but directly manipulative influence formal model isn't selected and as a result, mathematically evaluate the impact is not possible.

In Gubanov researches [61-63] presented the overview of impact model in social networks, the observed the basic models classes of social networks and established correspondence between models classes of and modeling parameters object. Analysis of these models allows to study relationships between objects in a social group influence and dependency information for the person.

Gubanov says that social network plays an important role in the dissemination of information, ideas and influences between its members. The impact of literature on social networks is closely associated with the term "diffusion of innovations» , that's why Gubanov considers, in particular, appropriate models such diffusion, which are based on some fixed network and local rules of interaction between its members.

Researcher was allocated to the following models classes of influence in social networks:

1. Optimization and simulation models [61, 64]

a) linear threshold model [61].

b) independent cascade model, which belong to the category of models of so-called "systems of interacting parts" [64].

c) percolation and contagion models [62.64]. Models percolation and contagion, used in various applications - from models to the study of epidemics oil fields and is a popular way to study the dissemination of information (innovation).

d) Ising model [64]. Ising Model - mathematical model that describes the origin of magnetization of the material

d) model, which based on cellular automata;

e) model, which based on Markov chains [61].

2. "Theoretical-gaming" model, where the focus is on awareness and the relationship between players (agents). Winning depends on the actions of opponents (other players). The agent acts so as to maximize profits [61].

3. Network autocorrelation models [76]. Consider deterministic discrete-time linear process in which the installation (attitude) change under the influence of other agents: $y_{t+1} = Wy_t$, where y - vector installations in time t; W - matrix of effects.

4. Imitative behavior model[66]. Imitative behavior model in which each of the agents can choose action (called binary choice).

5. P^*-model social impact [54]. For the analysis of connections and relationships between agents in social networks using probabilistic models that take into account the distribution of information on the structural characteristics (or configurations, or subgraphs) in the general population networks with desired properties (e.g., set tops) and allow to test hypotheses about distributions , the significance of the model parameters, suitability model for describing data.

6. "innovations diffusion" models related to the formation of public opinion.

In Horbulin's monograph discusses the modeling and analysis of information operations as a information confrontation component . Investigating dynamic and polyagents models that gained wide acceptance in connection with the development of computer technology, distributed computing capabilities [67].

According to [67], Horbulin describes two types of information operations models, nonlinear social operations models and multi agent model [68].

Horbulin reviewed several examples of multi simulation models, which provide the manipulative influence of great interest in the model:

1.artificial society" model [69-71].

2 people preferences model [72].

3. Simulation model [73].

However, most of the models, which proposed by Horbulin have formalized description and not appreciated by the author. Models are described only verbally and allow the surface to get acquainted with the manipulative influence of mass media.

Analysis of current manipulative influence models conducted in the following basic criteria (Table. 2): IE- taking into account the impact of the information environment; MTI - consideration of manipulative techniques impact; LE- taking into account the links between information environment elements; FD - availability formal description of the model; IEC - taking into account the information environment content; TC - consideration the transmission channel of content; CA - consideration of the content adequacy. As a result found that all these models are not perfect and have some restrictions on practical applications to solve problems of various kinds of information-psychological security.

Established that mass media manipulative influence model is only effective and adequate for modern media methods if this models meets the above listed criteria.

Table 2. The results of analysis models manipulative influence

№ з/п	Name	Criteria						
		IE	MTI	LE	FD	CIE	TC	CA
1.	Peleshchyshyn- Huminskiy model	+	-	+	+	+	+	+
2.	Shiyan's model	+	-	-	+	-	-	-
3.	Hubanov's models	-	-	+	+	-	+	+
4. Horbulin's models								
5. Grade 1. Optimization and simulation models								
5.1. linear threshold model		-	-	+	-	-	-	-
5.2. independent cascade model		-	-	+	-	-	-	-
5.3. percolation and contagion models		-	-	+	-	-	-	-
5.4. Ising model		-	-	+	-	-	-	-
5.5. model, which based on cellular automata		+	-	+	-	+	-	-
5.6. model, which based on Markov chains		-	-	+	-	-	-	-
6.	Grade 2. "Theoretical-gaming" model	+	-	+	+	-	-	-

7.	Grade 3. "Innovations diffusion"	+	-	+	-	+	-	-
8.	Grade 4. Network autocorrelation models	-	-	-	+	+	-	-
9.	Grade 5. Imitative behavior model	-	-	+	-	+	-	-
10.	Grade 6. P^*-model social impact	+	-	+	+	+	+	+
11.	Grade 7. "Innovations diffusion" models related to the formation of public opinion.	+	-	+	-	+	+	+

Thus, it was revealed that there is no mass media manipulative influence model on the person and social group that would have enabled quantitatively or qualitatively assess the impact of media on the person or social group, and further create a model to protect people from this exposure.

4. Building mass media manipulative influence model on the person and social group

For the construction of general manipulative influence model it is expedient to consider the mass media models in created information environment.

```
MassMedia= <Content, Members, Channel>,                  (1)
```

where Content - the information content; Members - the members in information environment; Channel - channel through which transmitted the information.

While, a formal channel model, which transmitted the information, considering (1) is defining by:

```
Channel = {Broadcast media, Digital media, Outdoor media,
Print media, organizing and public speaking},
```

where Broadcast media - cinema, radio, music, or television; Digital media - Internet and mobile communications media; Outdoor media - advertising, billboards, posters or kiosks placed inside and outside the buses, commercial buildings, stores, sports stadiums, subway cars or trains, aerial advertising; Print media - books, comics, magazines, newspapers, pamphlets; Organizing and Public speaking - public speaking.

Considered the channels and the environment in which operates MI, found that it meets properties (filling information variability, design and communicative orientation) and features information environment.

Mass media information environment can provide:

```
InfSpace = < MethInfl, Channel, Members>,
```

where MethInfl - a set of methods MI; Channel - a set of channels, which will be the information transmission; Members - information environment members.

```
MethInfl = <MythInfl, PsTechInfl, InfFlInfl, EmotInfl,
SocCntr, LogicInfl, EmtSphInfl>,
```

where MythInfl - mythological influences methods; PsTechInfl - manipulative psychotechnology methods; InfFlInfl - manipulation using information management or information environment ; EmotInfl - value-emotional manipulation methods; SocCntr - social control mechanisms methods; LogicInfl - logical principles methods. Manipulation rational, convincing arguments; EmtSphInfl - emotional sphere control methods.

Mass media manipulative influences system in person and social group can be represented as a kind of socio-technical systems. The modern concept of socio-technical systems theory as opposed to technological determinism, which asserts unilateral action of technology on people, based on the idea of human interaction and technology, ie the interrelated effects. Socio-technical system consists of the following subsystems: subsystem includes technical devices, tools and technologies that transform inputs into output in a certain way, which improves the efficiency of the system; social subsystem includes people, their knowledge, skills, mood, values, related to the functions, management structure, a system of incentives. In view of this, to describe the quantitative and qualitative characteristics of information circulating in the system must take into account factors as information corresponding to the characteristics of information that are important for its security - a basic characteristics (integrity, availability, confidentiality) and additional (adequacy, completeness, relevance, redundancy, targeting).

Thus, in general, the coefficient characterizing information from a security perspective can be displayed as a cortege $\{К_к, К_ц, К_д, К_а, К_п, К_{ак}, К_н, К_{ад}\}$. This convoy and set the operations of the characteristics of each breach of information security can be described mechanism for the implementation of each mass media method of MI in person and social group.

For example, the method of "Creation of reality" described in [74-79], which is classified manipulation using information management or information systems can be considered in 4 different variations, due to various forms of misinformation.

Based on formal developed models, formalized mass media MI model will be as follows: (Figure 1), which IFAgent - is the agent of influence, that is the person who sends some information - Content (C); Ch - channel, which is transmitted (includes use $P_j = (1,2,3), P \in M_i$), $M1, M2, M3$ - members of the information environment or individuals.

In general algorithm influence, according this model can be described as follows (Fig. 1):

1) an agent of influence (individual) transmits information (content);

2) information passes through the channels, in this case, the channel refers to media that uses the MI methods;

3) information, interact with points of impact (fear, feelings, stereotypes);

4) information provides the impact on person or social group.

Implementation of information-managing impact of mass media channels for the method of "Creation of Reality" can be represented using structural and analytical models of information control destructive influences that can be divided into:

– transformation;
– pseudo-information;
– misinformation;
– metamisinformation;
– multiinformation.

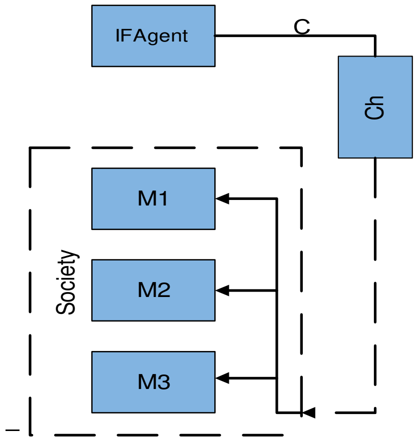

Figure 1. Mass media manipulative influences model

The "Creation of Reality" method can be presented in 3 different models variations misinformation.

Simulation misinformation - is false information, which is associated with the false original $I_f$creation.

Dissimulation misinformation - is false information, which is associated with concealment of the true originals.

Embarrassing misinformation - a combination of false and hidden originals.

Consider detail 3misinformation models on the the information characteristics(basic and additional).

Introduce some variables for a clear understanding of misinformation models:

x_1, x_2, x_3 - set of originals; original -reporting from totality of great reports numbers on the exit of influence source (mass media);

y_1, y_2, y_3 - set of interim reports; interim reports (intercommunicate) - message from the set of messages, which is located between the exit of source and entrance receiver of influence;

z_1, z_2, z_3 - set of images; image - the message from transverse messages set which is located on the exit of influence output receiver;

v – information image after informing;

I – information;

I_v – psevdoinformation.

Model 1:simulation (fig. 2). Model parameters: $К_д < 1$; $К_п < 1$.

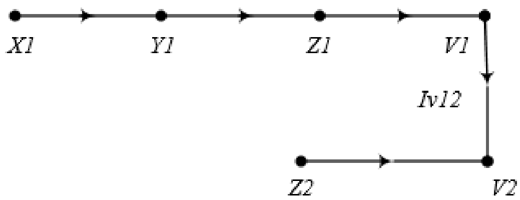

Figure 2. Graphic representation of simulation misinformation

The image v_1 - the result of converting the original x_1, the same image v_2 not the result of converting this original, it appears in the other extraneous reasons. Information I_{v12} - simulation misinformation, as information of I_{x12}. is absent in the great originals number.

Model 2:dissimulation (fig. 3). Model parameters: $K_{a\partial} = 1$.

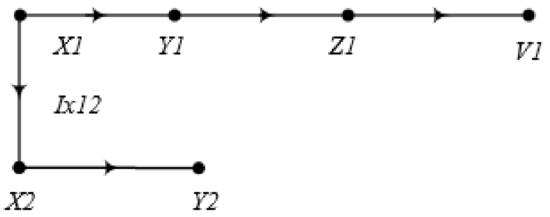

Figure 3. Graphic representation of dissimulation misinformation

The original x_1 is regenerate in image v_1, at the same time, when the original of x_2 is not recoded in the desired image, as necessary for this purpose chain code is interrupted on some intermediate report. As a result, although in the plural of originals present information of I_{x12}, there is not information of I_{v12}. in the great number of characters.

Model 3: embarrassing (fig. 4). Parameters $K_o < 1; K_n < 1$.

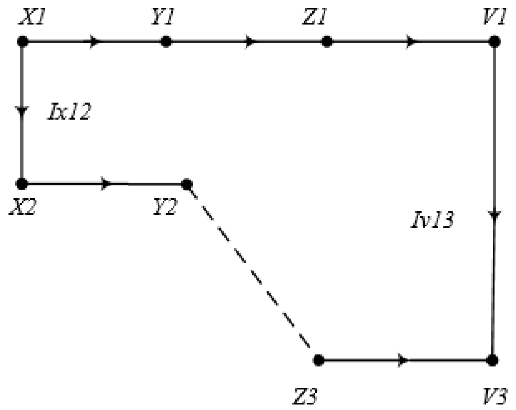

Figure 4. Graphic representation of embarrassing misinformation

The original of x_1 is regenerate in image of v_1, at the same time, when the original of x_2 is not recoded in the desired image, but in the image plural there is image of v_3, which got by another way. As a result, although great number of originals and contain information of I_{x12}, a great number characters have no information of I_{v12} (dissimulation misinformation), but contains information of I_{v13}, although the great number of originals does not contain information of I_{x13} (simulation misinformation).

Taking into account developed formalized model there is a question in calculation the probability of manipulation influences success, that can be expected by binomial distribution law:

$$P = C_n^k p_0^k (1 - p_0)^{n-k},$$

where p_o- probability, n – object quantity MB, k – manipulative influences objects.

Accordingly for a few groups of MI n_i, $i = 1, \dots, N$,,will have elementary p_{oi} probabilities. Using this method give an opportunity to substantially improve the accuracy of the MI processes description.

So the mathematical expectation will be:

$$M = \sum_{i=1}^{m} [n_i p_{0i}].$$

The power of several influences object:

$$N = \sum_{i=1}^{m} n_i.$$

The MI effectiveness in this case can be divided attitude, which obviously less than unity:

$$E\ MB = \frac{M}{N} = \frac{\sum_{i=1}^{m} [n_i p_{0i}]}{\sum_{i=1}^{m} n_i}$$

These mathematical expressions can be used for evaluating the effectiveness of the "Creation of Reality" method, which presented in the three different models misinformation variations form (Fig. 2-4) and will adapt to other IPI methods.

5. Conclusion

The aim of the Ukrainian cybersecurity strategy is to create conditions for the safe cybersecurity operation, its using for the individuals, society and the state benefits. However, it is difficult to achieve this goal without taking into account all possible IPI aspects and countermeasures from it. Therefore, it is appropriate to learn the formulation and distribution system knowledge about the basic ways to ensure IPI and study the population how to detect IPI and protect from it.

The paper analyzes the cybersecurity strategies, defined the advantages and disadvantages of strategy, particularly in the IPI context. In addition, techniques developed classification mass media MI methods that due to the partial generalizations of theoretical positions and practical achievements in this field, can extend the choice of certain methods for the information operations implementation and develop preventive measures to ensure the population of Ukraine psychological aggression. Also investigated the structural and analytical MI models that due to the synthesis of formal mass media representations, channel influence the information environment and set cortege of information make it possible to assess the mass media impact effectiveness on the person and social group that today has strategic importance for security Ukrainian society.

Obtained in the results can be used to develop preventive and counter measures to counteract negative information influence, including media channels, developing practical recommendations for the population of Ukraine in information warfare conditions in order to increase IPI the citizens, society and state. In addition, on the basis of the work can develop specialized software for evaluation and prevention mass media IPI on consciousness and subconsciousness of people that facilitate the task of the national Ukraine security.

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SYSTEM INFORMACYJNY DO ZBIERANIA DANYCH WPROWADZANYCH Z KLAWIATURY

Streszczenie: Artykuł przedstawia opis systemu informatycznego do analizy danych statystycznych użytkowników na podstawie pisma z klawiatury. Ostatecznym celem jest opracowanie technologii, która implementuje systemu uwierzytelniania użytkownika na podstawie pisma na klawiaturze.

Słowa kluczowe: biometria, uwierzytelnianie biometryczne, pisanie klawiatury

INFORMATION COLLECTING SYSTEM OF PERSONAL KEYBOARD HANDWRITING

Summary: This article describes the information system of statistics collection users' keyboard handwriting. The main goal is to create and develop the technology that improving the system of authentication of each keyboard handwriting.

Keywords: biometrics, biometrical authentication and authorization, keyboard handwriting

1. Introduction

One of the most important questions of biometrical science is authentication of person based on physical and behavioral characteristics [1]. Physiological characteristics including fingerprints, retina cornea of the eye also geometry structure of the face and hands. Behavioral characteristics including the dynamic of reproduction personal signature, style of using keyboard and even voice [2, 3].
Biometric methods divided into two big groups:

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- Static methods basing on physiological characteristics of each person, it means that this method basing on unique qualities that given to everyone from birth and never changing during the life;
- Dynamic methods based on behavioral (dynamic) human characteristics especially uncontrolled moves during process of acting any certain move (signature, pronunciation and speed of keyboard handwriting) [4].

Research and practice [5-6] shown that keyboard handwriting same some other biometric data with very high reliability identify the person.

Biometric authentication doesn't specify out the user with absolute fidelity. Systems recognizing the user with certain probability according this system sometimes able do not recognize a legal user moreover it can accept the stranger for owner. That's why all biometric systems evaluated by two categories:

- Deny of access (first kind of error – FRR, false rejection rate) – showing the level of probability that system won't recognize the registered user;
- Error access (second kind of error – FAR, false access rate) false access to the system of illegal or nonregistered user.

According to the simplicity and low price of project and implementation no need of additional hardware such system becoming very popular.

Each person using own texting, writing and printing including keyboard that showing special typical unique speed, the habits of using main and additional parts of keyboard, the specific of keystrokes the strength of press, established during work with computer. The evaluation of these individual specification often used in modern system of information security and is one of the methods of identification of user according collected biometrical data and characteristics. Recently more important is protecting and defense of information taking parts the systems which using as instrumentality of identification and authentication of computer systems. As a result several of methods applied in different types of information systems, according each of them have its own features and abilities, reliability, price of implementation and service also maintenance.

Based on these facts rapidly almost torrentially developing systems of biometric identification using as input data the keyboard handwriting which is a reflection of personal using of keypad.

Information Systems biometric authentication are very similar [7]. Their task is to read biometric data to process them, prepare to verify the information and based on this to compare and determine is this person real or not (fig.1).

Users' authentication methods using keyboard handwriting based on statistical methods processing and forming the initial data source direction or vector which is the ID of the users.

As the initial data using time intervals between keystrokes on the keyboard and the time of intervals of maintenance. At the same time intervals between keystrokes showing how fast person working and the maintenance showing the style of work.

During training user input few times suggested test phrases. Meanwhile calculated and commit to memory reference characteristics of the user (fig. 2). On the stage of authentication calculated estimates compared with primary according to this making conclusion about matches and differences settings of the keyboard handwriting.

The reference user characteristics obtained during training stage allows making a conclusion about stability of keyboard handwriting and determining confidence interval spread options for the next authentication of the user. To avoid the discredit of the system necessary to screen out the users whose keyboard handwriting doesn’t have “stability” [8].

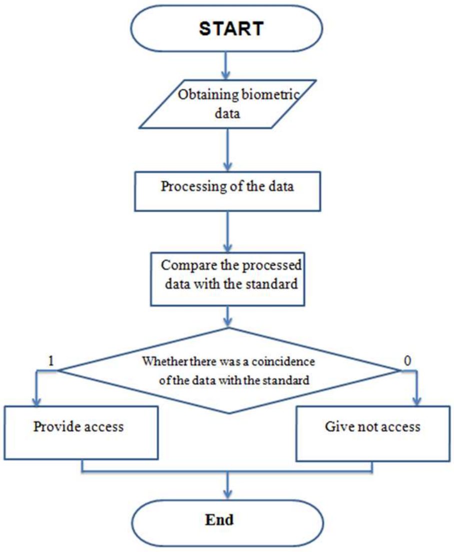


Figure 1. Algorithm for biometric authentication

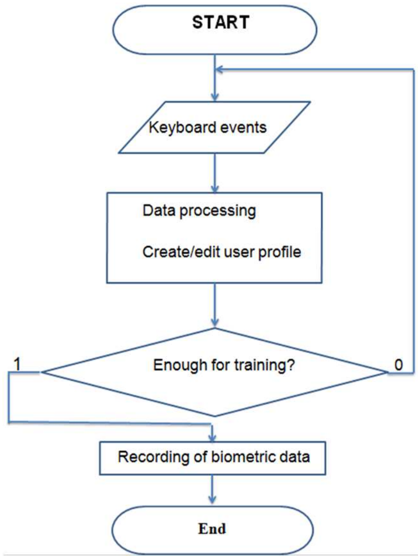


Figure 2. Learning algorithm IS

Used at this research monitor-program one of the most important parts of biometric authentication keyboard handwriting because from its functioning depends how correct will be collected information also will it be possible based on this data to create reference information that received during authentication data and will be it suitable for comparison.

The process of the program can be divided into several logical blocks:

- Keyboard monitoring;
- Start of sub processes for each action and processing;
- Data processing in sub processing (definition of user, determine the pressed keys, record the time since it was pressed.

At this system exists 4 objects: ”User”, “Program Monitor”, “Program Manager”, ”DataBase”. Sequence diagram of the system of biometric keyboard handwriting shown in figure 3.

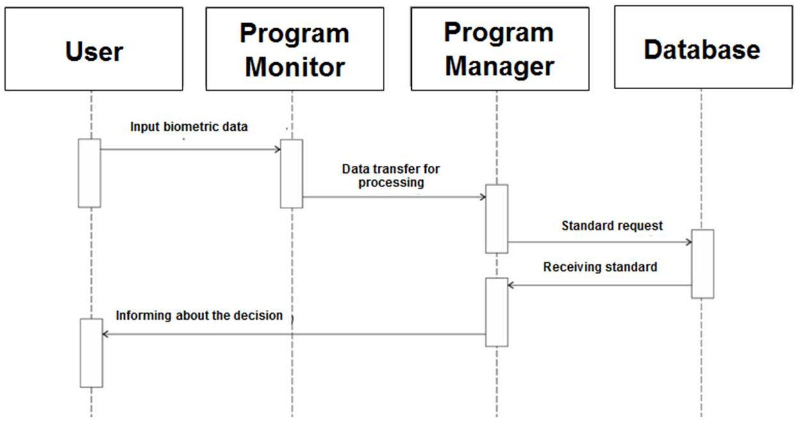


Figure 3. Sequence diagram of the system biometric authentication by keyboard handwriting

This software system contains 3 blocks: Monitor, Manager and Database. Monitor block including methods for monitoring the system for obtaining biometric data. Manager block provides the methods used to process the data, also for taking decisions on the admission of users system. In Database used methods to get and record data to Database. Diagram block shown in figure 4.

For monitor-program uses high-level programming language Java appropriate development environment. Among other things this programming language has built-in functions of recognizing actions of keypad. For this existing class KeyEvent, which contains all the variation of keyboard and interface KeyListener its includes the following methods:

- void keyPressed(KeyEvent e);
- void keyReleased(KeyEvent e);
- void keyTyped(KeyEvent e).

Method Void key Pressed (Key Event e) uses when any key pressed before; method void key Released (key Event e) – when the key was release and method void Key Typed (key Event e) – when any symbol already been text [9].

In order that data info did not create delays in the program can be able to read the data without any internal obstruction suggested during the pressing to create a new thread which will be carried elaboration of every single keypad button.

In Java programming language multistreaming without using additional; technologies that is also an argument for use this language of programming Gui implemented using library of Java language – AWT (Abstract Window Toolkit) – this is original package classes of Java programming language which is used to create a graphical user interface. AWT defines basic set of elements for managers, windows and dialogues that support simple in use but limited in their capacity GUI.

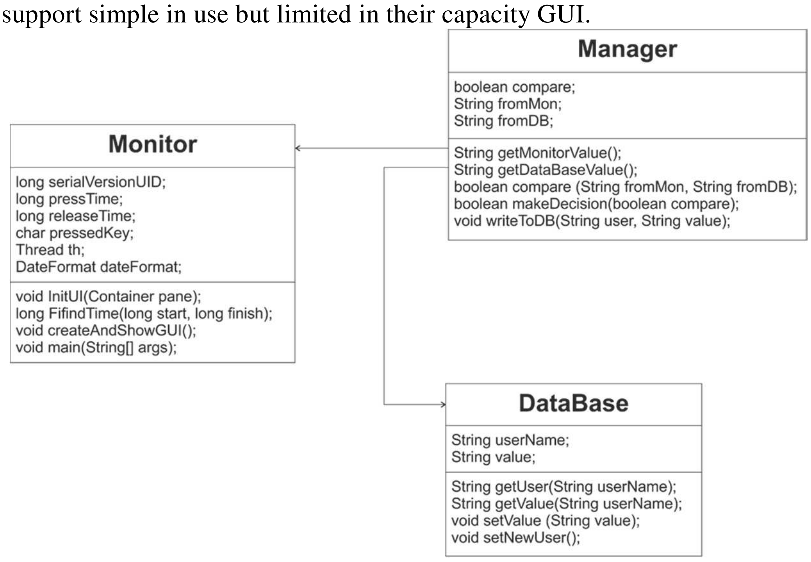


Figure 4. Class diagram of the system biometric authentication handwriting keyboard

One of the reasons that limit AWT is that AWT transforming visual components into corresponding equivalents platforms where Java machine placed. For algorithm presentation created program that allows you to read temporal characteristics of the keys. For easy checking algorithm was design GUI (fig. 5) which displays text fields for input password and records keystrokes from the moment of press or duration of time (how long the user holds on the button) Received results after processing are records to database. Also this information for convenience you can find in text file (fig. 6).

As the result we receiving text file (fig. 6) according to each press of button in a line says:

- Data
- Time
- User Name
- Computer Name
- Sign of the Key(letter)
- Time of Holding the Key

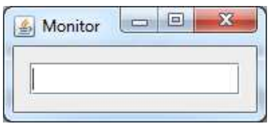
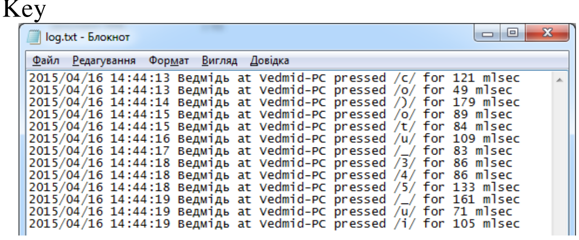


Figure 5. GUI



2015/04/16 14:44:13 Ведмідь at Vedmid-PC pressed /c/ for 121 mlsec
2015/04/16 14:44:13 Ведмідь at Vedmid-PC pressed /o/ for 49 mlsec
2015/04/16 14:44:14 Ведмідь at Vedmid-PC pressed /)/ for 179 mlsec
2015/04/16 14:44:15 Ведмідь at Vedmid-PC pressed /o/ for 89 mlsec
2015/04/16 14:44:15 Ведмідь at Vedmid-PC pressed /t/ for 84 mlsec
2015/04/16 14:44:16 Ведмідь at Vedmid-PC pressed /u/ for 109 mlsec
2015/04/16 14:44:17 Ведмідь at Vedmid-PC pressed /_/ for 83 mlsec
2015/04/16 14:44:18 Ведмідь at Vedmid-PC pressed /3/ for 86 mlsec
2015/04/16 14:44:18 Ведмідь at Vedmid-PC pressed /4/ for 86 mlsec
2015/04/16 14:44:18 Ведмідь at Vedmid-PC pressed /5/ for 133 mlsec
2015/04/16 14:44:19 Ведмідь at Vedmid-PC pressed /_/ for 161 mlsec
2015/04/16 14:44:19 Ведмідь at Vedmid-PC pressed /u/ for 71 mlsec
2015/04/16 14:44:19 Ведмідь at Vedmid-PC pressed /i/ for 105 mlsec

Figure 6. The result of the program in a text file

For theory and practical research towards biometric authentication keyboard handwriting developed software that allows you to collect data of key press by define user also system time that needed for better grouping of results.
Data were collect using a Pc keyboard connected to an authorized user. The password chose the word «ПРОМІНЬ» (beam) because this word doesn't contain the letters that repeating also this word is not tiny for analysis. According to this we can assume that the experiments took place using fixing sustainable text. It allows collecting data necessary for processing and preparation of statistical profile. Also should be mentioned that this method requires some definite preparation of users, especially the ability during texting use all 10 fingers and special typing speed. Also during all experiments carried same hardware and software that excluding the possibility of any influence on the PC analysis.
For convenience the data of time retention of keys shown on histograms (fig. 7-8) and graphs (fig. 9-10)

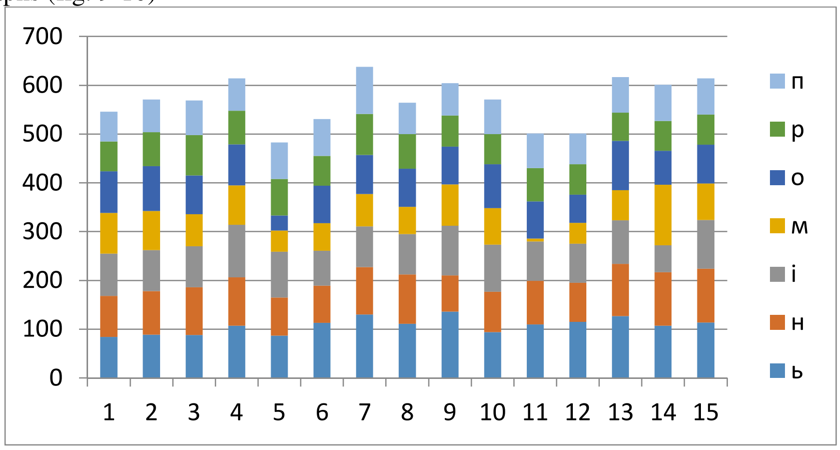


Figure 7. Bar chart with the accumulation of the collected time characteristics for each letter of the first user

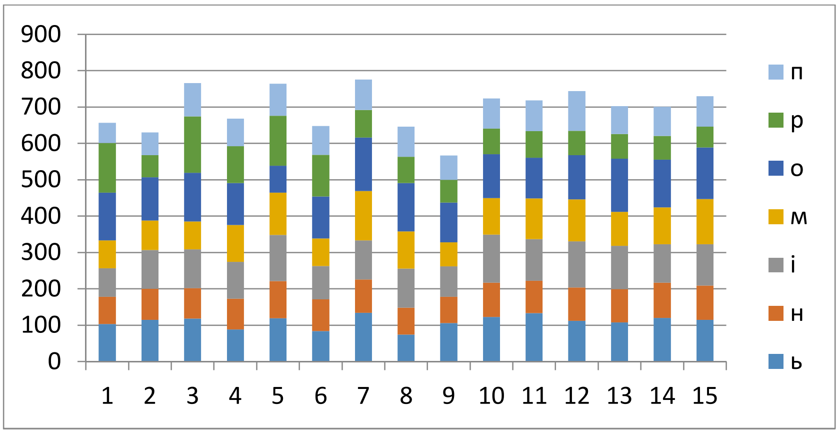


Figure 8. Bar chart with the accumulation of the collected time characteristics for each letter of the second user

In resulting chart you can see the retention time of each button key in various experiments and the total time of experiment. You may notice that the time for one or other key on each experiment absolutely different but the user even don't pay attention to the fact that enter the password each time in different ways. According to this the simple comparison of retention time of individual key button is not practical for biometric authentication keyboard style. Therefore, in next research and selection of Math models should be including additional options in processing time characteristics.

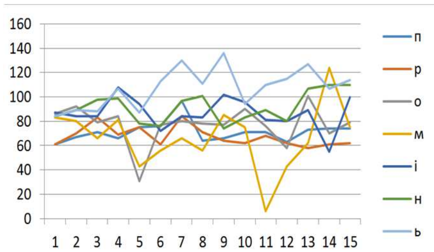


Figure 9. Time keeping key characteristics of the first user

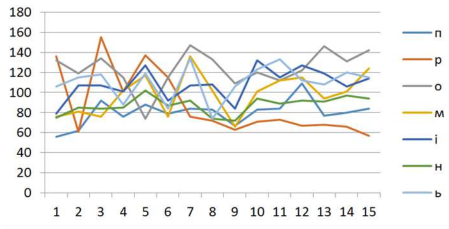


Figure 10 Time keeping key characteristics of the second user

The majority charts are similar. It's because the user enter the password with his usual style – keyboard style. Also you may notice that some graphs are differ one from other. This may be due by various factors including the fact that something could distract the user during experiment or because of some physiological factors. These effects minimized by using more samples.

On the figure 11 shown medium results of the time characteristics of two users. As can be seen from the graph even knowing the password each user enters with his own typical only for him rhythm (different time characteristics for the same letters).

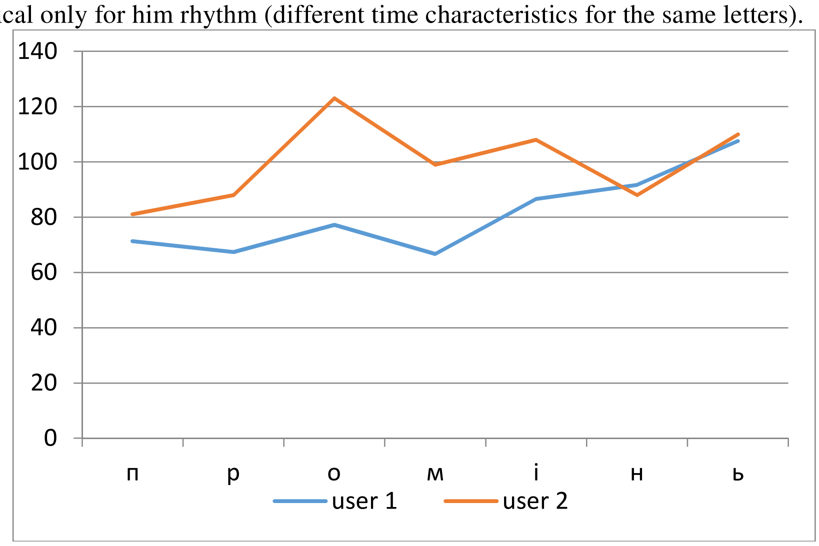


Figure 11. Comparing medium results of the time characteristics of two users

According to the results of research we can make a conclusion that biometric authentication technology shown itself as perfect additional method of security information system. Also need to add that it's suitable for use for experienced PC users because it requires certain PC operator skills and without authentication using this method will be very problematic.

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METODY ORAZ MODELE OCENY BEZPIECZEŃSTWA INFORMACJI PRZESYŁANYCH PRZEZ SYSTEMY TELEKOMUNIKACYJNE

Streszczenie: W obecnej sytuacji na rynku IT-technologii, jeśli chodzi o rozwój technologii telekomunikacyjnych, to wyróżnia się wskaźniki jego poziomu – jak np.: parametryzacja, innowacyjność, konieczność zapewnienia wymaganego poziomu bezpieczeństwa i analizy prywatności. Wymagania co do tych wskaźników stale rosną. Jednym z priorytetów jest zapobieganie nieautoryzowanemu dostępowi do informacji, jej zablokowania lub awarii systemów informatycznych i telekomunikacyjnych. Pracę poświęcono rzeczywistemu problemowi rozwoju algorytmu do wyznaczania prawdopodobieństwa bezpieczeństwa systemu informacyjnego i telekomunikacyjnego przy istniejących zagrożeniach i stosowanych nowoczesnych środków ochrony.

Słowa kluczowe: informatyka, systemy telekomunikacyjne, bezpieczeństwo, ochrona danych, modele ryzyka

METHODS AND MODELS OF EVALUATING SECURITY OF COMPLEX DISTRIBUTED INFORMATION AND TELECOMMUNICATION SYSTEM

Summary: Within the current situation in the market of IT-technologies, in terms of the growth of telecommunication technology, its development, parameterization, innovation, the need to provide the required level of security and privacy analysis is steadily increasing, in order to prevent unauthorized access to information, its blocking and malfunctions of information and telecommunication systems. The work is devoted to an actual problem of the development of the algorithm for determining the likelihood of security of information and telecommunication system of the existing threats of modern means of protection.

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Keywords: Information technology; telecommunication systems; security; data protection, model risk events

1. Introduction

Evaluating security of complex distributed information resources of information and telecommunication systems currently relies on the approach which is based on assigning a particular universal class of security to a system in terms of the degree of compliance with the mechanisms of securing typical configurations of protective measures implemented in the system. This approach is outlined in all existing Ukrainian and foreign regulations: the Law of Ukraine "On the Information Protection in Telecommunication Systems" of 05.07.1994 No. 80/94-VR which regulates relations in the sphere of information protection in information, telecommunication as well as information and telecommunication systems, specifies an interrelated set of organizational and engineering measures, measures and methods of information protection [1]; "Trusted Computer System Evaluation Criteria", USA [2]; "Information Technology Security Evaluation Criteria (ITSEC)" - information security standard, developed in Europe (France, Germany, the Netherlands and the United Kingdom) in 1991 [3]. However, security of information resources is one of the most important characteristics of any information and telecommunication system. And, as any characteristic, it must have a measuring unit, relevant reasoned methods and models for evaluating security of complex distributed information resources of information and telecommunication systems, that is an urgent issue in today's conditions.

The scientific significance of the paper is in the systematization and generalization of materials on evaluating security of complex distributed information resources of information and telecommunication systems against threats to information security; building new approaches and methods to evaluate the state of security of complex distributed information resources of information and telecommunication systems; building the method of forming a protection subsystem for distributed computer network that ensures a given security level of complex distributed information and telecommunication systems.

Distributed information and telecommunication system (DITS) can be represented as a geographically distributed system of local computing networks, telecommunication channels and means, as well as individual computers, intensively interacting in terms of data and control.

Due to DITS features, there are many different kinds of information security threats:

– operation errors;
– deliberate actions of violators and criminals;
– natural disasters and accidents;
– DITS equipment (hardware) failures;
– consequences of errors of design and development of DITS components.

1.1. The structural model of a distributed information and telecommunication system

The structural model of a distributed information and telecommunication system the allows decomposing information resources, as well as hardware and software of a system into a set of structural components available for inspection in terms of the impact of specific threats to information security, that allows evaluating security of information resources related to these structural components is shown in Figure 1.

Security of information resources (IR) is determined both by the parameters of protection means, components of information security subsystems (ISS) of a distributed information and telecommunication system, and by security threats parameters [4]. All parameters are probabilistic in nature, that is, the IR security can be described as a probability of preserving the state of their confidentiality, integrity and availability. In this situation it is advisable to apply the concept of "risk of an information security breach" which reflects the essence of threats realization processes.

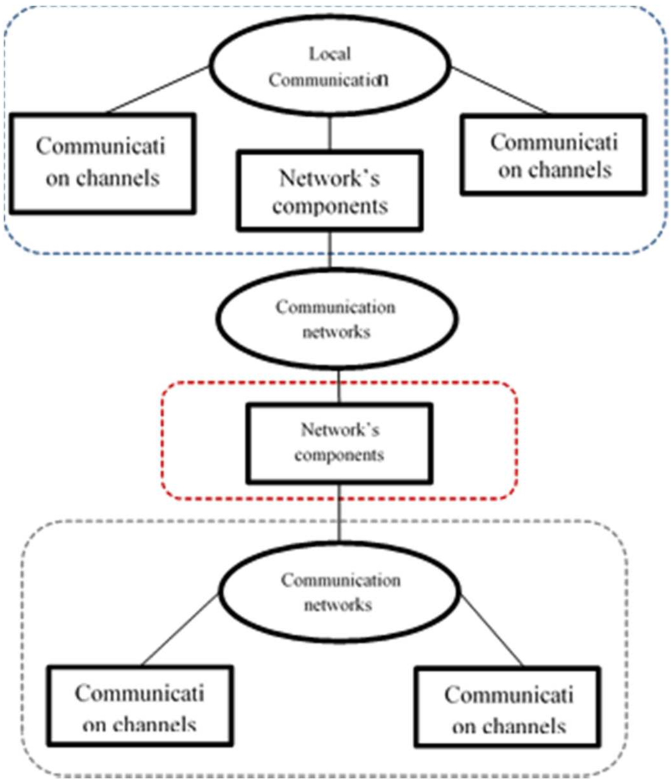

Figure 1. The structural model of a distributed information and telecommunication system

Information security (IS) system of complex distributed information and telecommunication systems can be represented as a hierarchy of links of five levels.

The first level of hierarchical protection model is individual protection means providing countering particular ways of realizing threats to IS in a dedicated structural component of a local environment functional link (end systems, communication means, local communication channels).

The second level of a protection system ensures countering specific way of realization of a threat to IS implementation by all means of protection of an information environment information security subsystem.

The third level of a protection system ensures security of complex distributed information and telecommunication systems in a component of functional link of the local environment against all ways of ways of realization of one threat.

The fourth level of a protection system ensures security of complex distributed information and telecommunication systems in a component of the local environment functional link against all threats to information security.

The fifth level of a system of protection of complex distributed information and telecommunication systems ensures security among all the components of the information environment against all the existing threats to security in general.

The model is based on the principle of equal importance and equal weight of the components of complex distributed information and telecommunication systems for all the possible ways of realization of possible threats to information security. This means that the risk assessment of IS breach is equal to the maximum risk of IS breach among the components of complex distributed information and telecommunication systems in this segment, that is the assessment is carried out on the most vulnerable component.

Practical implementation of findings enables building quantitative assessments of security of individual information objects that constitute information resources for each individual structural component of the complex distributed information and telecommunication system with which this object is associated by storing, processing and transfer procedures; obtaining, in accordance with the protection principle the assessments of security of individual information objects throughout the system as a whole and the formation on their basis the assessments of security of information resources of the system as a whole.

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SIMULATION AND SECURITY OF SENSOR NETWORKS

Abstract: Basic classification features of the sensor networks and security issues are analyzed as well as wireless sensor networks with different threats are simulated in this article.

Keywords: WSN, IEEE-802.15.4, ZigBee, simulation, security problem

MODELOWANIE I BEZPIECZEŃSTWO SIECI SENSOROWYCH

Streszczenie: W niniejszym artykule przeprowadzono klasyfikację sieci sensorowych. Ponadto, sieci sensorowe bezprzewodowe zostały opisane oraz przeprowadzono analizą ich zagrożeń. Analizowane zagadnienia symulowano za pomocą specjalnego oprogramowania, wyniki symulacji zagrożeń opisano w artykule.

Słowa kluczowe: bezprzewodowe sieci sensorowe, zasady IEEE-802.15.4, ZigBee, modelowanie, bezpieczeństwo

1. Classification of sensor networks

Wireless sensor networks (WSN) are developing rapidly and soon will occupy a dominant place among the data collection and communication. WSN is a set of sensors that are able to gather some data, transform it into electromagnetic signals that carry their broadcast, receive signals from neighboring sensors and retransmit them on the air [1].

Sensor is an integrated platform that combines the capabilities of sensors (acoustic, vibration, radiation, chemical, biological etc.) and microcomputers, that is connected to the wireless network. This allows the sensor to start their own processing and storage of the external information system.

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The main elements are the sensors to monitor the environment, microcomputer, and power supply and radio transceiver [2] as shown at the Figure 1. Items are autonomous sensor that contains everything to work.

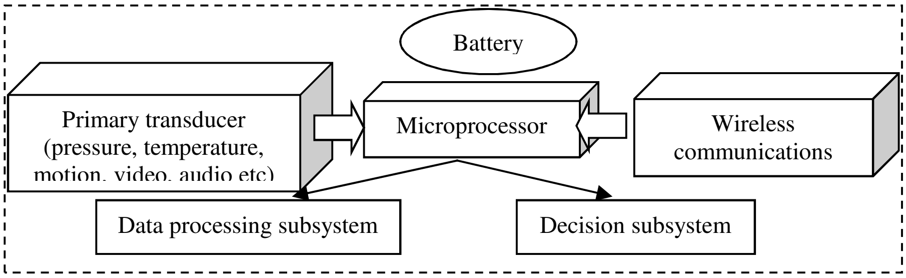

Figure 1. The structure of sensor technology elements

Sensors, which are characterized by low power and low data rate, form a WSN. The sensor, as any information and communication node and/or terminal, includes hardware and software. As shown in Figure. 1 sensor generally consists of three subsystems (monitoring, perception, processing) and communications system and power supply.

Monitoring subsystem allows the sensor to collect data on the environment: temperature, light intensity, vibration, acceleration, magnetic field, chemical analysis of air, acoustics etc. Just the monitoring subsystem determines an area or application which the sensor can be used in.

Subsystem perception usually consists of an analog device that directly takes some statistics and analog-to-digital converter that converts analog data into digital for further processing.

The data processing and decision subsystems include a data memory and CPU that can store and process the data generated by the sensor and system data necessary for the correct and effective functioning of the communication's subsystem [2].

To understand the technology of sensor networks are proposed classification features (see Figure. 2).

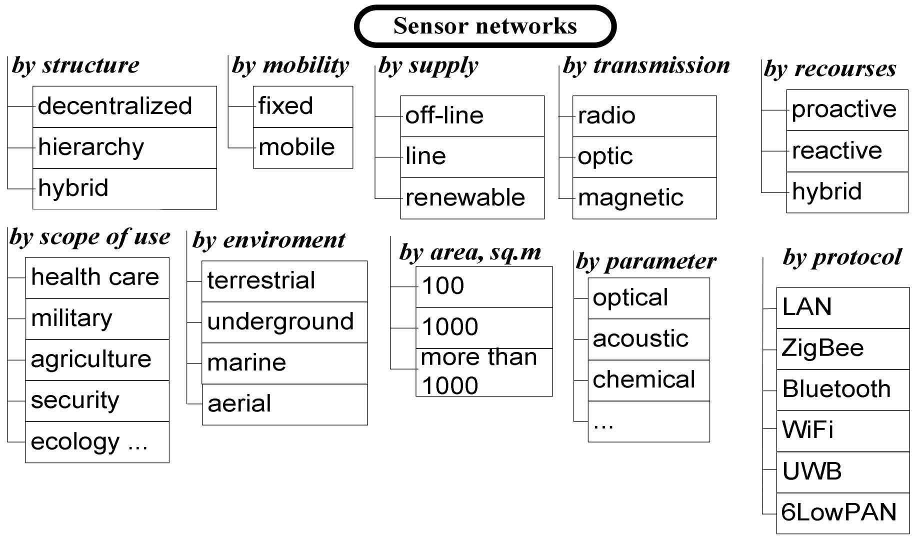

Figure 2. Sensor networks classification

By protocol: sensor networks can be built as wire or wireless networks. In the first case the LAN topology is used. In case of WSN, ZigBee, Bluetooth, WiFi or 6LoWPAN technology is used.

The best known of the protocols is *WSN ZigBee* protocol [3]. To develop a standard protocol stack for wireless sensor networks ZigBee Alliance used previously designed IEEE 802.15.4 standard that describes the physical level and the level of access to the medium for wireless data networks over short distances (up to 75 m) with low power consumption, but with a high degree of reliability. IEEE 802.15.4 standard is the basic foundation for the ZigBee protocol.

WSN is also implemented by using *Bluetooth* wireless technology [4]. These networks consist of a slave and basic devices (roles can be combined), capable of transmitting data in both synchronous and asynchronous modes. Especially for the WSN were proposed the low energy version of the specification v.4.0 Bluetooth wireless technology named the Bluetooth low energy (BLE).

To implement the WSN it is used a set of IEEE 802.11 (*WiFi*) communications standards. The IEEE 802.11s protocol can be used for the hierarchical organization of wireless ad-hoc networks with mobile and static nodes (mesh-network) [5].

WSN is implemented also on the basis of wireless communication technology at short distances at low energy *UWB* (Ultra-Wide Band) [3].

The *6LoWPAN* concept obtained from the idea that the IP is the more convenient protocol including the smallest devices and that low-power devices with limited processing capabilities have to carry the Internet of Things. The 6LoWPAN group has defined encapsulation and header compression mechanisms that allow IPv6 packets to be sent and received over IEEE 802.15.4 based networks. The target for IP networking for low-power radio communication is applications that need wireless internet connection at lower data rates for devices with very limited form factor [6].

There are sensor networks *by power supply*: self-powered (off-line), connected to the power supply (line) and renewable (energy that is collected from resources which are naturally replenished e.g. solar energy). This feature is very important because of

WSN nature which depends on battery or no, and thus can use or no different processing resources.

By structure: the decentralized, hierarchy or hybrid networks. The decentralized network consists of the similar sensors. These sensors perform distributed processing. Information transfer is carried out using multiple retransmissions (routing). One or more sensors are wireless external gateway, which in turn is linked to other networks (wired, cellular, and others). Cluster hierarchical architecture consists of different sensors (video, audio, and scalar sensors) transmitted data to the main node (cluster) that is responsible for the implementation of a centralized data processing. The head node sends the collected information through an external gateway hub in memory and the central station. Hybrid network combines both the similar and different sensors. Each layer performs different functional tasks. The similar low powered sensors are responsible for carrying out simple tasks, while the sensor devices with high power are responsible for the decision of the complex problems (processing, communication and so on) [1].

By mobility: fixed or mobile sensor networks are proposed depending on the scope of the possible use. Mobile sensor network is a special case named MANET [7].

By scope of use: proactive, reactive or hybrid network. The nodes of the proactive network periodically turn on their sensors and transmitters, read and transmit them to the base station. Thus, they make "instant picture" of his environment with some frequency, and it generally used for applications that require regular monitoring of certain values. Reactive network nodes with a certain periodicity read data, but do not pass them while the value stays in normal range. At the same time information about the sudden and sharp changes in the sensors readings or the normal range out is immediately transmitted to the base station. The hybrid network is a combination of the abovementioned types, sensor nodes periodically send captured data, as well as indicate sudden value changes [7].

By environment: depending on placing there are terrestrial, underground, marine and aerial sensor network.

By monitoring parameters sensor networks can measure acoustic, chemical and other parameters. Depending on monitoring environment, nodes use sensors and microcomputers, which register certain parameters (for example, radiation levels in the contaminated area).

2. Security problems of sensor networks

The remote location of the sensors and automatic operation increases their vulnerability to outside intrusions and attacks. Wireless connection is easy enough for the intruder to sensors packet interception. For example, most of the greater threat is the denial of service attack, devoted to break the correct functioning of the sensor network. There are various options for anti-theft security systems, but for many of them requires high resource requirements, that is difficult to achieve on a strictly limited sensor nodes. Therefore, WSN requires new solutions for creating keys, their distribution, identification and protection [8].

The problems of information security WSN can be divided into challenge and secondary problem (see figure 3). Priority targets are well known and include confidentiality, integrity, availability and authentication. Secondary security problem includes fresh data, self-organizing, time synchronization, localization data.

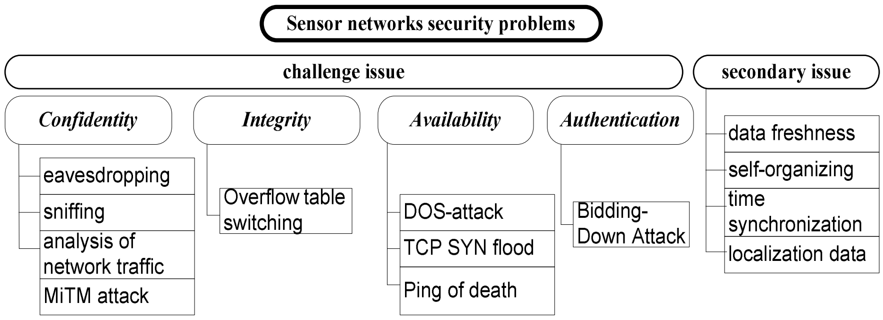

Figure 3. WSN security problems classification

Confidentiality in WSN needs to protect transmitted network data, thus close access to potential intruders through various mechanisms such as access control, encryption and so on [7]. Eavesdropping, sniffing and analysis of network traffic [9-11] use weakness in the network protocols and equipment. MiTM attack simple eavesdropping is a passive attack, in which an adversary`s goal is to steal some confidential information.

Authentication data is needed to confirm the authenticity of data through identification of origin/source and allows checking the legitimacy of the data sender and recipient. Authentication data is provided through the using of symmetric and asymmetric arrangements, which sensor network nodes send and receive for key exchanging. Because of WSN nature without constant involvement the providing of authentication data is quite challenging [8]. Bidding-Down Attack is possible in scenarios a list of choices to establish a secure channel is available, and the selection of the best pairing protocol is negotiated based on some criteria, such as device capabilities or user preferences [9].

Data integrity in WSN is the ability to protect data from changes during communication between the sensor network nodes. For example, network data integrity may be jeopardized in case of compromised network nodes that are implemented in WSN or in case of data loss or corruption due to unstable conditions. That is, you cannot deliberately affect their behavior, but you can prevent normal work and thus undermine fault area network or the entire network, e.g. overflow table switching [9].

Data availability implies the possibility of using sensor network transporting data between the nodes. In case of violation of property data, WSN can continue to operate and maintain the provision of its functions. The availability of WSN can be easily compromised by disrupting the base station or cluster head node. The general goal of adversary launching a DoS attack is to prevent communication between wirelessly connected nodes. However, in the case of device pairing, a DoS attack prevents two legitimate pairing partners from establishing a secure channel [9]. This type of attack is not aimed at obtaining access to the network or any information. DOS Attack makes network inaccessible to ordinary use by exceeding permissible limits the of a network node resource [11].

The freshness of data in WSN to determine which sensor data received and sent over the network for the first time, and not a copy of the old data repeatedly sent to the network. To ensure the freshness of the data in the data package can be implemented temporary counter that will serve as a signal to remove the package in excess of a certain value.
Self-organizing requires that each WSN is sufficiently independent and flexible to be able to heal itself in topology, depending on various situations. This property is necessary because the sensor networks are usually decentralized in natures, which do not have a fixed infrastructure. These features provide certain difficulties in ensuring security. In the absence of self-damage, the resulting attacks can be devastating.
Remote time synchronization is a necessary feature, which is based on the successful work of different mechanisms and protocols in sensor networks. As with any distributed system, time synchronization in sensor networks necessary to determine the total timeline for all nodes in the network and their local built-temporal mechanisms.
Protected localization is necessary to ensure the ability of sensor network with accuracy and automatically detect each node in the network (for example faulty node). Unfortunately, the attacker can easily manipulate unprotected location information, for example, using false reports of signal intensity or using reproduction signals [8].

3. Experimental study

To resourcing the WSN we tried to use different simulation software. The main goal is the looking for system which allows simulating different WSN with variety of injurious effects scenarios and protection methods.
The JTossim is a Graphical User Interface (GUI) to TOSSIM, the TinyOS simulator [12]. It allows defining simulation parameters (like radio settings and network topology) and provides different visualization of the results of simulations (see Figure 4).
As a small drawback should be noted functional environment of JTosSim. Therefore, we consider a different programming environment.
The TRMSim-WSN (Trust and Reputation Models Simulator for Wireless Sensor Networks) is a Java-based simulator aimed to test Trust and Reputation models for WSNs [13].
It provides several Trust and Reputation models and new ones can be easily added [13]. It allows researchers to test and compare their trust and reputation models against a wide range of WSNs. In this environment, static or dynamic network, the percentage of fraudulent nodes, the percentage of nodes acting as clients or servers, etc are chosen. It has been designed to easily adapt and integrate a new model within the simulator (see Figure 5).

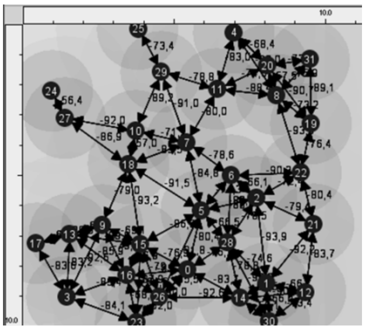

Figure 4. Example of sensor network simulation environment in JTosSim

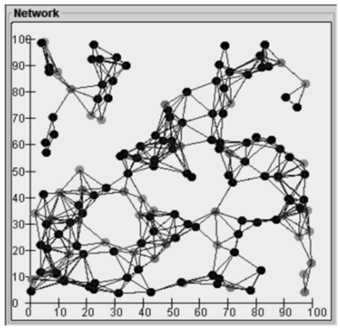

Figure 5. Example of WSN simulation environment in TRAMSim-WSN

Only a few classes have to be implemented in order to carry out this task [7].
As the parameters used to assess the effectiveness of:

- Accuracy (precision) - the accuracy of the model, that the accuracy of the choice of a trusted node for data transmission.
- Pathlength (path length) - the number of transitions ("hops") required for each network node to achieve the trusted node (cluster head or base station).
- Energy consumption (power consumption) - the amount of energy consumed by each type of network nodes.

After entering these values as: num executions 100, num networks 50, min num sensors 50, max num sensors 200, clients 19%, relay servers 18%, malicious servers 79%, radio range 9, have the following meanings Accuracy, Pathlength, and Energy consumption. The result of simulation is shown at the Figure 6.

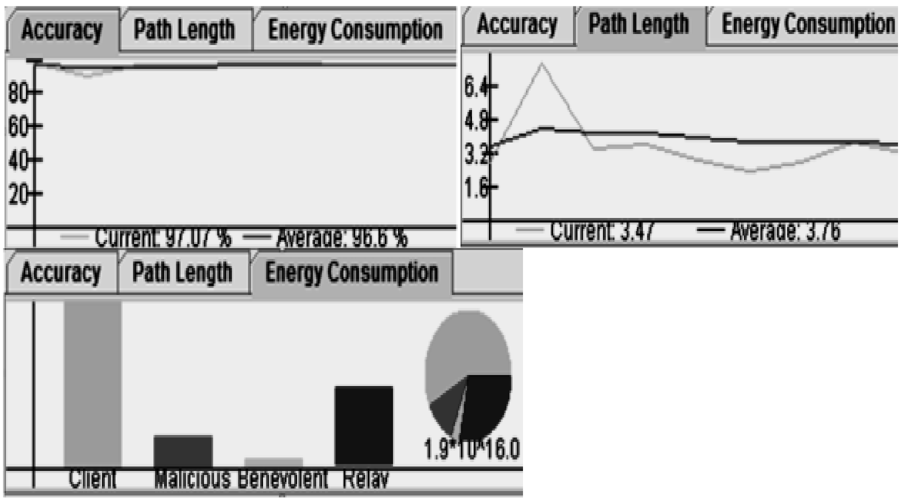

Figure 6. The result of the simulation TRAMSim-WSN with accuracy, path length and energy consumption

Result of application analyzing shows that the JtosSim and TRMSim-WSN not give up the methods and ensuring the WSN protection properly, thus it is required usage of other software.
It would therefore be considered Riverbed software.
Riverbed Modeler provides a modeling and simulation environment for designing communication protocols and network equipment. Riverbed Modeler Academic Edition incorporates tools for all phases of a study, including model design, simulation, data collection, and data analysis. Zigbee technology presents Riverbed software.
Topology refers to the configuration of the hardware components and how the data is transmitted through that configuration. They describe the physical and logical arrangement of the network nodes. There are three network topologies i.e. Star topology, Mesh topology, Tree topology.

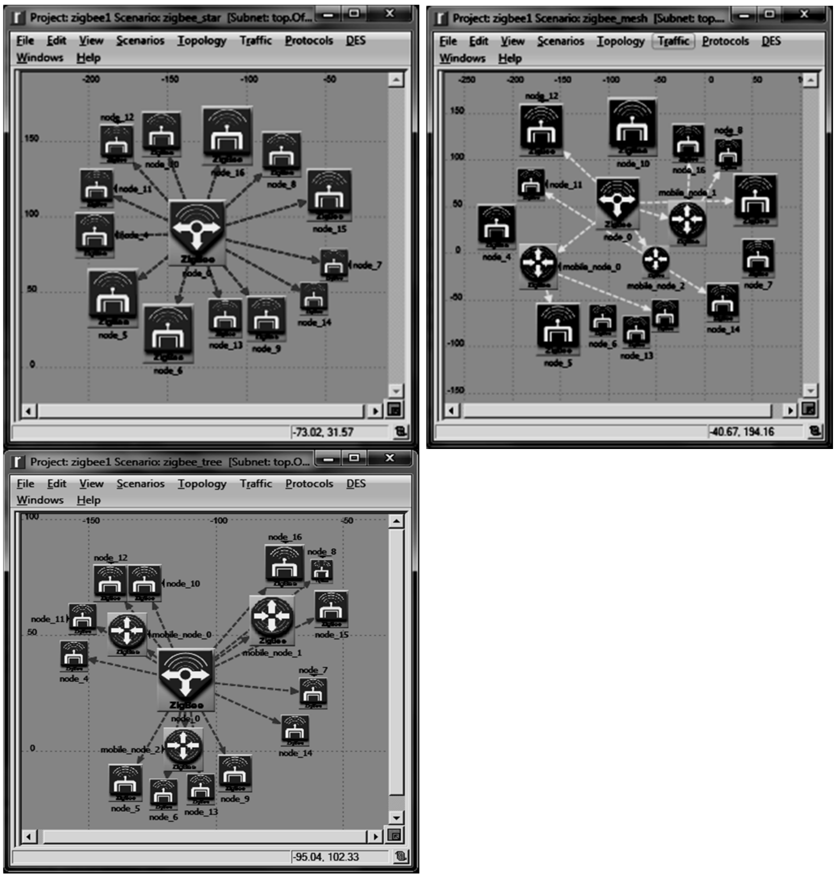

Figure 7. Simulation of Star topology (A), Mesh topology (B), Tree topology(C)

Simulating of all these topology discussed below:
A. Star Topology
The star topology consists of a coordinator and several end devices (see figure 7 A). In this topology, the end device communicates with the coordinator only. Any packet

exchange between end devices must carry through the coordinator. If a ZigBee end devices needs to transfer data to another end device, it sends its data to the ZigBee coordinator, which subsequently forwards the data to the intended recipient. The main advantages of star topology are its simplicity, predictable and energy efficient behavior. The drawbacks are limited scalability and coordinator as a single point of failure.

B. Mesh Topology

The mesh topology (Figure 7 B) offers multiple paths for messages within the network; this lends itself to greater flexibility than other topologies. If a particular router fails, then ZigBee self-healing mechanism will allow the network to search for an alternate path for the message to be passed. Mesh topology is highly reliable and robust. The advantage is that if any individual router becomes inaccessible, alternative router is rediscovered and used. The limitation of this topology is a higher communications overhead than the star topology, which can result in increased latency and lower end-to-end performance.

C. Tree Topology

The tree topology (Figure. 7 C) consists of a Coordinator, to which other nodes are connected as follows:

1. The Coordinator is linked to a set of Routers and End Devices - its children;
2. A Router may then be linked to more Routers and End Devices - its children.

This can continue to a number of levels. This hierarchy can be visualized as a tree structure with the Coordinator at the top. For every connected child router, additional child routers are also connected, creating different levels of nodes. In order the messages to be passed to other nodes in the same network; the source node has to pass the messages to its parent, which is the one level higher-up node. The message is continually relayed higher up in the tree until it is passed back down to the destination node. Thus, the number of potential paths of message is only one. A router therefore can be used in place of an end device in a tree network, but the message relay functionality of the router is not used. Only its applications are relevant.

After setting all parameters as shown at Table 1, ZigBee network model is ready for the simulation. The simulation results concerning the Throughput, End to End Delay, Number of Hops, across the full ZigBee stack, under different topology-deployment strategies with variable Back off Exponents, are analyzed.

Table 1. Installation options ZigBee

Parameters	Star	Mesh	Tree
No. of Sensor Nodes	50	50	50
Transmit Power	0.05	0.05	0.05
Number of Retransmissions	5	5	5
Maximum Backoff exponent	1	1	1
Maximum number Backoff exponent	5	5	5
Packet power Threshold	-80	-80	-80
Mesh Routing	Disabled	Enabled	Disabled
Transmission band (MHz)	2450	2450	2450
Transmit power (sensor nodes)	0.4	0.4	0.4
Transmit power(coordinator)	0.5	0.5	0.5
Packet size	1024	1024	1024
Packet inter arrival time (Constant)	0.5	0.5	0.5

End-to-end delay refers to the time taken for a packet to be transmitted across a network from source to destination.
Result shown at Figure 8 concludes that Mesh topology has maximum value of end to end delay whereas star topology has minimum end to end delay. This is due to more number of hops travel, information takes extra time in order to reach to its destination in mesh topologies and tree topologies as compare to star.

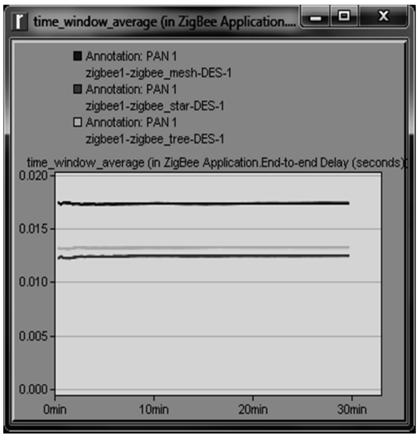

Figure 8. End-to-End Delay

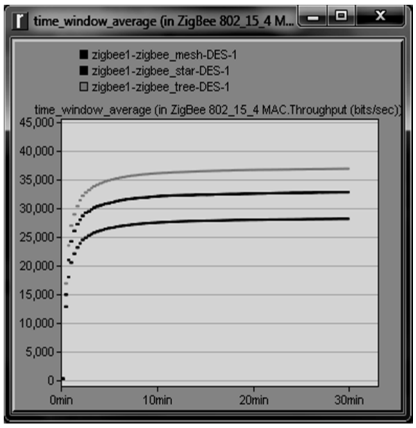

Figure 9. Average Throughputs of Star, Tree and Mesh Topology

Throughput is the ratio of the total amount of data that a receiver receives from a sender to a time it takes for receiver to get the last packet (Figure 9). Throughput is the data quantity transmitted correctly starting from the source to the destination within a specified time (seconds). A low delay in the network translates into higher throughput. Throughput is quantified with varied factors including packet collisions, obstructions between nodes and the type of used topology.
The above result shows the maximum throughput achieves in tree topology as compare to mesh and star (Figure 10).
Network Load represents the total load (in bits/sec) submitted to 802.15.4 MAC by all higher layers in all WPAN nodes of the network.

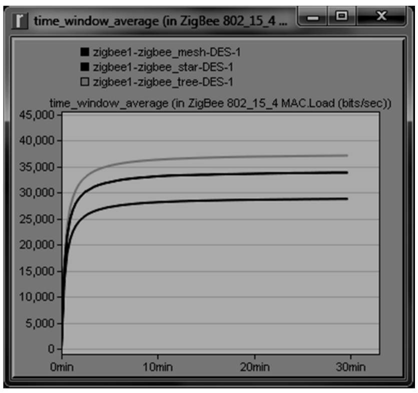

Figure 10. Network Load in Star, Tree and Mesh Topologies

Here we conclude that tree topology has the maximum networking load as compare to mesh and star topologies, this is because more number of hops travels by the data packets in case of tree topology rather than star and mesh.

CONCLUSIONS

Basic classification features of the sensor networks: by power supply, by protocol, by structure, by mobility, by transmission, by recourses, by scope of use, by environment, by area, by parameter are researched in this article.
The challenge and secondary security issues as well as the real attacks on WSN and WSN with different conditions and threat are analyzed.
We have analyzed the ZigBee/IEEE 802.15.4 standard using three possible topologies. In this work we provided a versatile analysis of the characteristics of the IEEE 802.15.4 topology formation process and the significant impact on the overall network performance using different parameters like throughput, MAC delay, number of hops, network load etc. The results show that tree topology outperforms among all other topologies. We performed an extensive simulation analysis, combined with a topological variation parameters related ZigBee wireless sensor networks. Overall, the performance evaluations show that the ZigBee can only be use for low-data rate and low-power smart grid applications not having very high reliability requirements and real-time deadlines. Sensor networks with malicious nodes are modulated.
The simulation of sensor networks with own security mechanisms is planning.

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OPROGRAMOWANIE ANTYWIRUSOWE PRZECIWKO ATAKOM HACKERSKIM DLA SYSTEMU OPERACYJNEGO ANDROID

Streszczenie: Ataki hackerskie możliwe do zrealizowania w przypadku użytkowania system operacyjnego ANDROID zostały przeanalizowane w artykule. W szczególności analizowano podstawowe cechy oprogramowania typu ‘spyware’, które służy do ujawnienia linków używanych przez pewnego użytkownika. Ponadto, analizowano znane programy antywirusowe wykrywające ataki hackerskie. Baza danych znaczników obecności wirusów oraz aplikacji do wykrywania działalności oprogramowania szpiegowskiego zostały dokonane i opisane w artykule. Niektóre z nich zostały udoskonalone i zaadaptowane do systemu operacyjnego Android. Analizy przydatności zostały przeprowadzone i są opisane w artykule.

Keywords: Android, wirusy komputerowe, oprogramowanie szpiegowskie, wirus Trojan, detekcja, podpis – znacznik obecności wirusa

PROTECTION TOOL AGAINST MALWARE FOR ANDROID OPERATING SYSTEMS

Abstract: Peculiarities of malware performance developed for the operational system Android were analyzed, in particular spyware performance basics were considered. Known malware detection algorithms were analyzed. The signatures database and the application for spyware scanning of operational system Android were developed based on these analyses results.

Keywords: Android, malware, spyware, trojan programs, detection, signature, application permissions

Introduction

Mobile devices are gaining popularity increasing among users each year. And main mobile platform at the market is Android operating system. According to the recent data of the analytical agency Kantar Worldpanel ComTech Android nowadays covers

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a huge percentage of the European market – 70.4%, while iOS has 17.8% [1]. Although the Android kernel is based on Linux, it stands somewhat aloof from Linux-community and its development frameworks. The basic element of the operating system is Dalvik the implementation of the Java virtual machine, and all its software and applications base on this operating system element [1].

According to the latest report of the research company Gartner, in a few years Android platform could become the most popular operating system in the world [2]. Therefore increasing popularity of Android causes increasing quantity of applications for this operating system. Thus, the amount of risks and the number of threats associated with the installation of these applications are increasing respectively [2]. That's why it is important to develop software tools, which allow to reduce those risks for a user of such applications.

The goal of this research was to reduce the possibility of malware installation (mostly focusing on the spyware and Trojan horses). The following tasks were solved for achieving this goal:

- analysis of the current state of malware protection at Android and its features, which could be used for malware protection;
- determining of malware presence signatures;
- malware detection method designing;
- software tool development for this method implementation.

The several key features that distinguish devices based on the Android platform from similar products are pointed out by its developers from Google [2]:

- Android lets user access the main functions of mobile devises using standard API;
- application framework providing to developers ability of reusing and sharing different applications components;
- user can combine information from the web with data stored at the phone, such as contact information or data concerning user's current geographical location;
- there is no difference between standard phone applications and third-party software;
- depending on the equipment it allows to implement GSM and CDMA telephony and wireless data sharing technologies (Bluetooth, EDGE, Wi-Fi etc);
- provision of database processing using pecular database managment system SQLite;
- built-in support of multimedia encoding (MPEG4, H.264, MP3, AAC, AMR, JPG, PNG, GIF);
- fairly supported SDK allows to create and run Android applications, including real simulator device and advanced debugging tools.

The draft of the main Android components is presented in Fig. 1.

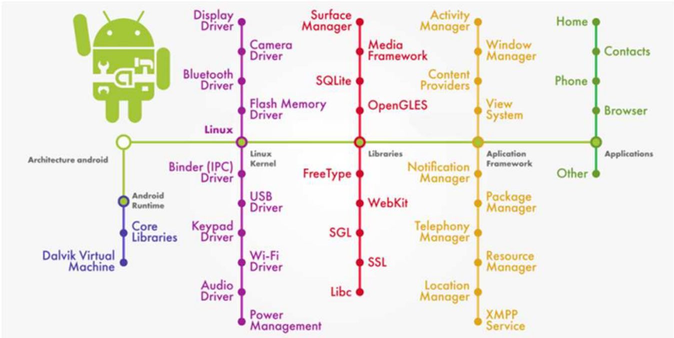

Figure 1. Operating system Android components

All software, which is available at the App Store, is a preliminary tested. Installation of the not official application is unavailable for users. Android is a platform for mobile devices, developed by Open Handset Alliance (OHA), which is initiated by Google [3]. It allows to create Java-applications, manage device by special libraries for a common developer, which increasing pace of Android improving. However it is also granted to intruders ability to develop applications using other platform-oriented programming languages, such as C++, by using the Android Native Development Kit [3]. There are also support of recording and viewing video by the device camera; both support of communication interfaces, such as Bluetooth, and ability to connect automatically to them among other Android features, which is in particular interest for the spyware developers.

So, diversity of Android features encourage intruders to develop malware, because this process doesn't much differ from the developing of the common application. Combining of the latter and a lot of personal data usually being stored at the mobile devices creates good reasons for the spyware development. That's why some security measures are to be performed before application installation.

Nowadays Android operating system includes different implementation drawbacks, ranging from low-level protection in the basic Linux kernel (including libraries components and Application Framework) to the very applications themselves [2]. Thus high level of Android operating system driven platforms openness allowed it to become the market leader of mobile devices' system software, but it causes widely recalled fragmentation [3]. Usually such actions as money stealing from the mobile account or payment card, theft of personal information including listening, location monitoring, accessing to the camera performed using malware programs, which somehow were previously installed on the victim's device. In most cases the malware is gotten by guising itself as harmless applications, browsers, music players, games, books and even antivirus [3]. This is achieved by malware by just "pretending" to be original and actually bearing a rather different purpose, or it could be the original application, which were altered by addition of certain malicious code sequence. Android version 6.0 issuing allows to control applications access to personal data, cameras, memory and other device resources. Consequently mobile device user has gained the ability to enable or disable permission for the application to access operating system features and mobile device resources. This allows to significantly reduce the insertion of spyware installed into applications. But today version 6.0 isn't installed on older devices. According to research performed by Google of the most popular operating system in this family Android 4.4 KitKat is the most popular system version, which is installed on 39.8% of devices. Jelly Bean is the second one with 39.2% of devices. All results are presented in Fig. 2 [6].

Version	Codename	API	Distribution
2.2	Froyo	8	0.2%
2.3.3 - 2.3.7	Gingerbread	10	3.0%
4.0.3 - 4.0.4	Ice Cream Sandwich	15	2.7%
4.1.x	Jelly Bean	16	9.0%
4.2.x		17	12.2%
4.3		18	3.5%
4.4	KitKat	19	36.1%
5.0	Lollipop	21	16.9%
5.1		22	15.7%
6.0	Marshmallow	23	0.7%

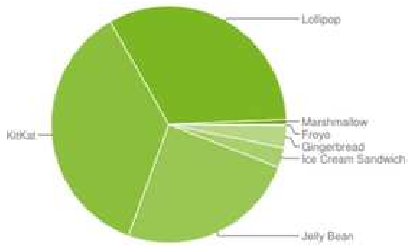

Figure 2. Popularity of different Android versions

It appeared from these result analyses, that 99,3% of mobile devices running operating system Android couldn't use the latter security features. Moreover to implement this features users should know all the features of application being installed and understand Android operating system architecture.

Therefore it is rather possible for the intruder to insert malicious code into applications and manage mobile device of other users when they wouldn't even suspect this. Nowadays it is possible to watch the progress of both operation system Android protection development and intruders ways of breaching it.

The research was focused on the program backdoors finding among installed applications, and development of the software tool for installed on mobile devices applications scanning to detect malware. The research was conducted using specially developed user listener embedded in mobile game as an instance of malicious software. Listening was carried out by means of the microphone in the mobile device. The installation process of the game by the user were simulated.

During the installation process the operating system alerted user about needed access parameters, which were asked for the application. Once the permissions had been granted, the game was set.

The analysis of these actions performed research showed, that statistically 70% of mobile devices users with Android operating system grants access to all components without paying attention to the potentially dangerous parameters [4]. That's why it was considered, that the game was successfully installed with all permissions granted. To decide which permissions are to be granted the user must bear in mind the purpose of the installed application. For instance, it is obvious, that the common game does not need providing of sending SMS. Such non-functional needs of application access should alert the user. On the similar basis all possible permissions were analyzed and the most dangerous ones were determined. There are the following ones among them:

– the request of root privileges
User with root privileges could manage operating system without any restrictions. By default, Android such privileges isn't granted, because inexperienced users can mess their mobile devises. Root privileges are granted by the process, which is called "Rooting the Android device". And if the application gets these privileges it can perform whatever it pleases. For a instance of showing how the application runs the shell-script with super-user privileges to restart the device:

```
Try{
String[] reboot = new String[] { "su", "-c", "reboot" };
Process process = Runtime.getRuntime().exec(reboot);
process.waitFor();
} catch (Exception e) {
Toast.makeText(getApplicationContext()," Device not rooted.\n
Could not reboot...",Toast.LENGTH_SHORT).show(); }
```

– permission requests for personal data reading and writing:

```
<uses-permission
android:name="android.permission.READ_CALENDAR"></uses
-permission>
<uses-permission
android:name="android.permission.WRITE_CALENDAR"></use
s-permission>
<uses-permission
android:name="android.permission.READ_CALL_LOG"></uses
-permission>
<uses-permission
android:name="android.permission.WRITE_CALL_LOG"></use
s-permission>
<uses-permission
android:name="android.permission.READ_CONTACTS"></uses
-permission>
```

– message sending request:

```
<uses-permission
android:name="android.permission.SEND_SMS"></uses-
permission>
```

– instance of SMS sending:

```
String message = "Hello Android fans! ";
String number = "xxxxxxxxxxxx";
SmsManager.getDefault().sendTextMessage(number,null,
message, null, null);
```

– user location request:

```
<uses-permission
android:name="android.permission.ACCESS_COARSE_LOCATION"></u
ses-permission>
```

Thus, considered situations of personal data leakage could be caused by careless users. But it is also possible, that the certain spyware could use microphone both for user purposes and for parallel user listening by mobile device for intruder purposes. In this case the only action user are to perform to become victim is malware executing. And that's why the protection should be developed against this threat.
To solve this task mobile application was developed, that searches dangerous software within Android operating system,. The software is based on the signature and heuristic methods [5]. The heuristic method concerns analyses of actions, processes, connections of installed applications on a mobile device.
The draft of Android application analyses using signature search method is presented in Fig. 3.

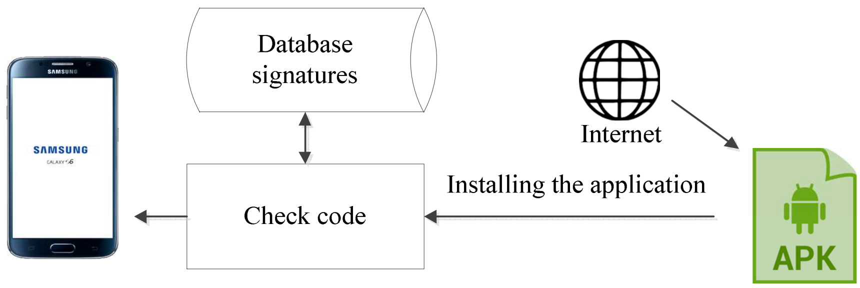

Figure 3. Application code review using of malware signatures database

The application has two scan options, the first one is scanning on the user demand and the second one is scanning determined by the schedule (the schedule is designed by the user using application settings). Besides installed application, the scanning covers files, which were saved by user as a result of browsing and are stored at the Download folder. There are also enhanced security mode, in which files stored at the memory card are checked if any kind of their change is performed.

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DWUKRYTERIALNY PROBLEM KOMIWOJAŻERA – PROGRAM WIZUALIZACYJNY

Streszczenie: Artykuł zawiera opis działania programu i zawartych w nim algorytmów dla dwukryterialnego problemu TSP. Problem TSP będzie rozwiązywany przy użyciu algorytmów genetycznych, w których zdefiniowano specjalne operatory mutacji oraz krzyżowania, przy określonych parametrach populacji i procentach mutacji. Zostanie pokazane również porównanie algorytmów turniejowych dla wyboru elementów przechodzących do kolejnej populacji.

Słowa kluczowe: TSP, mutacja, krzyżowanie, algorytm turniejowy

BI-CRITERIA TSP – VISUALIZATION PROGRAM

Summary: The article contains a description of a program and contained there algorithms for bi-criteria TSP problem. The TSP problem is solved by means of genetic algorithms, in which special operations of mutations and crossover were defined, with the specified parameters of the population as well as chosen percentage of mutations. It will be shown some algorithms' comparison for choosing the best tournament of the passage to the consecutive populations.

Keywords: TSP, mutation, crossover, tournament algorithm

1. Introduction

The Traveling Salesman Problem (TSP) belongs to the classic graph theory problems [13, 14]. However, in the present paper it is considered in bi-criteria or bi-objective approach.

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In general, there is not known any standard, simple and effective algorithm to solve this problem, so called classic procedure as for example Kruskal, Prim and Boruvka algorithms for minimal spanning tree problem. In case of multi-criteria approach it even becomes more difficult to solve. Therefore, some algorithms belonging to the field of artificial intelligence have been recently utilized e.g. ant colony [1, 4, 7], fuzzy linear programing [3], simulated annealing [6], shuffled frog-leaping [8] and evolutionary [12]. We decided to choose the evolutionary approach because it is relatively easy to program as well as it has been described as successful in some classic books dedicated to evolutionary algorithms [2, 5, 9, 15]. In these books, also, proposals of dedicated evolutionary operations are given. Moreover, evolutionary algorithms can be tailored to multi-objective approach [11, 12]. General remarks and analyses of evolutionary multi-objective considerations can be found in the book [10]. The presently described program has been done as a project on the master level of computer science. It has also additional goal i.e. to visualize the results of calculations during its operation as well as monitoring the course of algorithm throughout of the full performance course until reaching the stop condition.

2. General description of the problem

We consider the bi-criteria Traveling Salesman Problem i.e. searching in a particular graph G(V, E, f1, f2) for the shortest closed path passing through every graph vertex exactly one time.

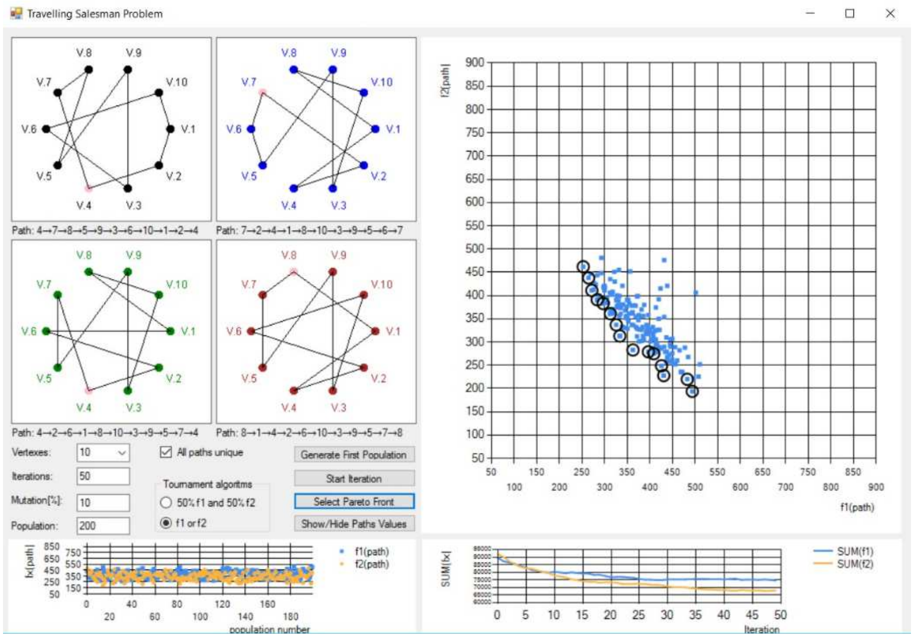


Figure 1. General appearance of the program

The problem was restricted to some special cases. So, we assume that the graph is a full, regular graph i.e. clique. Number of vertices n = |V| was also assumed as

relatively low n =10. Due to this assumption, the path is represented by a permutation of the names of its vertices, because all connections are possible.
The approach is theoretical, therefore the values of objective functions f1 and f2 (f1, f2: E →N) were generated randomly. The view of the program screen is shown in Picture 1. The screen is divided in several sub-windows showing: the closed paths as graphs drawn on circles. Values of evaluation of all members of current population. Moreover, the monitoring of course of the algorithm in two charts showing variability of the best members evaluation f1, f2 as well as total sums of population weights. In our program we show the visualization for the bi-criteria Traveling Salesman Problem. The final stage, it could be distinguishing of Pareto front. We use genetic algorithm with operations such as mutation or crossover. In performance of algorithm, we also use two tournament algorithms which can be switched during visualization, just for their comparison.

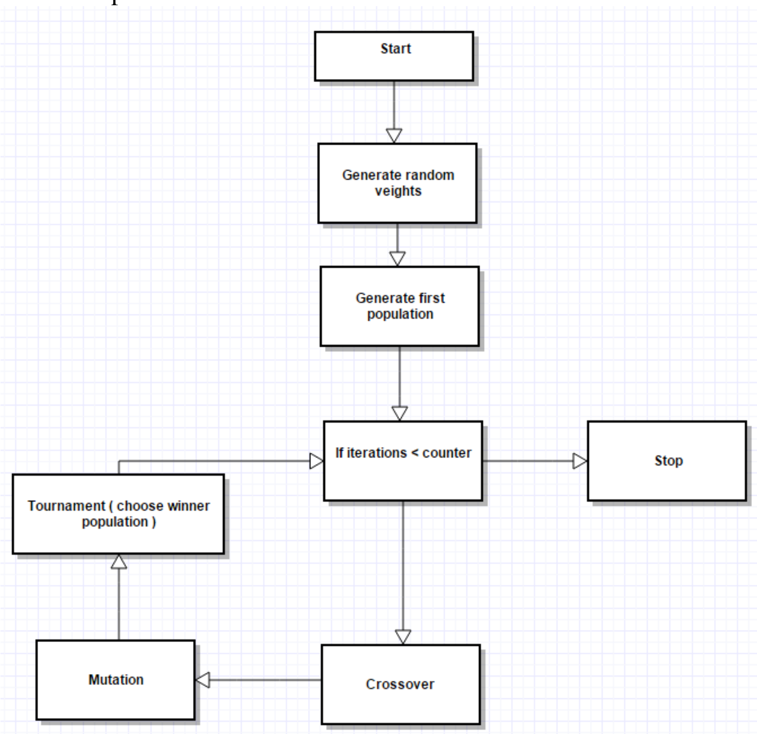


Figure 2. Basic program flow

At the beginning we need to define start values (parameters) for our visualization like: population size, number of iterations, percentage of mutation (how much percentage of population will be mutated) as well as numbers of vertices which will be used for our simulation. Also we can define, if our paths in population can contains duplicates or they're need to be unique. Our program can show differences between different approaches using the same variables. We can also change the tournament algorithms and unique path option during each iteration to show how the results on diagrams will change.

We assume that our weights are generated randomly from range 1 to 100 for both $f_1(x)$ and $f_2(x)$. Those weights are generated separately, so there is small chance that $f_1(x) = f_2(x)$. The exemplary randomly drawn values of target function are presented in Picture 3. One can see the matrices of values of these functions are symmetrical.

0	1	2	3	4	5	6	7	8	9	10
1	0	6	79	15	38	55	24	47	51	91
2	6	0	1	9	55	8	48	45	98	38
3	79	1	0	87	97	43	6	48	17	34
4	15	9	87	0	10	61	51	72	46	86
5	38	55	97	10	0	80	69	48	96	32
6	55	8	43	61	80	0	31	93	10	26
7	24	48	6	51	69	31	0	83	27	40
8	47	45	48	72	48	93	83	0	68	62
9	51	98	17	46	96	10	27	68	0	86
10	91	38	34	86	32	26	40	62	86	0

0	1	2	3	4	5	6	7	8	9	10
1	0	59	42	27	33	81	55	61	48	71
2	59	0	77	20	20	32	70	32	21	39
3	42	77	0	57	60	79	63	15	17	47
4	27	20	57	0	68	98	5	73	21	12
5	33	20	60	68	0	87	38	66	33	46
6	81	32	79	98	87	0	17	94	68	8
7	55	70	63	5	38	17	0	24	91	57
8	61	32	15	73	66	94	24	0	92	54
9	48	21	17	21	33	68	91	92	0	82
10	71	39	47	12	46	8	57	54	82	0

Figure 3. Input data matrices

For each iteration, next generation is generated by crossover of the old one and the mutation after the mentioned crossover. We also assume that the percentage of mutation items is around x% of population. That means, if we declare 20% of mutation, the 20% items of population might be mutated.

All we want to achieve is to get the best path with smallest $f_1(x)$ and $f_2(x)$ which does not mean that it's the smallest value of $f_1(x)$ and value of $f_2(x)$ at all. We want to find the best path for both f_1 and f_2 at same time, which makes this problem as a bi-criteria TSP. Applying few different approach, one can easily spot the difference by looking at the resultant diagrams, so user can use few ways to achieve our goal. All algorithms and their definitions as well as the screens are roughly described in next chapter.

3. Applied algorithm and remarks on computer program

3.1. Crossover

Firstly, genetic algorithm used in our application, performs mutation with repair operation included in it standard execution. Cross over is a process of taking two parent solutions and producing a children solution from them.

First we need to select point where 'cut' operation will be performed- it's selected randomly. Single, same crossover point on both parents organism strings is selected. All data beyond that point in either "organism string" called as chromosome or code is swapped between two parent chromosomes. The resulting chromosomes are the children. In our programm it can look like this:

1st parent: 1-2-5-4|3-6-8-7

2nd parent: 5-4-1-2|7-8-3-6

1st Child: 1-2-5-4-7-8-3-6

2nd Child: 5-4-1-2-3-6-8-7

In aforesaid example every child (called sometimes offspring) is produced with unique point inherited from both parents. But it can happen that same point(s) will be in both parts after crossover operation:

1st parent: 1-2-5-4|3-6-8-7
2nd parent: 5-4-1-3|7-8-2-6
1st Child: 1-**2**-5-4-7-8-**2**-6
2nd Child: 5-4-1-**3**-**3**-6-8-7

Every item represents the graph vertex, therefore the current solutions are not the TSP routes. So repair operation should to be performed because we can't have duplicated points, every point must be unique.

```
for (int j = 0; j < secondB.Count; j++)
{
  if (!newChromosomeFirst.Contains(secondB[j]))
{
  newChromosomeFirst.Add(secondB[j]);
}
    else
{
      for (int z = 1; z <= pointsCount; z++)
{
         if        (!newChromosomeFirst.Contains(z)        &&
!secondB.Contains(z))
{
         newChromosomeFirst.Add(z);
         break;
}}}}
```

First we add first part of one parent. Then we look through each point of second part, from other parent, to check for duplicated values. If no duplications were found then whole part is added without any change. But when we find that point from second part already exist in child then we simply pick first value that is not included either in first part or second and insert it instead of duplicated value. And we do the same for every child.

3.2. Mutation

Second genetic operation being integrated part of the algorithm used in our application is mutation. It runs for a defined percentage of the population. Worth to mention is that percentage of mutation is not assured, but will oscillates around defined value. It is because we use clock time generator to select which chromosome should be mutated instead of i.e. taking first x% of the population. It gives certainty that all chromosomes have the same probability of being mutated.
Once chromosomes are chosen, mutation will run for each. Mutation is choosing two random points and replace its values. This way gives us 4 different values between points in new path.

Example of mutation for chromosome that contains 8 elements (or red paths that after mutation will change values):
5→2→7→4→1→8→3→6
←-----------------
Mutate (2→8)
5→6→7→4→1→8→3→2
←-----------------

Other mutation ways and other operations can be found in the cited books [2, 5, 9].

3.3. Tournaments

In our program we used two types of tournaments to find the best paths passing throughout all vertices. They are define for the chromosome codes of elements. First of them divides a population into two groups. For the first group it compares values of the paths for both populations counted for a first matric variables. Depends on which population has smaller value (better result) it is added to a winner population. In that group we do not look on population value for a second matrix. That is made for a second group. In that group we compare only results of population counted for a second matrix values. It is connected with bi-criterial problem In case of greater number of targets population is divided in greater adequate number of subpolutions.

```
for (int i = 0; i < population.Count / 2; i++)
{
  if (f1ValuesPopulation1[i] < f1ValuesPopulation2[i])
    winnerPopulation.Add(population[i]);
  else
    winnerPopulation.Add (populationSecond[i]);
}

for (int i = population. Count / 2; i < population.Count; i++)
{
  if (f2ValuesPopulation1[i] < f2ValuesPopulation2[i])
    winnerPopulation.Add(population[i]);
  else
    winnerPopulation.Add(populationSecond[i]);
}
```

Second tournament compares sum of values counted for both population. If sum of values counted for first population is smaller than for a second population, then is added to a winner population, otherwise second population will appear on the tournament for a next iteration.

```
for (int i = 0; i < population.Count; i++)
{
  if ((f1ValuesPopulation1[i] < f1ValuesPopulation2[i] ||
f2ValuesPopulation1[i] < f2ValuesPopulation2[i]))
    winnerPopulation.Add(population[i]);
  else
    winnerPopulation.Add(populationSecond[i]);
}
```

Program performance can be observed during the conference session. Then the results for other sets of parameters will be compared and analyzed.

4. Visualization of the program results

In Pictures 4-7, we can observe the values of evaluation of the particular population contents by means of functions f1 and f2. Value of a particular path is obtained via summation of adequate weights of all graph edges belonging to the considered path. Analyzing the pictures which are drawn after e.g. 1, 5, 10 and 15 iteration, respectively.

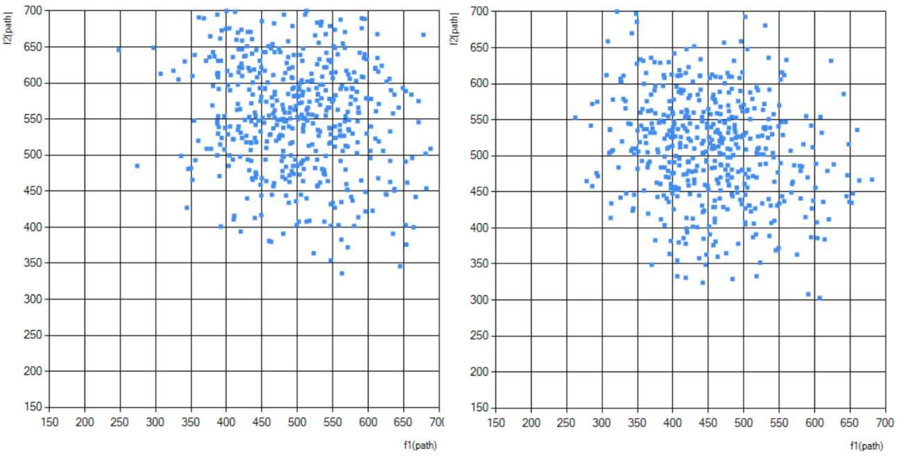


Figure 4. On left starting value of the program, on right result of use first tournament after 5 iterations.

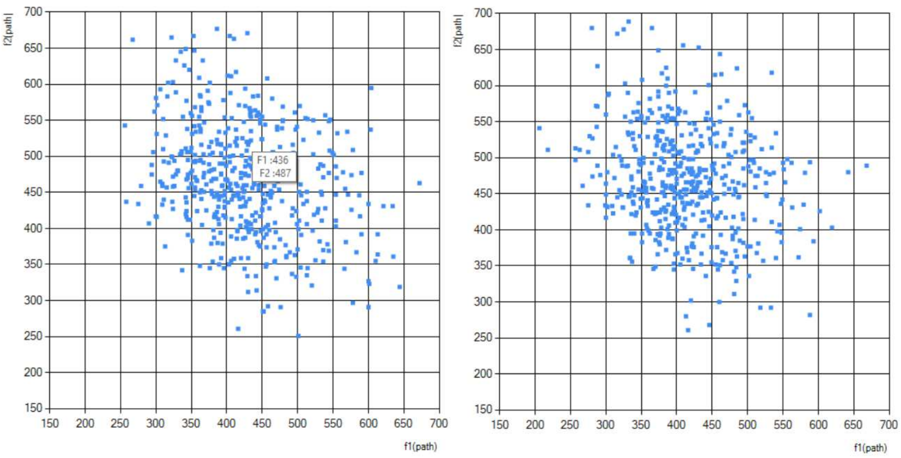


Figure 5. Result of use first tournament after 10 iterations (left) and 15 iterations (right).

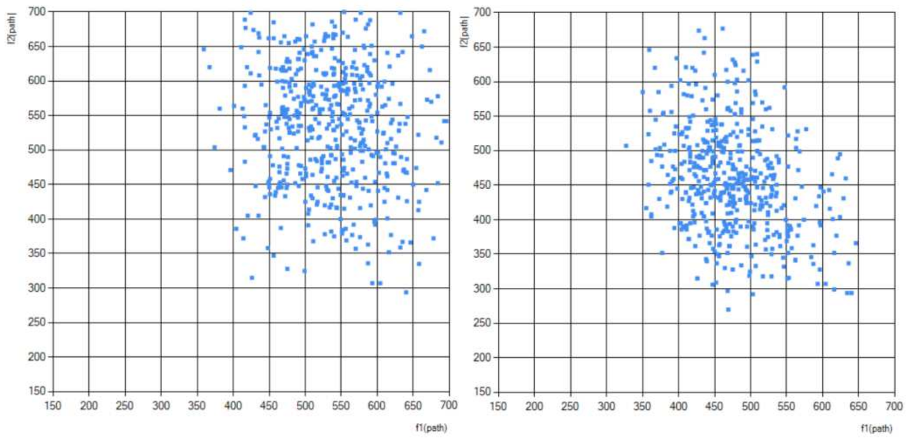


Figure 6. On left starting value of the program, on right result of use second tournament after 5 iterations.

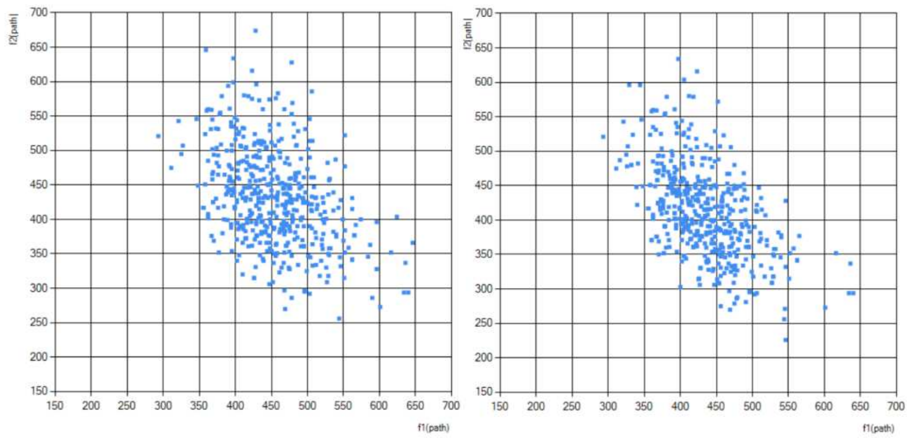


Figure 7. Result of use second tournament after 10 iterations (left) and 15 iterations (right).

We can observe the tendency to shifting of the cloud of results towards the both axes as well as towards the origin of the co-ordinate system.

Other analyses can be observed in Pictures 8-10. The summary results are registered for each iteration of the program i.e. minimal values of functions f1 and f2 for individual paths as well as adequate sums of f1 and f2 for all elements belonging to the consecutive iterations. We can observe local fluctuation of variability of these evaluation indicators. Their character is connected with the essence of evolutionary algorithms, especially of their randomness. Nevertheless in longer terms the lowering tendency could be spotted.

The present work is on the student project level, in case of professional science attempts described in the cited papers, better achievements are connected with advanced artificial intelligence algorithms, special operations, special form of chromosomes, hybrid algorithms and many other sophisticated solutions.

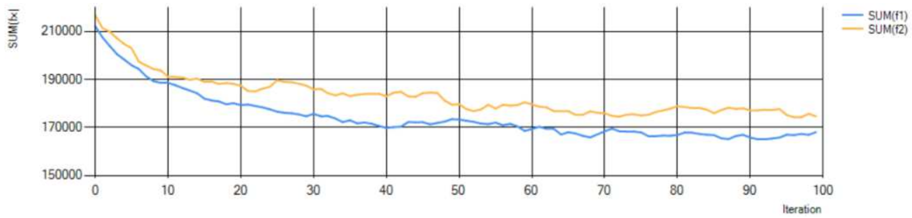


Figure 8. Graph shows impact of mutation and crossing on population with use tournament which divide population into two groups and compare only one value from each matric.

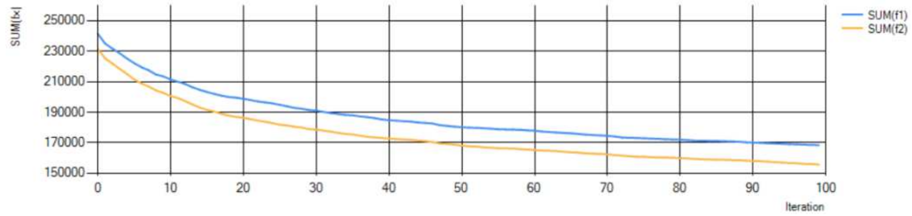
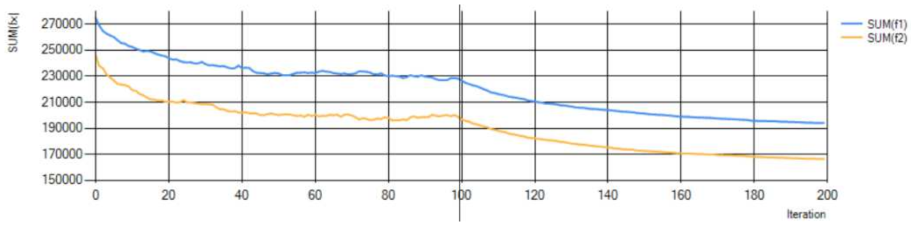


Figure 9. Graph shows impact of mutation and crossing on population with use tournament which takes the smaller value for population from both matric.



Picture 10. Comparison of both tournaments.

Picture 10 shows comparison of results for both tournaments. As we can see that the first tournament (first 100 iteration on graph) can only partly optimize path. It is because we do not compare values for both criteria, simultaneously. Using second tournament (second 100 iterations), which compares sum of both values for both populations the results are slightly. It ensure that we do not get worse chromosome values between iterations.

5. Conclusions

The described computer program solved the bi-criterial travelling salesman problem in the following sense that it generates a population of results based upon which the Pareto front can be distinguished. The visualization allow for presentation of: exemplary paths, their codes, full contents of population in the f1-f2 co-ordinate charts as well as course of the best (minimal) values of target function in the (f1,f2)-number of iteration chart. The program contains procedures programed originally by the authors. It could be used for educational purposes. Moreover it itself represent successfully solves advanced programmers task.

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SKUTECZNY I AUTOMATYCZNY TEST PENETRACYJNY KORZYSTAJĄCY Z DOCKERA W CHMURZE

Streszczenie: W niniejszym artykule omówiono testy penetracyjne jako aktualną proaktywną technikę do oceny bezpieczeństwa zasobów internetowych. Porównano dwie metody: konteneryzacji typu Docker i standardowej metody wirtualizacji. W pracy omówiono wdrożenie technologii Docker ze strategią docker-compose. Docker model klastra swarm został zbudowany na infrastrukturze Amazon Web Services. Zautomatyzowane algorytmy planowania testów penetracyjnych w oparciu o częściowo obserwowalne procesy decyzyjne Markowa (POMDP) zostały omówione.

Słowa kluczowe: test penetracji, POMDP, procesy decyzyjne, audyt bezpieczeństwa, chmura, doker, automatyzacja, kontenery, skrypty, wdrażanie, luka

EFFICIENT AND AUTOMATED PENTESTING BY USING DOCKER IN CLOUD

Summary: Penetration testing was discussed as real proactive technique for security evaluation. Docker containerization and standard virtualization approaches are compared. Docker technology implementation with docker-compose deployment strategy was suggested. Docker swarm cluster model was built on Amazon Web Services infrastructure. Automated penetration testing planning algorithms based on partially observable Markov decision processes (POMDP) were discussed.

Keywords: penetration test, planning, POMDP, decision processes, security audit, cloud, docker, automation, containers, scripting, deployment, vulnerability

1. Introduction

Our previous research topics were related to penetration testing, its phases and detailed explanation about it as a component of professional security testing and validation of vulnerabilities. Pentest is the one of the most important parts of the full security audit. It is used for proactive defense and information systems protection.

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You've been living under a rock if you haven't noticed the high profile security breaches that have shaken the technology industry in recent years. From huge government spying scandals to the countless company databases infiltrations, we have never been more aware of the need for securing the complex systems on which we so heavily rely on. Security awareness is at an all-time high, but the information security profession largely still remains out of reach for most in the tech industry. Nowadays, cyber attacks on information systems or networks have become one of the greatest threats to the world of business and economics. Furthermore, that attacks are then one of the weapons during modern hybrid war. Amount of damage has been growing every day and more companies or institutions have become victims of attacks or data breach performed by black hats.

Hence, companies are looking for best way to protect their systems and essential information. Most popular way is to probe their systems via penetration tests by certified ethical hacker teams, which can proactively defend computer systems. A lot of work had been done by ethical hackers for last 20 years to involve automation in penetration testing, but most of solutions are not very useful. So modern tendency is related to automate of everything related to pentesting, start from environment build, pentest execution, report generation and then pentest system shutdown. One of the main benefits of testing in the cloud platform is that the whole penetration system can be deployed there rapidly and we can manage it from any point in the world by remote access [2].

For example, we used a few scripting languages for creation of automated exploit execution via Metasploit framework. This is only simple automation in order to run pentest on existing environment. However, we need to install new Kali Linux image (or other hacker's OS), update OS, update all existing security tools, start all appropriate services or utilities and only then we can start penetration testing from the first phase, as it was established by best practices and security methodologies (NIST, OSSTMM, PTES, OWASP) [1].

That manual preparation for every new penetration testing is very trivial and sometime really time-consuming procedure. It is wasting of time, which pentester can use to find more important and complicated vulnerabilities in target systems. That's why automation of many routine processes and clear environment preparation is vital for security expert nowadays. This automated procedure can help also avoid human errors in penetration testing and gives auditors more time for sophisticated exploitation execution. For successful penetration testing we should always use clear image of Kali Linux and clear databases in embedded security tools like nmap, Metasploit or sqlmap. This will effect on decreasing issues with data from previous customer pentesting and allows us to concentrate on the one goal. That newly prepared OS should have latest updates and all reports and logs must be clear. This approach came from ethical hackers best practices and it has been proven during our research.

2. Docker containers and advantages

As we see, automation of environment deployment, preparation and turning off became very important task for pentesters. For this purpose, new technology has been grown since last 5 years and became worldwide popular in 2015 – it's Docker.

Judging from security community feedback, currently we can't find better OS for penetration testing than Kali Linux (developed by Offensive security community). Kali Linux is a well known Debian based distribution for security audit and ethical hacking. It comes bundled with a huge list of security related applications and makes it easy to perform penetration testing. Recently, Kali Linux 2.0 was out and it is being considered as one of the most important release of this operating system. On the other hand, Docker technology is getting massive popularity due to its scalability and ease of use. Every modern IT company or corporation is trying to move to container technology and docker management solutions nowadays. Dockers make it super easy to ship your software applications to users or deploy those systems by the one short command. Breaking news is that you can now run official Kali Linux image via Docker. So now integration of those two powerful systems is very interesting area of research.

Docker is an open source project that automates the deployment of applications inside independent Linux containers, and provides the capability to package an application with its runtime dependencies into a container. It's an additional layer of abstraction and automation of operating-system-level virtualization on Linux. It provides a Docker CLI - command line tool for the lifecycle management of image-based containers. Linux containers enable rapid application deployment, simpler testing, maintenance, and troubleshooting while improving security.

2.1. Docker basics

Docker works with the following fundamental components:

- Container – an application sandbox. Each container is based on an image that holds necessary configuration data. When you launch a container, a writable layer is added on top of this image. Every time you commit a container (*docker commit* command), a new image layer is added to store your changes.
- Image – a static snapshot of the containers' configuration. Image is a read-only layer that is never modified; all changes are made in top-most writable layer, and can be saved only by creating a new image. Each image depends on one or more parent images.
- Platform Image – an image that has no parent. Platform images define the runtime environment, packages and utilities necessary for containerized application to run. The platform image is read-only.
- Registry – a repository of images. Registries are public or private repositories that contain images available for download. Some registries allow users to upload images to make them available to others.
- Dockerfile – a configuration file with build instructions for Docker images. Dockerfiles provide a way to automate, reuse, and share build procedures.

Docker provides an API for container or image management and a possibility to use a remote registry for sharing containers. This scheme benefits both developers and system administrators with advantages such as:

- *Rapid application deployment* – containers include the minimal runtime requirements of the application, reducing their size and allowing them to be deployed quickly.

- *Portability across machines* – an application and all its dependencies can be bundled into a single container that is independent from the host version of Linux kernel, platform distribution, or deployment model. This container can be transferred to another machine that runs Docker, and executed there without compatibility issues. Image can be easily transferred as .zip archive.
- *Version control and component reuse* – you can track successive versions of a container, inspect differences, or roll-back to previous versions. Containers reuse components from the preceding layers, which makes them noticeably lightweight.
- *Sharing* – you can use a remote repository to share your container with others. Red Hat or Docker Hub provides a registry for this purpose, and it is also possible to configure your own private repository.
- *Lightweight footprint and minimal overhead* – Docker images are typically very small, which facilitates rapid delivery and reduces the time to deploy new application containers.
- *Simplified maintenance* – Docker reduces effort and risk of problems with application dependencies.

2.2. Comparison with virtual machines

Virtual machines (VMware, Vbox etc.) represent an entire server with all of the associated software and maintenance concerns. On the other hand, docker containers provide application isolation and can be configured with minimum run-time environments. Docker uses the resource isolation features of the Linux kernel such as cgroups and kernel namespaces, and a union-capable file system and others to allow independent "containers" to run within a single Linux instance, avoiding the overhead of starting and supporting virtual machines. In a Docker container, the kernel and parts of the operating system infrastructure are shared. For the virtual machine, a full operating system must be included. Following differences emphasizing docker benefits:

1. You can create or destroy containers quickly and easily. Virtual Machines require full installations and require more computing resources to execute.
2. Containers are lightweight; therefore, more containers than virtual machines can run simultaneously on a host machine.
3. Containers share resources efficiently. Virtual machines are isolated. Therefore multiple variations of an application running in containers are also able to be very lightweight. For example, shared binaries are not duplicated on the system.
4. Virtual machines can be migrated while still executing, however containers cannot be migrated while executing and must be stopped before moving from host machine to host machine. Nevertheless, we can use images for migration and then transfer will very easy procedure(copy archive)

Containers do not replace virtual machines for all use cases. Careful evaluation is still required to determine what is best for your application. [3] There’s a couple of areas where security testers can see Docker being quite useful, mainly due to the ease of maintaining and installing applications and also the reduced resource utilization over “traditional” virtual machines.

During our investigation we noticed a lot of positive features in docker for security audit. The first one is an isolating of security testing applications which require a bit of setup or a particular environment to operate in. Some very useful security testing tools are slightly more complex to setup and run than just doing a git clone of the repo and running a script and there can always be conflicts in the version of underlying tools and libraries required for them to run. These tools can benefit from the isolation that using a containerized version brings.
One of the nice things about containers built using the automated build approach is that Docker Hub will show you the Dockerfile used to build the container, which provides some level of transparency over what you're downloading (and the syntax is relatively basic, so easy to see what's going on). You still obviously have to trust Docker Hub and the sources of data used to build the container, which may not be applicable to some environments, and there a better option might be an internal docker repository with internally validated builds. Even there, the Docker Hub examples are useful to base your Dockerfiles on. For example, we can create our own Dockerfile based on some official or community image from Docker Hub.
Another way in which containers can be handy is in creating new, consistent, security test environments for each piece of work done. A common problem in security testing is ensuring that your testing environment is clear of any data from previous reviews, to avoid inadvertent contamination and also ensuring that your tools are regularly updated.
Using a containerized image as your base here is quite straightforward as you just get an image, and then create a new container based on that image for each review. Next section will describe it more details.
Now you could replicate this with virtual machines, but the downside there is that the disk space requirements for a new VM per test would be pretty hefty and cloning/starting a new VM can be a bit slow, when compared to containers. Depending on the type of testing you do, you may need the more complete environment that a VM provides, but we reckon for a lot of penetration testing a container should work just fine. Only in case of some Windows tests we can adjust pentesting approach and perform pentesting on both VM and docker.
Another potential advantage of container approach is that you could archive off the container at the end of the test which could make reproducing findings at a later date simpler. It's because of less risk of tools updates changing the results of a pentest [7].

3. Docker images for security audit

An official and public Docker registry – Docker Hub: *https://hub.docker.com/* - consists of many images built previously by official software and operation system developers. For example, we can find here Ubuntu, CentOS or Debian images of old and latest versions. Some specific software images are also available and ready for your pull by one command.
From the security perspective, we can find many interesting images of famous security tool or penetration testing instruments. See following list of useful public security images:

- docker pull kalilinux/kali-linux-docker - official Kali Linux,
- docker pull owasp/zap2docker-stable - official OWASP ZAP,

- docker pull wpscanteam/wpscan - official WPScan,
- docker pull pandrew/metasploit - docker-metasploit,
- docker pull citizenstig/dvwa - Damn Vulnerable Web Application (DVWA),
- docker pull wpscanteam/vulnerablewordpress - Vulnerable WordPress Installation,
- docker pull hmlio/vaas-cve-2014-6271 - Vulnerability as a service: Shellshock,
- docker pull hmlio/vaas-cve-2014-0160 - Vulnerability as a service: Heartbleed,
- docker pull opendns/security-ninjas - Security Ninjas,
- docker pull diogomonica/docker-bench-security - Docker Bench for Security,
- docker pull ismisepaul/securityshepherd - OWASP Security Shepherd,
- docker pull danmx/docker-owasp-webgoat - OWASP WebGoat Project docker image,
- docker pull citizenstig/nowasp - OWASP Mutillidae II Web Pen-Test Practice Application.

So we can use all of them for penetration testing purposes or even for some vulnerabilities verification, for example, for Shellshock or Heartbleed vulnerabilities. Docker hub also provides ability to check source code of the image – Dockerfile. Hence, ethical hackers can build own image by using those Dockerfiles or simply pull existing previously prepared images.

4. Docker compose and pentest automation

It would be interesting to see if we can setup an even more automated environment by using Docker Compose. Docker Compose is a mean of creating a linked set of containers, which you can configure to be started up together, so useful where you want to make use of multiple systems at the same time. Some administrators call it docker cluster. It is a future for docker containers.

For the use case of penetration testing, our research proved that it would be nice to have containers which provide a service that you connect to over a network port, for example Dradis or OpenVAS, alongside your main command line driven container which has tools that you're more likely to use interactively on a test, for example Nmap or Metasploit.

It turns out this is relatively straightforward using Docker Compose. You can setup a .yml file with information on the containers you want to instantiate (the default name is docker-compose.yml) and then just spin that up with a single command:

```
docker-compose -f docker-compose.yml up -d
```

For stopping all containers (all cluster) you can run:

```
docker-compose -f docker-compose.yml down
```

This is very easy approach to automate your cluster creation and termination.

So for this research we built a simple the Docker Compose file, which contains 4 docker containers with different security tools ready for pentest execution inside local network. Following example is the real test which can be used for environment deployment and pentest preparation:

```
version: '2'
services:
  dvwa:
    image: citizenstig/dvwa
```

```
      expose:
        - "3306"
        - "80"
      command: /bin/bash
      links:
      - dradis
      - openvas
      - kali
      volumes:
        - data:/data
    dradis:
      image: raesene/auto-docker-dradis
      expose:
        - "3000"
      command: bundle exec rails server
      volumes:
        - data:/data
    openvas:
      image: mikesplain/openvas
      expose:
        - "443"
        - "9390"
        - "9391"
      volumes:
        - data:/data
    kali:
      image: kalilinux/kali-linux-docker
      command: /bin/bash
      links:
      - dradis
      - openvas
      volumes:
        - data:/data
  volumes:
    data: {}
```

Our main vulnerable container is DVWA, which based on LAMP server with many vulnerability ready for exploitation. Kali Linux and OpenVAS containers are used for penetration testing and vulnerability assessment. Dradis framework is powerful tool for gathering information after intelligence sniffing, reconnaissance and scanning. This is a basic scheme for any sophisticated penetration testing scenario, which ethical hackers can perform on daily basis.

Docker Swarm technology is one of the latest feature of docker. It allows us to locate containers on a few instances, but manage them as a one docker cluster. Management should be done from manage node. For allocation of container we can use 3 techniques called strategies:

- spread
- binpack
- random

During research Amazon Web Services were investigated and Docker Swarm cluster was built as a part of cloud infrastructure. Picture 1 shows us all relations inside mentioned cluster below.

5. Pentesting planning algorithms

We consider the problem of automatically designing a penetration test to remotely evaluate the security of a target computer or network device. It doesn't matter are you in the cloud or in the physical local network. As we know, penetration test is a method of evaluating the security of a target by simulating an attack. In black box penetration testing, the tester has no prior knowledge of the system under test.

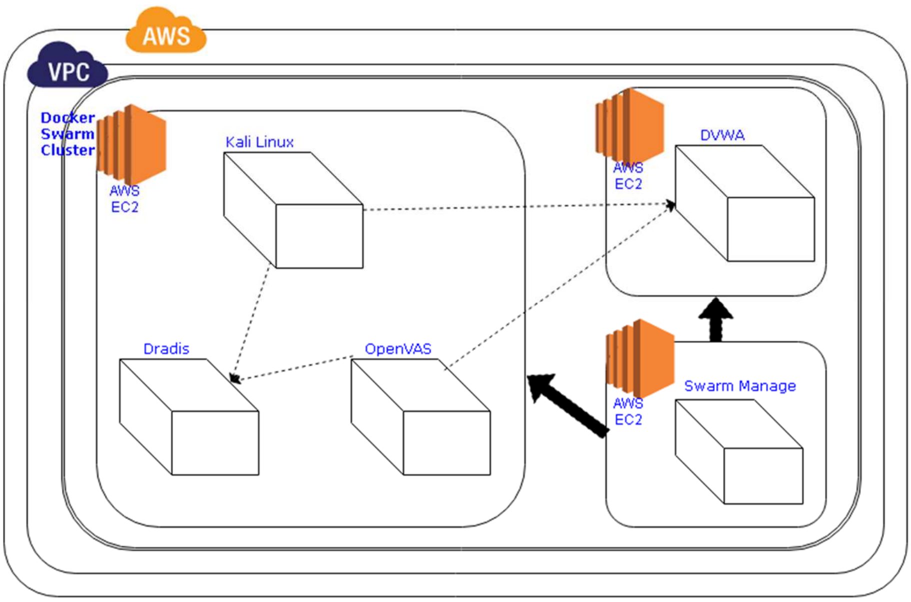

Figure 1. Amazon Web Services – pentest solution based on Docker Swarm

This form of testing requires the use of probing tools and thus the tester must rely on uncertain information to identify targets and vulnerabilities. Hence, information gathering still is one of the vital parts of pentest. After that step we should try to use multi-attack methods in order to reach our goal successful.

Multi-step attacks are often the most effective way for an attacker to compromise a system (computer) or network. In such an attack, the attacker attempts to achieve an access goal through the exploitation of a series of vulnerabilities, often called an attack chain. An attacker can take advantage of vulnerabilities in the operating system of the target or vulnerabilities in any enabled applications or services. Each piece of software may be secure in isolation, but their combination and interaction can often provide a pathway for the opportunistic attacker. The ability to detect and analyze the interaction of multiple potential vulnerabilities on a system or network of systems leads to a better understanding of the overall vulnerability of the target.

Attack graph generation and analysis is a way to reach this understanding [4]. An attack graph contains all possible attack chains for a given system or network of systems. Attack graphs provide a visual means of analyzing the multiple pathways to a given goal. Attack graphs have been used in many domains of information security, from vulnerability assessment and network design to intrusion detection and forensics.

The typical approach to attack graph generation is to consider an attacker to be omniscient, with complete knowledge of vulnerabilities on a target system and the ability to observe a system from all sides of defensive devices. Our research innovation is to consider a realistic attacker that must deal with the uncertainty of using remote tools to gain knowledge of a system before planning an attack. In the traditional approach the attributes of the systems, operating system and applications are assumed to be known with certainty. A realistic adversary will not have perfect knowledge of their potential targets. Furthermore, even when attack graphs are used as a tool by a system administrator on a managed network, it is unlikely the administrator would have a completely accurate inventory of the systems, operating systems and services on the network. In both cases it is important to model uncertainty in order to understand the true security of a target system.
The model we chose to tackle this research problem is the known mathematical model of partially observable Markov decision processes (POMDP). Algorithm for advanced penetration testing provides automated generation of multi-step penetration test plans that are robust to uncertainty during execution. In related works, Wang et. al. [5] and L. Greenwald [6] have proposed an attack- graph-based probabilistic security metric and Markov decision processes (MDP) implementation. That work represents security related conditions and the transitions between conditions that can be accomplished through vulnerability exploits. Discussed POMDP model captures similar information. While our work focuses on designing remote penetration test plans that are robust to uncertainty in both information gathering and exploit actions, that works focuses on developing probabilistic metrics to capture the intrinsic likelihood that an exploit can be executed and the overall likelihood that an attacker can successfully execute an exploit or satisfy a condition.

6. Conclusion & future work

Time has not stood still around cyber security while the connected world moved more and more towards cloud solutions over the last decade. Several large breaches of internal corporate systems have proven cloud security might not be so bad in comparison after all. With these changes, penetration testing has adapted to the new challenges. New external services have sprung up, and existing cloud services have incorporated the new methods and technologies.
Penetration testing process has been growing for last few years by the help of virtualization and containerization technologies. Most popular and useful approach to perform pentest nowadays is cloud infrastructure like AWS, Microsoft Azure, Google Cloud Platform (GCP). It gives us a lot of opportunities to deploy, run and share security images and execute automated scripts. Docker became revolutionary in this field and security experts can't skip it in penetration testing purposes.
We still have a lot of question related to penetration test planning improvement, multi-attack handle and automation. Also Docker containers have a few bugs as every software and Docker Swarm technique need to be investigated deeper in order to develop full automation system for penetration testing in the cloud. Automation algorithm based on probabilistic penetration test planning with mathematical model of partially observable Markov decision processes (POMDP) also need to be developed on scripting languages (bash, python, ruby) for implementation in our

future works. Nevertheless, our research demonstrates that automation of penetration testing is very useful task and it is truly helpful for ethical hackers. Deployment and automated execution with using hybrid Markov decision processes must show power and efficiency in penetration testing.
Gathered information will lead interested researchers in future to deeper investigation in security field in the cloud. This research can be used by security professionals to bolster their organization's security and risk profile. Additional understanding of how cloud technologies can be used maliciously will progress the maturity of cloud security as a whole.

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ATTACK ON BITCOIN PEER-TO-PEER NETWORK ADDRESSING MECHANISM

ATAKI W SIECIACH PEER-TO-PEER ZWIĄZANE Z MECHANIZMEM ADRESOWANIA

Summary: Currently, the world internet community actively unfolds in the direction of decentralization and openness. Numerous researches of the security of Bitcoin protocol show the relevance of studying addressing mechanisms in peer-to-peer network. The possibility of successful execution of the attack on the lower levels of application architecture significantly increases the possibility of attack on the upper levels.
In this work presents a model of the attack on Bitcoin peer-to-peer network addressing mechanism and analysis of potential attacks, which are based on the successful execution of the attack on lower level architecture (in our case – on the peer-to-peer network). Considered Bitcoin peer-to-peer network addressing mechanism. Model of attack on Bitcoin peer-to-peer network through the addressing mechanism has got further improvement.

Keywords: addressing mechanism, Bitcoin, peer-to-peer network, attack, node

Introduction

Bitcoin is the first cryptocurrency, which received widespread adoption. A key reason for its success is the integrated decentralization. Instead of using the central bank for control over currency system, the Bitcoin uses a decentralized network of nodes that use computational proof-of-work mechanism to reach consensus on a distributed public transaction ledger, called Blockchain. The basis of the transmission of information in the Bitcoin ecosystem is the concept of peer-to-peer network. The last few years have seen extensive research of Bitcoin protocol security, but the safety of the peer-to-peer network has been remained under-investigated. At present, a wide range of applications are being built on the basis of Blockchain technology and

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foundation of that technology is the peer-to-peer network. Thus, the research of the peer-to-peer network security is extremely urgent problem not only in the plane of Bitcoin and other cryptocurrencies, but also for a wide range of applications, based on such networks. Analysis eclipse attack mechanism is a very important task for further development countermeasures preserving the openness and decentralization in the peer-to-peer networks.
This paper presents an analysis of the eclipse attack mechanism on the example of Bitcoin peer-to-peer network and describes the main stages of its realization. To this end, section 1 provides an overview of Bitcoin peer-to-peer network information management aspect. Section 2 describes the main stages of the eclipse attack. Section 3 is devoted to the analysis of the attack's potential consequences.

Related works

Although the last few years several works were devoted to the security of computational proof-of-work mechanism in Bitcoin protocol [1, 2, 3, 4, 5, 6], less attention has been given to peer-to-peer network which is used for information transfer between Bitcoin nodes.
Work [7] is devoted to studying the issue how Bitcoin peer-to-peer network can delay or prevent the spread of the blocks. Works [8, 9] – how Bitcoin network can be used for deanonymization of Bitcoin users. Aspects of the Bitcoin network protocol is discussed in these works. The work [8] gives a complex description of the process of distribution ADDR messages. Other works map Bitcoin peers to autonomous systems [10], geolocation peers and measured churn [11] and consider using of side channels to explore the Bitcoin network topology [8, 12].

Defining the problem

The analyzed works have not been studied vulnerabilities that exist due to openness and decentralization principles of Bitcoin peer-to-peer network, was not carried out an in-depth analysis of the attack on network addressing mechanism and its potential consequences for the Bitcoin ecosystem. Definition and representation of model of attack on peer-to-peer network addressing mechanism, and analysis of potential consequences of this attack are actual problems.

The goals of work

The main goal of this work is to present the model of attack on Bitcoin peer-to-peer network and review of potential attacks on the protocol, that are based on the successful execution of the attack on addressing mechanism.
To achieve this goal it is necessary to solve the following tasks:
- analysis of Bitcoin peer-to-peer network addressing mechanism;
- coverage of the main phases of the attack on Bitcoin peer-to-peer network addressing mechanism;

- review of the potential consequences of the attack on Bitcoin peer-to-peer network addressing mechanism.

1. Network information management mechanism in Bitcoin peer-to-peer network

Definition 1. Peer-to-Peer Network – computer network, based on the equality of the participants, centralized servers don't exist in such network, and each peer is both a client and a server.

This approach provides availability network at any combination and any number of available nodes.

Peers in the Bitcoin network are identified by their IP addresses. A node with a public IP can initiate up to eight outgoing connections with other Bitcoin nodes, and accept up to 117 incoming connections. This aspect provides a variety of configurations. In this work, it is assumed that nodes have 8 outgoing connections, which is confirmed by measurements [12]. A node with a private IP address only initiates eight outgoing connections. Connections are made via the TCP protocol. Nodes only distribute and store the public IP-addresses. The node can determine if its peer has a public IP-address by comparing the IP packet header with the Bitcoin VERSION message.

Distribution of network information. Network information is distributed in Bitcoin network by the DNS-seeders and ADDR messages.

Definition 2. DNS-seeder – a server that responds on DNS-requests from Bitcoin nodes with cryptographically unauthenticated list of IP-addresses for Bitcoin nodes.

List size is bounded by DNS frames. Hence the maximum possible number of IP-addresses, which can be returned with a single DNS-request is about 4000. DNS-seeder receives these addresses by periodic collection of information about Bitcoin network. There are six DNS-seeders in Bitcoin network that are requested in only two cases. The first case – when a new node joins the network for the first time. Such node tries to connect to DNS-seeders for getting the list of active IP-addresses. Second case – when existing node restarts and reconnects to the new peers. In this case, the DNS-seeder is requested only after 11 seconds from the moment the node began trying to establish a connection and the node has at least two outgoing connections.

Definition 3. ADDR message – addressing message for obtaining network information from peers, contains up to 1000 IP-addresses with their time stamps.

If more than 1000 addresses are sent in the ADDR message, then the peer that sent such message, recorded into the black list. Nodes accept unsolicited ADDR messages. ADDR message is requested only when outgoing connection to the peer is established. Peer responds to 1-3 ADDR messages, each one contains up to 1000 addresses randomly selected from their tables. Peer sends n random addresses from the table of tried and new addresses, where n is a random number in the interval [x; 2500], where x – 23% of the quantity of stored addresses by peer.

Nodes send ADDR messages to peers in two cases. The first case – every day node sends its own IP-address in ADDR message to each peer. Second – when node receives ADDR message with no more than 10 addresses, it forwards ADDR message to two randomly selected peers. Note that, in fact, if ADDR message contains addresses that are non-routable for the peer, it will send ADDR message to one peer only. For example, peer with IPv4 address gets IPv6-address. To choose these peers, the node takes the hash of each connected peer's IP address and a secret nonce associated with the day, selects the peers with the lexicographically first and second hash values. Each node keeps a known list of addresses, which it has sent to or learned from each of the connected peers, and never sends address on the known list of its peer. It is necessary for preventing infinite propagation of outdated ADDR messages. Known lists are reset daily.

Storing network information. Public IP-addresses are stored in the table of tried and new addresses of node. Tables are stored on disk and saved when node restarts.

The table of tried addresses consists of 64 buckets, each one can store up to 64 unique addresses for peers to which node has successfully established incoming or outgoing connection. Along with every stored peer's address, node keeps the timestamp for the most recent successful connection to this peer. Each peer's address is mapped in the bucket in the table of tried addresses by taking a hash of peer's IP-address and the peer group, where the group is the /16 IPv4-prefix containing peer's IP-address. Each IP-address is mapped in separate bucket in the table of tried addresses and each group is mapped in no more than four buckets.

Peer's address is inserted into the corresponding bucket in table of tried addresses when node successfully connects to the peer. Bitcoin eviction mechanism applies if bucket is full (i.e. contains 64 addresses). This mechanism consists of the following stages:

- four addresses are randomly selected from the bucket;
- the oldest one is replaced by new peer's address in the table of tried addresses;
- the address is inserted into the table of new addresses.

The timestamp related to the peer's address is updated, if the peer's address is already presented in the bucket. The timestamp is also updated when an actively connected peer sends a VERSION, ADDR, INVENTORY, GETDATA or PING messages and more than 20 minutes elapsed since the last update.

The table of new addresses consists of 256 buckets, each one can hold up 64 addresses for peers to which the node has not yet initiated a successful connection. A node populates the table of new addresses with information learned from the DNS-seeders or from ADDR messages. Addresses in the table of new addresses also have a related timestamp. Addresses obtained from DNS-seeders are stamped with a random timestamp between 3 and 7 days old, while addresses obtained from ADDR messages are stamped with their timestamp from the ADDR message plus two hours. Every address *a* inserted in the table of new addresses belongs to a group and a source group, containing the IP-address of the connected peer or DNS-seeder from which the node obtained address *a*.

Each pair (group, source group) hashes into one bucket in the table of new addresses. Each bucket holds unique addresses. Bitcoin eviction mechanism is executed over all 64 addresses in the bucket if the bucket is full. If anyone of the addresses is more than 30 days old, or has had too many failed connection attempts, then the address is evicted in favor of the new address. Otherwise, Bitcoin eviction is used with the small change that the evicted address is discarded. A single address can map to multiple buckets if it is advertised by multiple peers.

Selecting peers. New outgoing connections are selected if a node restarts or if an outgoing connection is dropped by the network. A Bitcoin node never deliberately drops a connection, except when a blacklisting condition is met (e.g., the peer sends

ADDR messages that are too large). A node with $\omega \in [0,7]$ outgoing connections selects the ω +1 connection as follows:
1) Decide whether to select from the table of tried addresses or the table of new addresses, where

$$\Pr = \frac{\sqrt{\rho}(9-\omega)}{(\omega+1)+\sqrt{\rho}(9-\omega)}, \tag{1}$$

where Pr – the probability of selecting from the table of tried addresses;
ω – number of outgoing connections;
ρ – ratio between the number of addresses stored in the table of tried addresses and number of addresses stored in the table of new addresses [4].
Figure 1 plots the relationship between p and ω for different values of ρ .

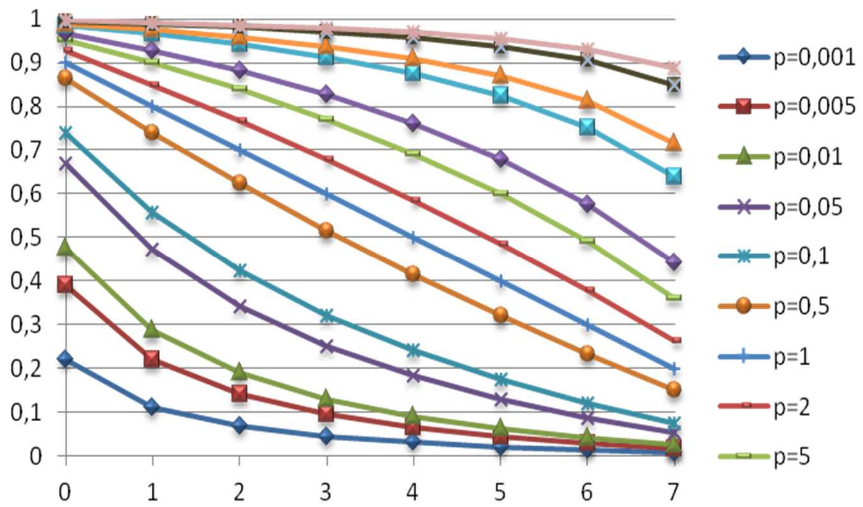

Figure 1. A plot of the probability of address selection from the table of tried addresses and number of outgoing connections for various values ρ

Thus, the address is more likely to be selected from the table of tried addresses when there are few outgoing connections or the table of tried addresses is large.
2) Select a random address from the table, with a bias towards addresses with fresher timestamps:
- chooses a random non-empty bucket in the table;
- chooses a random position in that bucket;
- if there is an address at that position, return the address with probability:

$$p(r,\tau) = \min\left(1, \frac{1.2^r}{1+\tau}\right), \tag{2}$$

where $p(r,\tau)$ – the probability of making decision;
r – the number of addresses that have been rejected until that time;

τ – the difference between the address's timestamp and the current time in measured in ten minute increments;
Otherwise, the address is rejected and return to step 1 [4].
3) Connect to the address. If connection fails, return to step 1.

2. Attack on Bitcoin peer-to-peer network addressing mechanism

The attack, which is considered in this work, is directed to the node with the public IP address. Attacker's actions involve the following steps:
stages:

- populating the table of tried addresses with adversarial addresses;
- overwriting the table of new addresses with IP-addresses, which are not part of the Bitcoin network. Such addresses are unallocated (listed as "available"), or as "reserved for future use" (e.g., 252.0.0.0/8). The table of new addresses is filled with "trash" addresses, because, in contrast to the attacker's address, "trash" is not a scarce resource;
- capturing control over attacked node's remaining 117 incoming connections.

Filling the tables of tried and new addresses. The attacker uses to populate the tables of tried and new addresses the following provisions:
1. Addresses from unsolicited incoming connections are stored in the table of tried addresses, so the attacker can insert an address into attacked node's table of the tried addresses simply by connecting to the attacked node from that address. In addition, the principle of Bitcoin eviction means that fresher attacker's addresses can evict any older legitimate addresses stored in the table of tried addresses.
2. Node receives unsolicited ADDR messages and addresses from these messages are inserted directly into the table of new addresses without checking the possibility of connecting to them. Thus, when the attacker connects to the attacked node from hostile address, it can also send ADDR messages with about 1000 "trash"-addresses. In the end, the "trash"-addresses will overwrite all legitimate addresses in the table of new addresses.
3. Nodes rarely request network information from peers and DNS seeders. Thus, while the attacker overwrites the attacked node's tables of tried and new addresses, the attacked node itself almost never counteracts the flood of adversarial information, prompting legitimate peers and seeders.

Restarting the attacked node. The attack, which is considered in this work, requires the attacked node to restart so they can connect to adversarial addresses that are constrained by attacker. There are several possible reasons why a Bitcoin node could restart, including ISP outage, a power failure, updating, attack or failure on the host operating system. It should be noted that the node with the public IP-address has a 25% chance off after 10 hours [8]. Another predictable cause of the restart is a software update. Updating is often necessary, especially if it corresponds to the critical security aspects. Moreover, since the community should be notified in advance about the update, the attacker can watch the alerts, and then begin its attack. Restarting can also be deliberately caused by using of DDoS [13], the memory exhaustion [8], or packets-of-death (which have been found for Bitcoind [14]), but these types of attacks are not considered in this paper. The bottom line is that the peer-to-peer network security should not rely on a completely trouble-free work of nodes.

Selection of outgoing connections. The attack, which is considered in this work, is successful if after restart the attacked node makes all of its outgoing connections to the attacker's addresses. To do this, the preference in the selection of addresses with fresh timestamps from the table of tried addresses is used. By investing additional time into the execution of the attack, the attacker ensures its address have fresh timestamps, while all legitimate addresses become increasingly obsolete.

Getting full control over the attacked node after successful attack. It is assumed that the attacked node has exactly eight outgoing connections. All that is needed in terms of incoming connections – this is to the attacked node had a few open slots for receiving incoming TCP-connections from the attacker. It is often assumed that the number of TCP-connections computer can work with is limited by operating system or number of source ports, but this applies only when OS-provided TCP-sockets are used. An attacker can open any number of TCP-connections, using a custom TCP-stack. Custom TCP-stack (e.g., zmap [15]) requires minimal processing and memory costs, and usually only limited by bandwidth. Bandwidth cost of attack on peer-to-peer network addressing mechanism is minimal.

Cost estimation for execution of the attack on addressing mechanism. To fill the table of tried addresses, the attacker repeatedly connects to the attacked node from each of its addresses. Each connection consists of a TCP-handshake, Bitcoin VERSION message and then disconnection via TCP RST. It is 371 bytes of outbound traffic and 377 bytes of inbound. Some attack connections also send one ADDR message with 1000 addresses; these ADDR messages cost 120087 bytes of outbound traffic and 437 bytes of inbound, including the TCP ACKs (confirmation).

Instituting control over the connections of attacked node. If the execution of the attack was successful, the attacked node has eight outgoing connections to the attacker's nodes, and the attacker must occupy the attacked node's remaining connections. To prevent other users from connecting to the attacked node, these TCP-connections can be maintained for 30 days, after which the address of the attacked node is evicted and forgotten by the Bitcoin network (Section 1.2). Bitcoin supports requests of block identification (block inventory requests) and sending blocks and transactions. It requires a large bandwidth, so the attacker does not to respond to identification requests. The request contains the identification data type identifier and the hash, which is used to identify blocks and transactions. They are available for download via Bitcoin peer-to-peer network. Thus, the configuration of each TCP-connection takes 377 bytes of outbound and 377 bytes of inbound traffic, and is supported by a ping-pong packets and TCP ACK-s, consuming 164 bytes every 80 minutes.

Bitcoin node will accept all incoming connections from the same IP-address. (We presume that this is done to allow multiple nodes based on network address translation NAT to connect to one/same node). Maintaining 117 incoming TCP-connections by default spends $164x117/80x60 \approx 4$ bytes per second, which easily allows one computer to monopolize several attacked nodes simultaneously. It should be noted that this also creates the opportunity for execution of connection starvation attacks [16], in which an attacker monopolizes all incoming connections in peer-to-peer network, making it impossible to connect to new peers for new nodes.

3. Potential attacks on the Bitcoin protocol

In addition to the disruption of the Bitcoin network or selective filtering attacked node's view on the state of Blockchain, attacks on addressing mechanism are useful building block for other attacks. Potential attacks, which are based on the success of the attack include:

1. Reducing the power of mining. Successful execution of the attack on addressing mechanism on some of the miners eliminates their power of mining from the rest of the network, which makes it easier to launch mining attacks (for example, 51% of the attack [5]). To hide the changes in the power of mining under natural variations, miners may be exposed to attacks on addressing mechanism slowly or intermittently.
2. Self-serving / exclusive mining. With such kind of mining [1, 2, 3, 6], the attacker strategically delay blocks to win more than makes up for the equitable distribution of awards for its mining. The success of the attack depends on the two values: α – the ratio of the mining power under control of the attacker, and γ – the ratio of the fair mining power, which will carry on the mining blocks on attacker's nodes during the block race. If γ is large, then α may be small. By miners under attack on addressing mechanism, the attacker increases γ, and hence, reduces α so that Self-serving mining becomes easier. To do this, the attacker throws any blocks found by controlled miners that compete with blocks found by self-serving miners. Then the attacker increases γ by supplying only self-serving miner's view on Blockchain to controlled miner. This makes it possible to assimilate the computational power of the controlled miners, using it for mining in the self-serving miner's Blockchain.
3. Engineering block races. Such block race occurs when two miners find blocks at the same time; one block will be a part of Blockchain, while the other "thrown block" will be ignored, without receiving any kind of compensation for mining. An attacker who successfully executes the attack on addressing mechanism to many miners can engineer a block race. He can do it by accumulating the block group found by controlled miners and releasing these blocks to both attacked and non-attacked miners, once a competing block has been found. Thus attacked miners waste their efforts on mining dropped blocks.

The attacks on miners can harm the entire Bitcoin ecosystem; mining pools are vulnerable if their gateways to the Bitcoin peer-to-peer network can be successfully attacked via addressing mechanism. The attack on addressing mechanism can also be used for double-spend attacks on non-miners, where the attacker spends a certain amount of the Bitcoins several times.

4. *N*-confirmation double spending. If the attack on addressing mechanism on the miners was successfully executed by the attacker, it is possible to start the *N*-confirmation double spending attack on merchant controlled. The *N*-confirmation transaction, the merchant sends the goods only after the transaction is confirmed in a block of depth *N*-1 in the Blockchain. The attacker sends a transaction to controlled miners, who include it in their (outdated) view of the Blockchain. Then the attacker shows this view of Blockchain to the controlled trader. After that he receives the goods and sends both the trader and controlled miners not antiquated view of Blockchain from miners who have not been exposed to attack on addressing mechanism. Blockchain of controlled miners is dropped, and the attacker receives the goods without payment. This is similar to an attack that launches by the mining pool [17],

but in this case the attacker attacks miners via addressing mechanism instead of using his own mining power.

5. 0-confirmation double spending. In the 0-confirmation transaction, a customer pays a transaction to trader who releases goods to the customer before seeing the block confirmation, in other words without seeing the transaction in Blockchain. Such transactions are used when impractical to wait 5-10 minutes, which are normally required to confirm the block, for example, in retail systems, such as BitPay, or online gambling sites, such as Betcoin [18]. To launch attacks against merchant double spending [19] an attacker carry out attack on addressing mechanism on merchant Bitcoin-node, then sends the transaction T to the trader for goods and sends the transaction T_0, twice spending Bitcoins, to the rest of the network. The trader sends goods to the attacker, but since the attacker controls all of the trader's connections, the trader can not tell the rest of the network about transaction T, and meanwhile the network confirms T_0. Thus, the attacker receives the goods without payment. This attack is just as effective as Finney attack [20], but using addressing mechanism instead of the mining power.

There are other attacks, such as transaction hiding attacks on nodes, working in the SPV mode [8].

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SZKOLENIE I ANALIZA METODY CYFROWEJ STEGANOGRAFII

Streszczenie: Celem niniejszej pracy jest porównanie metod ukrywania tekstu w pliku obrazu przy użyciu algorytmów Least Significant Bit (LSB), dyskretnej transformaty (DCT) oraz dyskretnej transformaty falkowej (DWT) jako elementów steganografii. Oszacowanie zalet konkretnej techniki jest oceniane na podstawie parametrów BRE, PSNR, ostrości oraz wydajności obrazu.

Słowa kluczowe: cyfrowa steganografia, porównanie efektywności, metody analizy

THE STUDY AND THE ANALYSIS OF DIGITAL STEGANOGRAPHY METHODS

Summary: The goal of this work is to compare methods of hiding text in an image file using algorithms Least Significant Bit (LSB), Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) based steganography. An estimation of the particular technique is evaluated based on the parameters BRE, PSNR, robustness and capacity of the cover image.

Keywords: digital steganography, analysis, metods

1. Introduction

Modern computer data processing technologies have significantly increased the level of information security due to the deep integration of cryptographic tools in information systems. Steganography software tools, unlike the cryptographic information protection, help hide the fact of detection of existing information. The digital steganography studies the methods of steganography that hide information in

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digital signal streams. These methods can be applied by means of computer software. The intensive development and distribution of technologies allow by means of a computer to integrate, process and synchronously recreate the various types of signals. The issue of information protection submitted digitally is constantly drawing focused attention of intruders who wish to intercept, forge or assign this information. That is why the significance value of steganography methods is steadily growing.
Nowadays steganography is used in a big variety of industries. In manufacturing the bank notes, for example, steganography is used to check up their authenticity. Steganography methods are applied to the mounted water digital signs in cinematographic ribbons and many other spheres. The basic digital methods of steganography are studied in this article by various criteria.

2. Objects under study

The methods of digital steganography can be divided into two groups. The first group is frequency methods, such as the method of discrete cosine transform DCT (Discrete Cosine Transform) and the technique of discrete wavelet transform DWT (Discrete Wavelet Transform). The second group is spatial methods. The method of Cutter-Jordan-Bossen (hereinafter - the method of Cutter) and the LSB method (Least Significant Bit) are considered in this article.
In comparison, the following methods of embedding digital watermarks were chosen: two-coefficient Koch-Zhao algorithm based on the cosine transform technique, and John-Peng wavelet transform algorithm, the method of Cutter, and LSB standard method. Algorithm of John Peng belongs to a class of recording DWM (digital watermark) into the low-frequency plane of wavelet decomposition. It possesses a higher reliability in low frequency plane as compared to high frequency one.

3. Method of estimating the reliability and the conditions of conducting an experiment

To conduct an experiment, the following test data was selected: an image in which 10 semitone and 10 color images with resolution 640x640 pixels were used. To compare different methods of digital steganography, it is necessary for each of them to choose the optimum recording power. It means that DWM should be maximum resistant to impacts, but the image should not be distorted visually. Evaluation of the image distortion by using parameter PSNR (peak signal / noise) is calculated by the formula(1):

$$PSNR = 10\ \log \frac{255^2 * M * N}{\sum_{x,y}^{M,N} \left(f(x,y) - \hat{f}(x,y)\right)^2} \qquad (1)$$

where f (x, y) - container, f ^ (x, y) - stegocontainer, x, y - the coordinates of pixels, M, N - height and width of the image. The distortion is considered visible if PSNR ≥ 43 dB. These algorithms were tested for resistance of the embedded digital watermark to the most common adverse effects: image compression with losses (JPEG), scaling, filtering and noise vague.

Correlation of recorded and read information after external influence on a container is estimated by means of coefficient of erroneous bits of BER (Bit Error Rate), that takes on a value in a range from 0 to 1:

$$BER(S, S'') = \frac{\sum p_i}{N} \quad (2)$$

where N is the general number of bits, S " - bit reader ribbons, Si - j-th bit of the original recorded tapes.

Level wavelet is decomposition of this picture container. For steganography algorithms the range from1 to 3 was secelced. The coefficients of recording power DWM were selected from the conditions of the maximum level of image distortion container that does not cause the loss of information. DWM was presented as a pseudorandom bit sequence, and the length of bit sequence corresponded to the maximal volume of memory of image-container.

4. Analysis methods

When analyzing the resistance to JPEG-compression, the image was being compressed by JPEG algorithm in the full range of values of KJPEG parameter (ie from 0 to 100), which is responsible for quality compression. A result is presented in figures 1 and 2. As the figures show, the method of LSB is the least resistant, for semitone images the method of John-Peng is the most resistant to that types of images.

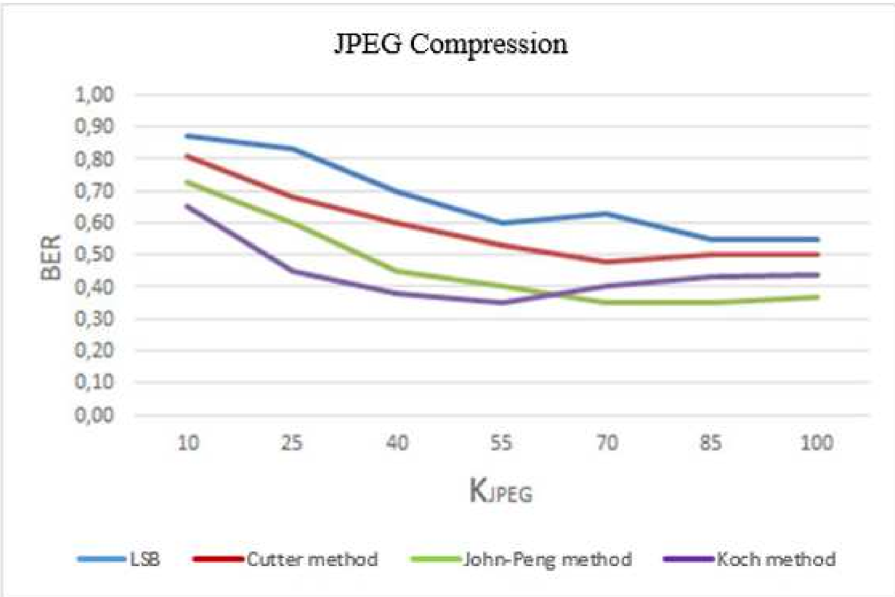

Figure 1. Dependence of BER color image on JPEG compression ratio

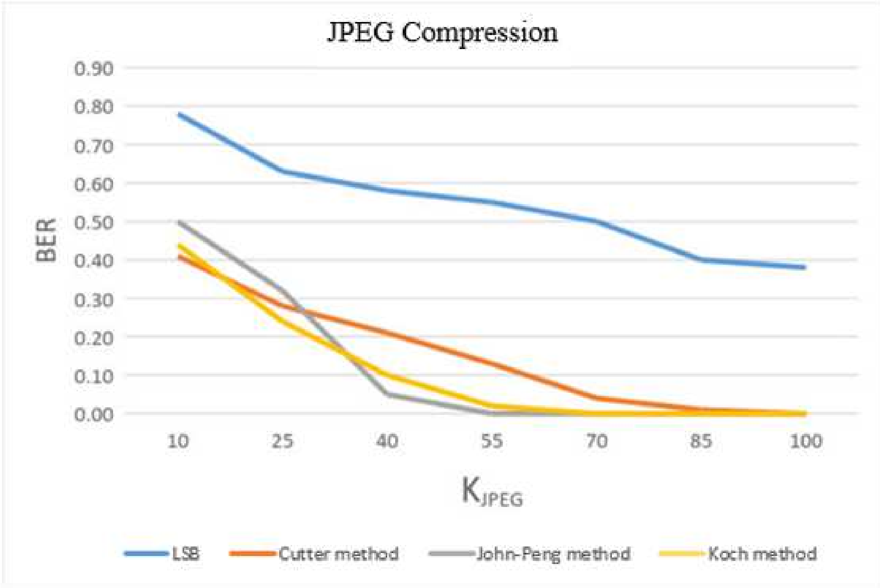

Figure 2. Dependence of BER halftone image on JPEG compression ratio

For the next analysis, a median filter that improves image sharpness was selected. Its window size is 3x3 pixel Analysis results are shown in Figures 3 and 4. LSB method is the worst for both types of images. The range of values BER for LSD in the analysis of a halftone image is wider than for the color ones. The Koch method is the most resistant.

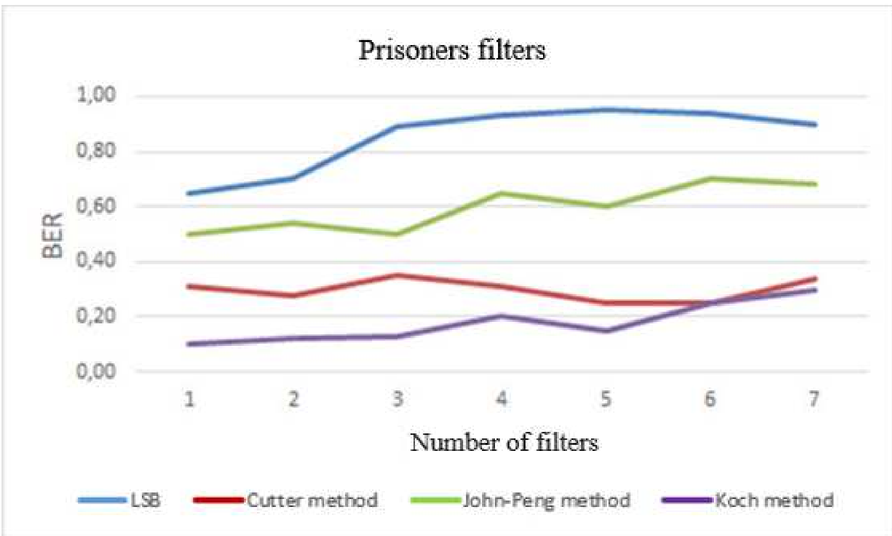

Figure 3. Dependence of BER color image on the number of prisoners filters

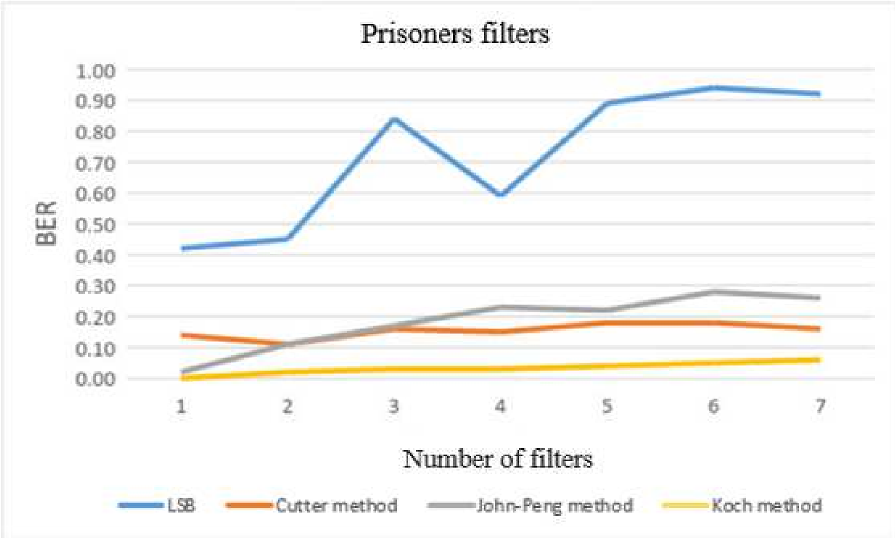

Figure 4. Dependence of BER halftone image on the number of prisoners filters

To check the resistance of the DWS to noise, the white Gaussian noise with zero average value and standard deviation random values that vary with the growth from 0 was placed in the container. It causes the image degradation and its further use for commercial purposes is impossible. The result is shown in Figures 5 and 6. The method of Koch is the worst one for color images at the large values of noise.

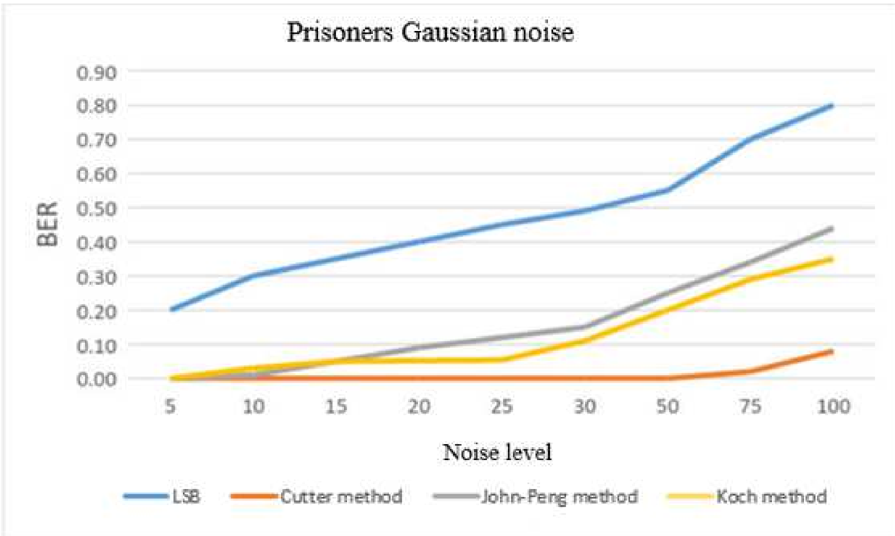

Figure 5. Dependence of BER halftone image on the degree of noise

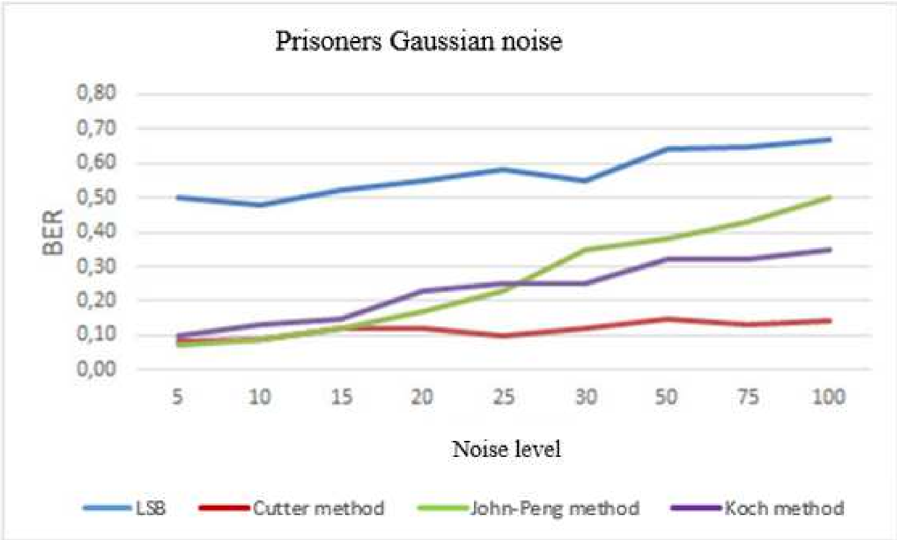

Figure 6. Dependence of BER color image on the degree of noise

As the sound is represented by single pixels, it affects both the high-frequency component factors and the low-frequency components that are subjected to strong impact, especially at significant noise vague.
During the analysis, the linear size of image container was half reduces, it means that the size of the image was reduced 4 times. Before reading the watermark, the size of image container was restored to the original size. The results are shown in Table 1.

Table 1. Dependence of BER on scaling container

	LSB	John-Peng method	Koch method	Cutter method
Color image	0.57	0.21	0.17	0.13
Gray scale image	0.72	0.46	0.21	0.29

Conclusion

The scaling of image container is the great danger for digital watermark embedded in the area DWT. With this type of external influence was reducing the linear dimensions of the image. The obtained results of the analysis of DWM resistance to external influences prove the theoretical advantage of using cosine transform technology in stehanosystem with special requirements for DWM resistance.
Spatial LSB algorithms and Cutter method should not be applied during filtering or deformation based on JPEG-compression as obtained results are insufficient. However, you can take into account the fact that the method of Cutter showed good results in the scaling and in noise vogue. To convert JPEG-Koch method is unreliable, especially at high compression ratios. Steganography algorithms using DWT, provide

high resistance of watermark to JPEG compression with losses. When low-frequency filtering, DWM resistance increases with increasing the level of decomposition. Filters that enhance the image contrast cause the significant DWM losses. To cut down these losses it is necessary to develop the systems of additional protection.

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DYNAMICZNA METODA KONTROLOWANIA INTENSYWNOŚCI STRUMIENIA WIDEO

Streszczenie: W pracy przedstawiono teoretyczne założenia dynamicznej metody kontrolowania intensywności strumienia wideo, na poziomie ramki przy użyciu trójwymiarowych transformowalnych bloków tzw. tframes waz z analizą zawartości poszczególnych ramek. Ponadto opisano również mechanizm pozwalający na zwiększenie efektywności powyższej metody.

Słowa kluczowe: prędkość przesyłu bitów, nasycenie bloku, kostka bitowa

DYNAMIC CONTROL METHOD OF THE INTENSITY VIDEO STREAM

Summary: This paper reveals essence of the method of dynamic control of the video stream intensity, on the frame level, using three-dimensional representation of transformed blocks of tframes. Furthermore features of each individual frame of stream is discussed. It describes a mechanism for increasing the effectiveness of the above method.

Keywords: bit-rate, saturation of block, bit cube

1. Tasks of the video stream intensity controlling method

Transmitting the video streams needs ensuring error and transmission delay rates, which can not exceed the ITU-T [1,2] recommendations. During the real-time translation of video data is necessary to provide a coordination of the intensity of the video stream and the bandwidth of network channels. The reason for this is the growing number of video services – streaming video, video conference and others, and their users. Under such conditions, increasing of bandwidth is retarded as compared with the increasing in the load on the network.

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Considering low efficiency of the methods of unloading of network traffic at network nodes, it makes sense to use a method of reducing the video traffic intensity on the terminal nodes. The task of the control method consists of a change of the intensity of the outgoing video stream in depending on the current capacity of the channel and the characteristics of video frames content. This problem consists of chapters: determining the characteristics of content of the frame blocks, determining the volume of data to representation of each one and forming the transmission data. One of the key steps of work of the method is dedicated to reduce the computational load. Reducing the processing load is achieved by a cut a set of transformants and their constituent bit planes, with low information content. This is especially true for high-resolution frames, such as HD-ready, Full-HD, and higher, since the processing of each of them can require considerable amount of time.

2. Steps of processing of reporting method of dynamic intensity controlling method

The source video frame is regarded as a set of blocks. After performing the color pattern changes, quantization and DCT transforming, every block is an array of the transformants, each of which is represented by bit planes according to the number of digits. Transformants, as bit-planes sets, can be represented as a bit-cubes, where in the top layer corresponds to the most informative bit plane (MSB) [3]. Assesses the contribution of each of the transformants in the total frame intensity, by analyzing the characteristics of the information content of their contents. The information thus obtained about the information content of each block to reduce the total number of choices of combinations of bit planes to represent the frame. Using the information, obtained during analysis of the characteristics of the transformants of blocks content, selects the particular combination of all transformants for frame presentation so as, to provide a compression, providing a minimum level of error at the lowest bit rate. In the next step, generates the codeword for all the transformants (transfer vector), determining transmitted bit planes and ignored bit planes for each of them. Next forms transmitting sequence, consisting of the transfer vector and transformants code. Data, transmitted by transmission vector, are used to reconstruct the original image at the receiving side.

3. Analysis of the characteristics of the content of the video frame blocks

Accounting the static, semantic and psycho-visual characteristics of video frames can provide an effective intensity distribution within the frame.
On this stage determines the saturation level K_{sat} of frame blocks. The source frame block is represented as a two-dimensional array, $h \times w$. For each row of the array determines the maximum K^i_{max} and minimal K^i_{min} values of coefficients. Value of K_{sat} for each blocks of frame performs according to the next equation:

$$K_{sat} = \sum_{h}\sum_{w}\left(K_{max}^{i} - K_{min}^{i}\right) \tag{1}$$

If the value of K_{sat} does not exceed a certain threshold K_{th} value, the block is considered as as low-saturated or middle-saturated. Otherwise, it is assumed that the block may be saturated. Thus defined arrays of transformants with varying degrees of informativeness: saturated, medium saturated and low saturated. Each of the arrays is processed separately according to its own algorithm. Division the transformants of blocks performs using the value of threshold K_{th}.

3.1. Division of frame blocks in the degree of saturation

Threshold [4] is a variable for the motion flow and determines for each frame separately. At the same time, within one video frame K_{th} is a fixed value. In this case, the above threshold value is a random number of transformants. This approach allows us to take into account the dynamics of the signal energy distribution within the frame, and the more informative blocks. The decision on the threshold value K_{th} is determined based on the saturation index K_{sat}^{max} of block within the frame, having a maximum value. In this case, the blocks may be considered as saturated, which is between 100% and 60% of K_{sat} values. In turn, blocks of saturation values K_{sat} is 60-30% of K_{th} consideres as middle-saturated. The remaining values range of K_{sat} from 30% to 0% corresponds to low-saturated blocks. Transformants of blocks, were included in the category of saturated, are transmitted in full bit by bit, starting with the MSB. Transformants of blocks, were identified as low-saturated, ignored, thus, transmission vector for such a transformants is not evaluated, forming of zeros.

4. Assessment of reduction of choices of bit planes for each of the blocks, to represent the frame

For the video frame, consisting of p blocks, each of which is represented by k bit planes, the number of choices of bit planes combinations can be defined by next formula:

$$W = (2^{k})^{p-p_{low}} \tag{2}$$

where the p_{low} - number of low-saturated blocks of current frame.

This approach reduces the size of the set W by reducing the total number p of cultivated transformants. For the transformants of medium- saturated blocks, performs truncation a number of bit- planes on a certain value k'. In turn, the reduction the value of k entails a decreasing in the number of choices of bit planes combinations W. The value W for the transformants of medium-saturated blocks is determined by this expression:

$$W_{med} = (2^{k-k'})^{p_{med}} \tag{3}$$

where the p_{med} - number of middle-saturated blocks of current frame.

An arbitrary frame generally represented by a set of blocks of three types - saturated, medium and low-saturated.
Thus, the total number of choices of bit planes for the frame, taking into account the expressions (2, 3), will be:

$$W = (2^{k})^{p_{hi}} \times (2^{k-k'})^{p_{med}} \tag{4}$$

where the p_{hi} - number of saturated blocks of current frame.

Using the expressions (2-4) is possible to determine the value, which reveals the degree of decrease in the volume of calculations suitable combination of bit planes.

The value W_{sub}, by which the reduced total number of choices of bit planes for the frame is given by:

$$W_{sub} = \frac{(2^{k})^{p}}{(2^{k})^{p_{hi}} \times (2^{k-k'})^{p_{med}}} \tag{5}$$

Using reviewed method provides matching bit-rate of video stream and bandwidth of network channels. Wherein the transmission is provided according to the IUT-T standards.

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ZASTOSOWANIE ALGORYTMU TRANSFORMACJI FALKOWEJ W STEGANOANALIZIE

Streszczenie: Stegoanaliza zajmuje się wykrywaniem ataków pasywnych oraz aktywnych na ukrytą informację przesyłaną wraz z obrazami, która była usuwana i zastępowana nieprawdziwą informacją. Dzięki zastosowaniu algorytmu transformacji falkowej przeprowadzono kodowanie, kompresję i podwyższono przepustowość, kosztem jakości obrazu.

Słowa kluczowe: steganografia, analiza steganograficzna, transformacja falkowa, kodowanie, kompresja

APPLICATION OF ALGORITHM OF WAVELET TRANSFORMATIONS IN STEGANOGRAPHIC ANALYSIS

Streszczenie: In the paper we discuss chosen activities connected with steganographic analysis. We have performed: passive and active attacks on so called stego-container, removal of hidden information from container as well as inserting false information into it. Due to an application of the algorithm of wavelet transformation, it was possible to perform encoding, compression and increase of capacity of transmission, at the expense of image compression.

Słowa kluczowe: steganographic analysis, wavelvet transformation, encoding, compression

1. Wstęp

Znany od bardzo dawna sposób kryptografii - steganografia i współczesne jest metody ujawniania, nazywane steganoanalizą, najprawdopodobniej nadal nie byłyby przedmiotem zainteresowania zbyt szerokiego audytorium, gdyby nie tragiczne wydarzenia, związane z rozpowszechniającymi się ugrupowaniami terrorystycznymi

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na całym świecie. Do tego momentu steganografia zdawała się być absolutnie nieszkodliwym elementem sieciowej kultury, a steganoanaliza przyciągała na siebie uwagę zaledwie kilku grup uniwersyteckich matematyków. W trakcie śledztwa tragicznych incydentów okazało się, że potencjalnym niebezpieczeństwem jest właśnie steganografia, ponieważ ona okazała się bardzo wygodna z punktu widzenia technologii terroru.
W obecnej chwili, w związku ze wzrostem objętości informacji, zwiększeniem przelotowości kanałów związku, coraz większej aktualności nabiera pytanie o ukrywanie informacji w sekwencje wideo. Przekazywanie cyfrowego wideo w ostatnich latach jest typowym wydarzeniem i nie wywołuje podejrzenia. Na przykład, serwis YouTube posiada setki milionów wideo plików, przy czym to samo wideo spotyka się w różnych formatach i różnej jakości.
Pomimo tego, że istnieje duża ilość formatów wideo, w praktyce do ukrywania informacji wykorzystuje się formaty MPEG-2 i MPEG-4. Trzy z najbardziej rozpowszechnionych sposobów wprowadzenia informacji w pliki formatu MPEG-2: umieszczanie na poziomie współczynników, na poziomie beatowej płaszczyzny i kosztem energetycznej różnicy między współczynnikami.

2. Przedstawienie problemu

Problem polega na konieczności usunięcia utajnionej informacji z kontenera, wsadzenie w niego innego utajnionego komunikatu dla dezorientacji odbiorcy i podwyższenie przelotowości kanału związku, kosztem kompresji, przy użyciu współczesnego algorytmu ściskania obrazów ze stratami.

3. Analiza badań i przedstawienie zadania

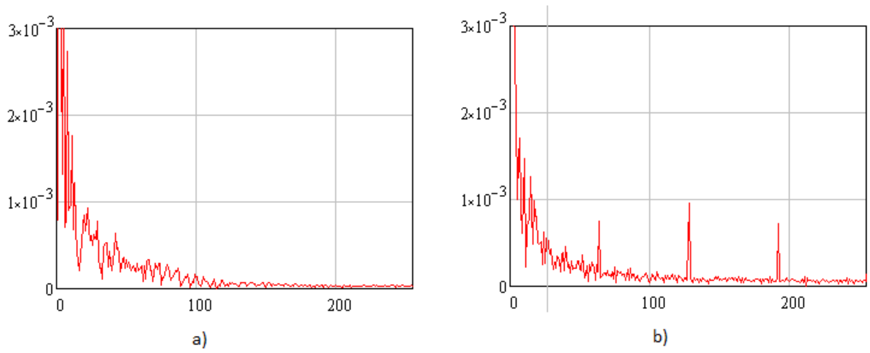
Kompresja falkowa - ogólna nazwa klasy metod kodowania obrazów, która wykorzystuje dwuwymiarowy rozkład falkowy kodowanego obrazu albo jego części. Zazwyczaj jest brane pod uwagę ściskanie ze stratą jakości.
Istotną rolę w algorytmach falkowej kompresji gra koncepcja przedstawienia wyników rozkładu falkowego pod postacią zero-drzewa (zero-tree). Uporządkowane w zero-bitowej płaszczyźnie współczynniki rozkładu falkowego stają się bardziej gruboziarniste i kodują się dalej z użyciem statystycznych metod kompresji.
Algorytm kompresji falkowej w nowoczesnych metodach kompresji pozwala istotnie (do dwóch razy), zwiększyć stopień kompresji czarno-białych i kolorowych zdjęć, w wizualnym porównaniu z poprzednią generacją algorytmów, opartych na dyskretnej transformacji kosinusowej (DKT), takich jak JPEG.
Algorytm JPEG, w przeciwieństwie do transformacji falkowej, kompresuje każdy blok oddzielnie w wyjściowy rozmiar obrazu o rozmiarze 8 na 8 pikseli. W efekcie wysokiego stopnia kompresji w odtworzonym obrazie widać strukturę blokową.
Podczas kompresji falkowej ten problem nie występuje, ale mogą pojawić się różne rodzaje zniekształceń, które mają postać „widma” w pobliżu ostrych brzegów. Uważa się, że te artefakty są mniej widoczne dla obserwatorów niż "Skrzynki" utworzone w JPEG.

4. Referowanie głównego materiału

Dla rozpatrzenia praktycznej realizacji algorytmu, docelowo będziemy wykorzystywać jeden kadr, ponieważ steganoanaliza w kolejności kadrów wykonuje się kadr za kadrem. Dla rozbicia całości na oddzielne kadry, w tej pracy wykorzystano pakiet programów SonyVegas10.0. Wprowadzenie do beatowej płaszczyzny przeprowadzono metodą najmniej znaczącego bita

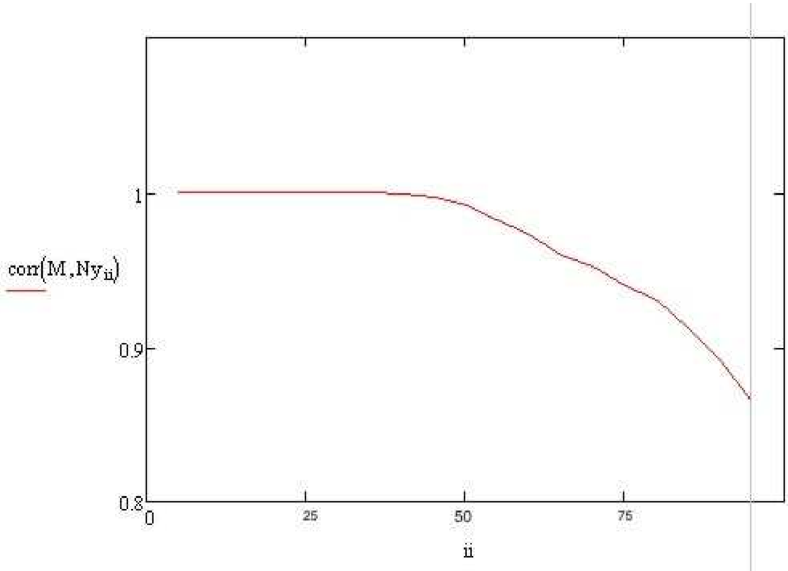
Rysunek 1. Wejściowy kadr (a) i kadr z włożoną w niego informacją (b)

Jak możemy zaobserwować, optyczna różnica między wyjściowym kadrem (Rys.1a) i kadrem z włożoną w niego informacją (Rys.1b) nie występuje. Dla ujawnienia utajnionego komunikatu w kadrze, czyli przeprowadzenia pasywnego ataku na stego kontener, skorzystamy z metody histogramowej steganoanalizy .



Rysunek 2. Spektrum pustego kadru (a) Spektrum wypełnionego kontenera(b)

Dalej, zgodnie z danymi przedstawionymi pod postacią spektrum wypełnionego kontenera, podejmujemy decyzję o obecności utajnionej informacji w kontenerze (Rys. 2). Jeśli decyzja jest pozytywna, przechodzimy do następnego kroku - podjęcia decyzji usuwania albo usunięcia utajnionej informacji z kontenera. Przy podjęciu decyzji o usunięciu utajnionej informacji z kontenera wykorzystuje się metodę transformacji falkowej.



Rysunek 3. Wartość zależności korelacji kontenera od zadanych współczynników falkowych (w procentach)

W tabeli 1pod postacią grafiki przedstawiono wartość zależności korelacji kontenera od zadanych współczynników falkowych, użytych przed i po zastosowaniu algorytmu. Zadajemy liczbę (w %) falkowych współczynników, które są użyte (TR). Wskazane jest, aby wybierać wartości, które nie są zbyt wysokie, ale powinny być wystarczające do usunięcia ukrytej informacji z pojemnika

Tabela 1. Zależność wielkości wartości kompresji danych TR

Tr(%)	Rozmiar do ściskania (Kb)	Rozmiar po ściskania (Kb)	Tr (%)	Rozmiar do ściskania (Kb)	Rozmiar po ściskania (Kb)
0	769	550	50	769	294
5	769	508	55	769	268
10	769	488	60	769	239
15	769	465	65	769	213
20	769	445	70	769	186
25	769	423	75	769	156
30	769	399	80	769	127
35	769	373	85	769	101
40	769	347	90	769	76
45	769	317	95	769	48

Wartość zależności korelacji danego kontenera od współczynników falkowych (w procentach), które są użyte do wybranego algorytmu aplikacji na poziomie 50%. Kodowanie strumienia danych informacji dostarczonych na wymianę pojemnika współczynników DCT w macierzy współczynników falkowych.
Informacje kompresji strumienia danych dostarczanych przez macierz kanału przesyłowego falkowych współczynników zamiast pojemnika, w postaci macierzy

współczynników falkowych. Gdy większość współczynników jest równa 0, to podlega on znacznie lepszej kompresji, jak pokazano w tabeli 1

M =

	325	326	327	328	329	330	331	332	333	334
42	13	10	22	48	0	1	6	10	13	12
43	7	4	13	35	14	15	9	1	1	6
44	1	0	0	14	29	29	18	1	1	2
45	9	4	2	12	9	18	20	12	7	9
46	11	8	2	6	2	5	8	7	5	4
47	8	5	1	1	13	3	1	8	12	6
48	9	9	3	4	11	2	8	34	45	29
49	6	8	5	2	14	1	9	50	74	53
50	5	6	4	1	7	2	6	40	76	78
51	3	4	2	1	5	7	8	18	45	63
52	2	3	1	1	3	11	10	1	5	19
53	1	2	1	1	2	4	3	1	1	3
54	2	2	2	2	8	0	0	6	12	6
55	4	4	5	6	8	1	1	5	9	4
56	5	5	6	8	1	3	6	1	1	0
57	14	4	1	10	10	4	2	5	4	...

a)

N =

	325	326	327	328	329
42	0	0	0	0	0
43	0	0	0	0	0
44	0	0	0	0	1.66
45	0	0	0	0	0
46	0	0	0	0	0
47	0	0	0	0	0
48	0	0	0	0	0
49	0	-2.495	0	0	0
50	11.215	0	-1.491	5.262	21.234
51	4.947	-1.961	0	3.152	0
52	1.696	0	0	0	0
53	0	0	0	0	0
54	10.326	-13.001	-4.932	-13.708	-36.938
55	5.404	-28.831	-18.244	-25.184	-8.154
56	6.199	47.196	-10.747	-16.737	17.141
57	-1.832	-1.877	-7.244	-2.431	...

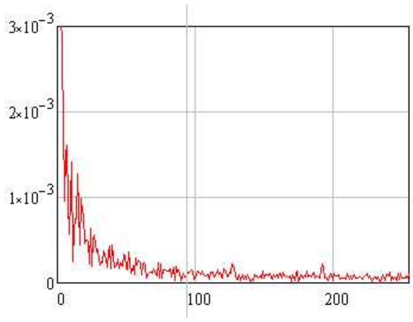
b)

Rysunek 4. Porównanie macierzy współczynników DCT (a) i współczynników falkowych (b)

Po wznowieniu przywróconego obrazu z matrycy współczynników falkowych (Rys. 4(b)) otrzymujemy oczyszczony kontener (Rys. 5).

Pojawienie się szumu na odnowionym kadrze, warunkowany użyciem algorytmu ściskania ze stratami, lecz jest to koniecznie dla podwyższenia szybkości przekazania, kodowania, i zniszczenia utajnionej informacji w kontenerze.

a)



b)

Rysunek 5. Odnowiony kadr (a) i jego spektrum (b)

Sprawdzono odnowiony kadr na obecność w nim utajonej informacji (Rys.5). Jak można zaobserwować, w porównaniu do Rys. 1, znikły wybuchy wysokiej częstotliwości w części obwodu kontenera. Sądząc z tego, można przypuścić, że z kontenera została usunięta utajniona informacja, czyli zrealizowano aktywny atak na kontener. Dla dezorientacji odbiorcy komunikatu, proponuje się po usunięciu utajnionej informacji wprowadzić do kontenera nieprawdziwe informacje, czyli jeszcze zrealizować atak zamiany.

5. Wnioski

W niniejszej pracy zrealizowano aktywny atak na stego-kontener za pomocą użycia algorytmu transformacji falkowej. Zaproponowano algorytm ściskania ze stratami, który wydala informację wniesioną do przestrzennego obwodu obrazu. Również, kosztem zamiany współczynników DCP współczynnikami transformacji falkowej, było uzyskanie kodowania kontenera i kompresji, kosztem czego zwiększa się przepustowość transmisji danych w kanale przekazywania informacji. Kompresja konteneru odbywa się kosztem ściskania matrycy, która jest przesyłana przez kanał komunikacji. Wartości zależności korelacji kontenera od zadanego odsetka współczynników falkowych, uzyskuje się, opierając się na danych otrzymanych metodą transformacji falkowej.

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DEVELOPMENT OF INFORMATION TECHNOLOGIES OF ARTERIAL OSCILLOGRAM ANALYSIS

Summary: In this work there are presented methods of temporal, spectral and morphological analysis of arterial oscyllograms for information system of medical (physical) rehabilitation. Expert system enables biocybernetic interpretation of results obtained in order to guarantee correct assessment of patient investigated

Keywords: information technologies, arterial oscillogram, biocybernetics

OPRACOWANIE TECHNOLOGII INFORMACYJNYCH ANALIZY ARTERIALNEGO OSCYLOGRAMU

Streszczenie: W artykule przedstawiono metody czasowej, spektralnej, morfologicznej analizy arterialnych oscylogramów dla informacyjnego systemu medycznej (fizycznej) rehabilitacji. Dla zapewnienia prawidłowej oceny stanu zdrowia badanego pacjenta system ekspercki zabezpiecza biocybernetyczną interpretację otrzymanych wyników.

Słowa kluczowe: technologie informacyjne, arterialny oscylogram, biocybernetyka

1. Wprowadzenie

Układ krwionośny to wskaźnik zdolności adaptacyjnych organizmu [13]. Patologia układu krwionośnego odnotowywana jest u 3/4 ludności Ukrainy, a w 62,5 % przypadkach stanowi przyczynę zgonu, wskaźnik ten jednoznacznie przewyższa znaczenie wskaźnika w państwach rozwiniętych [19]. Szczególnie zaniepokojenie budzi nie tylko wzrost przypadków zaburzenia układu krwionośnego, lecz „odmładzania": w kategorii nastolatków w okresie ostatnich 5 lat wskaźnik ten wzrósł o 28 %, zaś kategoria osób w wieku średnim liczy przyrost wskaźnika o 17 % [19], świadczy to więc o wadach systemu diagnozy chorób. Podwyższone ciśnienie tętna

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jest podstawowym faktorem ryzyka rozwoju katastrof naczyń krwionośnych. W Ukrainie zostało zarejestrowane ponad 5 mln. osób z nadciśnieniem tętniczym, co stanowi około 10 % ludności Ukrainy [10]. Obecnie społeczeństwu brakuje technologii diagnoz skutecznych i leczenia patologii naczyń [11]. Czas obecny wymaga zorganizowania jednolitego zespołu technologicznego do całokształtu dynamicznego diagnozowania układu krwonośnego pacjenta jednocześnie na różnych poziomach regionalnych i systemowych z wynikami analitycznie opracowanymi do interpretacji klinicznych i oceniania przez lekarza przebiegu układu krwonośnego w stanach zwyczajnych i patologicznych. Badanie dynamiczne układu krwonośnego ma być wyprowadzone na zasadniczo nowy poziom [2]. Stanowi to docelową potrzebę teraźniejszości w walce przeciwko „napaści" schorzeń serca i układu krwionośnego [11].

Biorąc pod uwagę aktualność tematu udoskonalenia metod diagnozy i monitoringu stanu systemu krwionośnego [7], autorzy opracowali zalecenia metodyczne pomagające opracowaniu i uzasadnieniu technologii informacyjnej analizy oscylogramu tętna.

Oscylogram został uzyskany przy stosowaniu ciśnieniomierza elektronicznego BAT41-2 umożliwiającego rejestrowanie znaczeń ciśnienia w mankiecie w okresie wzrostu kompresji i eksponowanie zmierzonych znaczeń w celu następnej ich analizy. Również zostały opracowane metody odczytu oscylogramów przy stosowaniu analizy morfologicznej, czasowej, widmowej, fraktalnej, korelacyjnej, skupień, które zostały faktycznie aprobowane w „Środowisku informacyjnym rehabilitacji medycznej (fizycznej)", a także został sprawdzony kompleks analizy impulsów biologicznych.

W powodu braku podobnych badań, do opracowania kryteriów odczytu oscylogramów z zastosowaniem analizy czasowej i widmowej do analizy, zostały wykorzystane dane do elektrokardiografii i elektroencelografii (R.M. Bajewski, 1997, 2001; N.I. Jabłuczański, A.W. Martynienko, 2010 i inni), a do analizy morfologicznej – dane stosowane w pletismografii oraz reografii (H.H. Jarulin, 1965; A.W. Pokrowski; K. Karo, 1981; T. Pedli, 1983; A.W. Czaszczyn, 2005; U.B. Łusczyk 2005; I. Cupko, 2008 i inne). Przy tym została zachowana terminologia stosowana w wyżej wymienionych metodach badań.

Do każdej metody analizy zostały zaproponowane kryteria informacyjne i uzasadnione ich stosowanie oraz określone kryteria normy, zostały przedstawione charakterystyki i tryb oceniania oscylogramu stanu poza normowego, również określone istotne kryteria uzupełniające i pomocne do analizy odrębnych oscylogramów. Zostały zbadane związki korelacyjne wskaźników czasowych i analizy widomej oscylogramów i synchronicznie odczytanych elektrokardiogramów. Analiza badanych parametrów została przedstawiona w odrębnych fazach kompresji tętnic ramiennych.

Zaprezentowane metody zostały zastosowane do badania zdolności adaptacyjnych układu krwionośnego pod różnorodnymi wpływami. Przeprowadzono 26 rodzajów eksperymenów. Między innymi fizyczne (test Ruffiera, procedura fizjoterapii, system uzdrawiający Chi Kung, Qigong, Reiki), mechaniczne (masaż segment-refleksyjny przy użyciu przyrządu firmy Huga Best), termiczne (sucha łaźnia i parowa, kąpiel zimowa (mors)), audi-wizualne (w najbardziej rozmaitych połączeniach kombinacyjnych) oraz inne czynniki.

2. Oscylometryczna metoda pomiaru ciśnienia krwi

Istotą oscylometrycznej metody pomiaru ciśnienia krwi w istniejących urządzeniach pomiaru ciśnienia arterialnego sprowadza się do rejestracji wielkości pulsacyjnych wahań ścianki tętniczej w mankiecie, a uzyskana krzywa odzwierciedla proces tłoczenia powietrza w mankiecie i wpływ naczyniowej ścianki arterii na mankiet. Sygnały oscylatorów rejestrowane w ten sposób, w pełni odzwierciedlają prawidłowość procesów, przebiegających przy formowaniu oscylogramu naczyń arterialnych pod wpływem wzrastającego ciśnienia w mankiecie i zachowują niezniekształconymi współzależności amplitudowo-czasowe [17].

Krzywa ciśnienia, po usunięciu z niej składowej, wprowadzonej działalnością kompresora, wykorzystywana jest dla wyznaczenia znaczeń wartości skurczowego i rozkurczowego ciśnienia krwi i częstotliwości skurczów serca (Rys. 1).

Tętniczy oscylogram, uzyskany bez stale wzrastającej części składowej ciśnienia w mankiecie pod działaniem kompresora, przedstawiono na rysunku 2.

2.1. Analiza morfologiczna oscylogramów.

Do morfologicznej analizy oscylogramów stosowane są następujące kryteria:

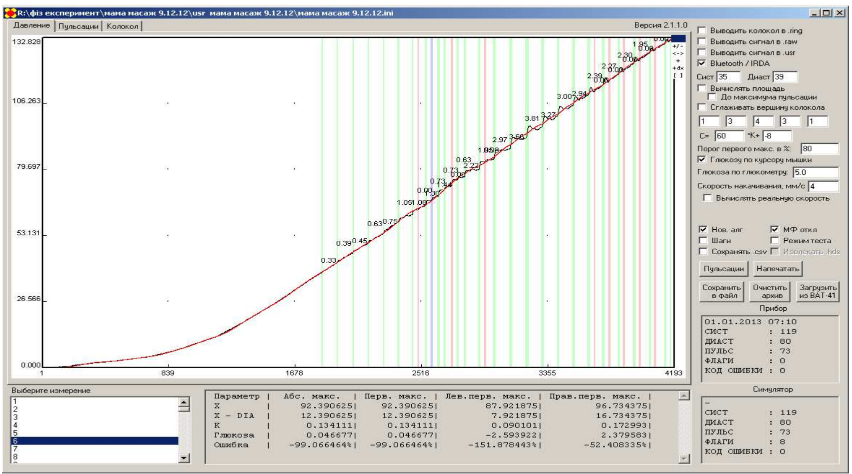
a) **kształt linii** (charakterystyka kopert, rytmiczność pulsacji, równomierność wzrostu i obniżenie amplitudy oscylacji w procesie zwiększenia kompresji);

b) obecność i ilość **maksymalnych oscylacji** z jednakową amplitudą;

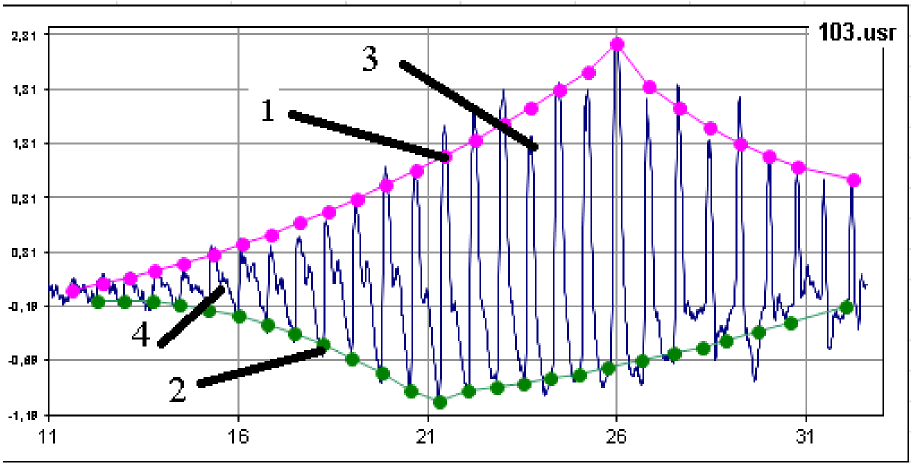
c) charakter **poszczególnych oscylacji** w różnych fazach kompresji (ich amplituda, kąty krańcowości, wschodząca i opadająca części);

d) obecność, rozmieszczenie, wielkość **dykrotycznych i dodatkowych fal** (załamków) na poszczególnych oscylacjach.

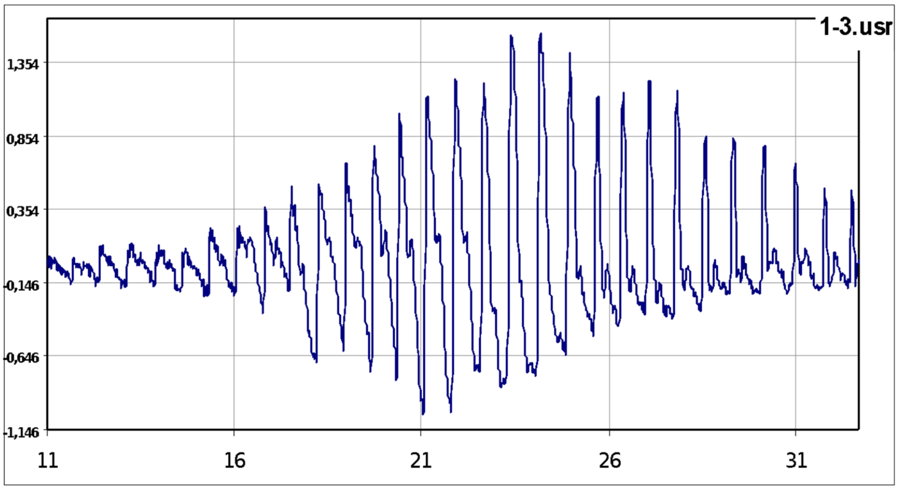
Dla ułatwienia analizy wizualnej oscylogramu, w zależności od etapu wzrostu kompresji wydzieliliśmy trzy jej części (Rys. 3).



Rysunek 1. Okno interfejsu programu Algorithm Debugger, gdzie przedstawiona jest krzywa ciśnienia po przeniesieniu z miernika ciśnienia tętniczego BAT 41-2. Przypis. Na osi X odzwierciedlono odliczania czasu w sekundach, na osi Y - wartości wahań ciśnienia w mankiecie, mm Hg.



Rysunek 2. Tętniczy oscylogram, uzyskany z wykresu linii ciśnienia. Na osi X odzwierciedlono odliczania w sekundach, na osi Y - wahania wartości ciśnienia, mmHg w mankiecie pod wpływem ścianki naczynia tętnic wieńcowych. 1 - koperta górnej części oscylogramu, 2 - koperta dolnej części oscylogramu, 3 - oscylacja, która odchyla się od górnej części fali oscylogramu podstawowego. 4 - ząb dykrotyczny



Rysunek 3. Oscylogram naczyń ramienia badanego. Mężczyzna, 20 lat. Przypis: na tym i na następnych rysunkach oscylogramów na osi X odzwierciedlono czas rejestracji oscylogramu(c), na osi Y - znaczenie wahań ciśnienia w mankiecie pod wpływem naczyniowej ścianki arterii (mm Hg.)

Pierwsza - początek kompresji (od początku kompresji do momentu nagłego wzrostu amplitudy oscylacji, wskaźników ciśnienia rozkurczowego, w naszym przypadku - do 18 s, **druga** - narastanie kompresji (od momentu szybkiego wzrostu amplitudy oscylacji do jej szybkiego obniżenia, wskaźnik ciśnienia skurczowego, 18-31 s), **trzecia** - maksymalna kompresja (ciśnienie w mankiecie wyższe od poziomu

ciśnienia skurczowego). **Druga** część włącza okres 2-a - jej wschodząca część (okres narastania kompresji do osiągnięcia pełnego ściśnięcia naczyń w fazie rozkurczowej 18-23 s) oraz 2-b - jej maksymalna oscylacja i opadająca część (do osiągnięcia pełnego zwarcia naczyń w fazie rozkurczowej, 23-31 s) [8].
Zestawienie danych analizy źródeł z literatury przedmiotu z otrzymanymi przez nas rezultatami badania 1680 oscylogramów dało możliwość wyciągnąć wniosek, że oscylogram praktycznie zdrowej osoby (Rys. 3) posiada następujące charakterystyczne cechy:

Forma oscylogramu

1. Rytmiczność oscylacji, stopniowy równomierny wzrost ich amplitud, osiągnięcie maksimum i obniżenie do końca rejestracji.
2. Zachowanie w procesie wzrostu kompresji kilku jednakowych co do amplitudy maksymalnych oscylacji (w okresie początku całkowitego ściśnięcia naczyń podczas rozkurczu serca).
3. Symetryczna lokalizacja kopert, stworzonych przy maksymalnych i minimalnych skrajnościach, ich kopulasta forma z równomiernym wzrostem i obniżeniem, występowanie szczytów maksimów po minimalnych skrajnościach.
4. Bardziej wyrazisty wzrost amplitudy oscylacji na wspinającej się części oscylogramu - wskaźnik rozkurczowego obniżenia na wyjściowe - ciśnienia skurczowego.

Charakter poszczególnych oscylacji w różnych fazach kompresji

1. Amplituda każdej pulsującej fali jest proporcjonalna w stosunku do zmieniającego się pod wpływem ciśnienia w mankiecie prześwitu magistralnego naczynia tętniczego: stopniowo wzrasta, osiąga maksimum i stopniowo obniża się.
2. Szczyty górne krańcowości są zaostrzone. Na początku kompresji ich kąt jest większy, w procesie wzrostu kompresji - najpierw zmniejsza się, a potem dochodzi do zera: górna część katakroty znacznie zbliża się do anakroty albo pokrywa się z nią.
3. Obszar wspinającej się części jest mniejszy, opadającej - większy. Odnoszą się one do siebie, jak 1 do 6.
4. Długotrwałość fazy powolnego wygnania krwi w procesie zwiększenia kompresji stopniowo wzrasta, faza rozkurczowa - skraca się.

Obecność, lokalizacja, wielkość dykrotycznych i dodatkowych fal na poszczególnych oscylacjach

1. Na wspinającej się części oscylacji dodatkowe fale nie występują.
2. Na opadającej części oscylacji, w końcu rozkurczowej, rejestruje się dykrotyczna fala. Na początku kompresji rozmieszczona jest ona na średniej części katakroty, zanika przy maksymalnej amplitudzie oscylacji. W procesie narastania kompresji pojawia się znów, lecz już na dolnej części katakroty i w każdym kolejnym tętnie stopniowo zbliża się do jej dolnego kraju. Amplituda dykrotycznych fal przy tym wzrasta.
3. W procesie wzrostu kompresji na opadającej części oscylacji w ślad za falą dykrotyczną rejestrowane są drobne jednakowego typu fale dodatkowe.
4. Pełną kompresję naczyń (lub ciśnienie skurczowe) można ustalić nie tylko na

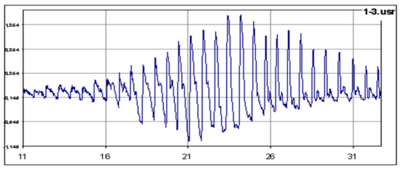
podstawie gwałtownego spadku amplitudy oscylacji, lecz również obserwując zanik dykrotycznych fal na opadającej części. Pojawienie się fali po fazie zakończenia katakroty to przejaw pełnego ucisku naczyń krwionośnych zarówno w fazie rozkurczu, jak i skurczu.

5. Jednakowe, co do typu drobne oscylacje w okresie, kiedy naczynie jest całkowicie ściśnięte, wynika w rezultacie działania sił bezwładności. One utrzymują się do wystąpienia kolejnego uderzenia hydraulicznego.

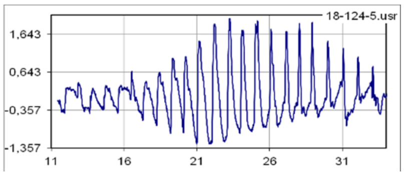
Przedstawionemu na rysunku 1 oscylogramowi zdrowej osoby właściwa jest harmonijność wzrostu i spadania amplitudy pulsacji, ich rytmiczność, prawidłowości lokalizacji dykrotycznych występów i dodatkowych fal. To wskazuje na adekwatny odruch reakcji układu sercowo-naczyniowego badanego na różnych poziomach stopniowo wzrastającego zwiększającego się ściśnięcia naczyń krwionośnych ramienia. Taki typ przyjęto uznawać za normę. Występował on u 8 % badanych. Według stopnia odchylenia wskazanych kryteriów oscylogramów od normy wydzielono 5 jego typów (rys. 2.3)

Dodatkowe równowartościowe kryteria analizy morfologicznej
Dla oceny stopnia odchylenia morfologicznych wskaźników oscylogramów od zaproponowanej przez nas normy opracowano 5 równowartościowych poziomów wizualnych kryteriów dla każdej z następujących 8 charakterystyk: 1) forma kopert według maksymalnych i minimalnych krańcowości; 2) obecność zakłóceń rytmiczności oscylacji, 3) reakcja naczyń na początek kompresji (do osiągnięcia ciśnienia rozkurczowego); 4) reakcja naczyń obszaru ramienia na kompresję względem amplitudy, obecności i ilości ekstremalnych (z nierównomiernym powiększeniem amplitud) oscylacji (harmonijność wzrostu i obniżenie amplitudy drgań); 5) ilość maksymalnych, co do amplitudy oscylacji; 6) forma górnych krańcowości oscylacji na początku kompresji; 7) zmiany w zakresie charakteru rosnącej części oscylacji; 8) zmiany w zakresie charakteru opadającej części oscylacji [12]. Przejawy „pogorszenia” charakterystyk narastają od 1 do 5 (Rys. 4).

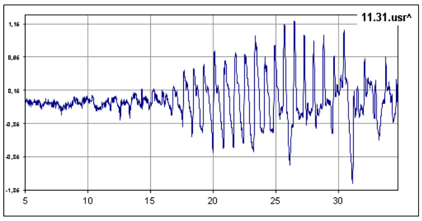
Morfologiczna analiza charakteru oscylogramów oraz, uzyskanej w procesie stopniowej kompresji naczyń, daje możliwość oszacować stan naczyń peryferyjnych i funkcjonalną zdolność układu sercowo-naczyniowego, do adaptacji w warunkach kompresji naczyń ramienia. Wyniki tych badań mogą być wykorzystane zarówno w klinicznej, jak i w eksperymentalnej medycynie w badaniach eksperymentalnych, jak i medycynie do wykrywania chorób układu sercowo-naczyniowego i naruszenia jego zdolności funkcyjnej.



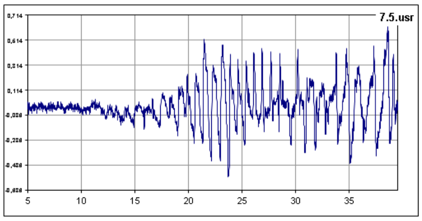
1-szy typ



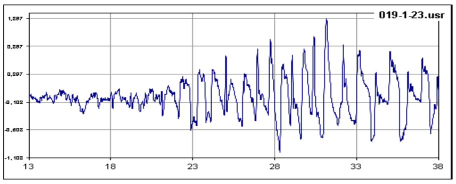
2-gi typ



3-ci typ



4-ty typ



5-ty typ

Rysunek 4. Morfologiczna charakterystyka typów oscylogramów, zróżnicowanych pod względem stopnia odchylenia harmonijności amplitud od zaproponowanej normy

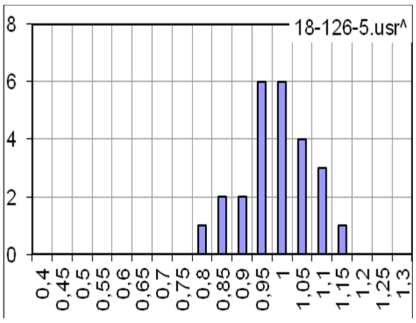
2.2. Czasowa analiza oscylogramów

Przy czasowej analizie oscylogramów przeprowadzono analizę i ocenę zmienności trwałości oscylacji według metod analizy i czasowej oraz wariacyjnej pulsometrii okres oscylacji, przyjętych dla oceny sygnałów elektrokardiograficznych [8]. W tym celu wykorzystano następujące wskaźniki: **SDSD** - standardowe odchylenie różnic między sąsiednimi normalnymi skrajnościami (ms); **NN50** - ilość kolejnych odstępów (z osobna maksimów i minimów), różnica między którymi przekracza 50 ms; **Mo** (moda) - skala znaczeń długotrwałości oscylacji, występujących najczęściej (c); AMo (amplituda mody) - liczba odstępów, które odpowiadają znaczeniu mody (%); **BP** (wariacyjna rozpiętość) - różnica maksymalnych i minimalnych znaczeń trwałości odstępów między sąsiednimi oscylacjami (c); **IBP** (indeks wegetatywnej równowagi), **IBP** = AMo / BP (j.u.); **ВПР** (wegetatywny wskaźnik rytmu) ВПР = 1/Mo x BP) (jednostka umowna); **IH** (indeks napięcia systemów regulatorowych), IH = AMo / (2*BP*Mo) (j.u.); **HRV**-індекс - Triangulacyjny indeks (j.u.); **RMSSD** - pierwiastek kwadratowy średniej kwadratowej różnicy między sąsiednimi skrajnościami (mc); **RR std** - standardowe odchylenie między skrajnościami (мс). Zbadano korelacyjną rytmografię lub skaterografię - graficzne odwzorowanie podziału stycznych oscylacji w dwumiarowej płaszczyźnie współrzędnych oscylogramów (poprzedniego i następnego) oraz chaosogramu, przeznaczonego dla analizy nieliniowych «chaotycznych» drgań długotrwałości oscylacji.

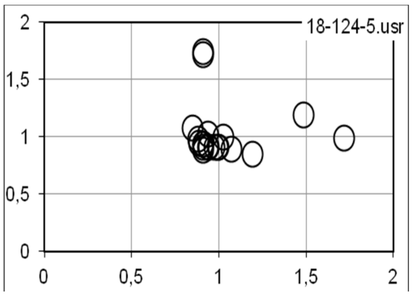
Przy badaniu wskaźników czasowej analizy oscylogramów wyznaczono ich średnie wskaźniki: **SDSD** - 0,45±0,02 ms, **pNN50** - 10,6±0,02, **Mo** - 0,87±0,02 мs, **AMo** -37,1±1,1, **IVR** -75,2±7,6, **IN** - 32,3±2,9, **HVR-index** - 29,2±0,12. Uwzględniając poziom odchylenia od średnich znaczeń wskaźników czasowych (-1 - +1) zgrupowano 10 kategorii (od -5 do -1 oraz od 1 do 5).

Uzyskane dane pokrywają się ze wskaźnikami histogramów i skaterogramów, zarejestrowanych przy analizie sygnału elektrokardiogramu [5, 6], przedstawionych na rysunku 5.

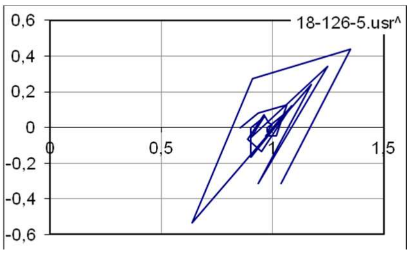
a) Histogram



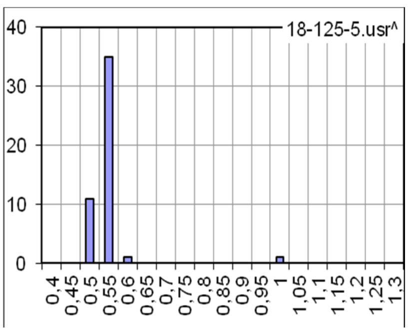
Skaterogram



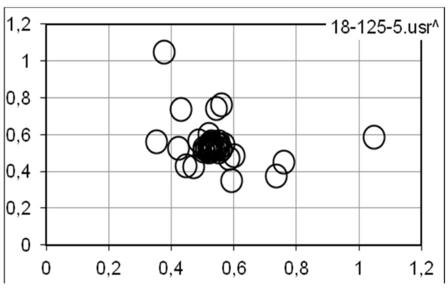
Chaosogram



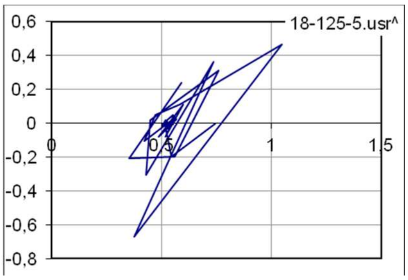
b) Histogram



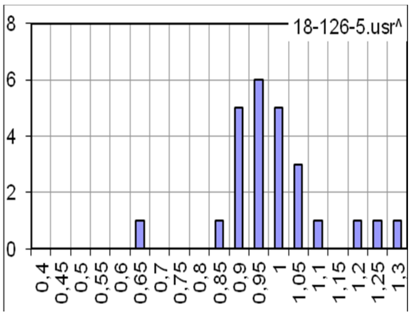
Skaterogram



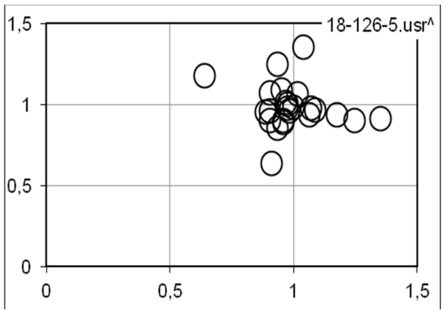
Chaosogram



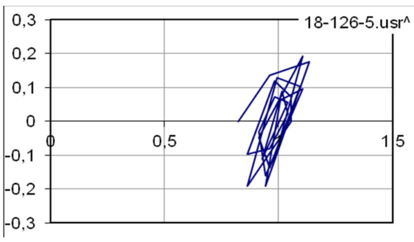
c) Histogram



Skaterogram



Chaosogram



Rysunek 5. Typy histogramów (lewy słupek), skaterogramów (średni słupek) i chaosogramów (prawy słupek), stworzonych na podstawie analizy oscylogramów. a) 1-szy typ - eutonia (badany M, 18 lat, b) 2-gi typ - sympatykotonia (badany K, 19 lat) c) 3-ci typ - wagotonia (badany B, 19 lat)

Jak widać na rysunku 5, przy eutonii podstawowy punkt na chaosogramie rozmieszczony jest w granicach 1 ms, przy wagotonii - przesunięty po przekątnej w prawo, przy sympatykonii - w lewo.

2.3. Spektralna analiza oscylogramów

Spektralną analizę arterialnych oscylogramów {przebiegu tętnic} (zgodnie z analizą sygnału elektrokardiogramu) [11] przeprowadzono drogą wyznaczenia mocy widma w pasmach o częstotliwości 0,003 Hz - 0,4 Hz: wysokich (HF, 0,15-0,40 Hz); niskich (LF, 0,04 - 0,15Hz), ponadniskich częstości (VLF, 0,003 - 0,04 Hz), Total

(TP<0,40 Hz ;) oraz k = LF/HF. Zgodnie z zasadami neurodynamicznej analizy [18] zbadano także moc widma w następujących skalach: Delta 0,4-4 Hz , Teta 4-8 Hz, Alfa 8-13 Hz , Beta 13 - 25 Hz, 25 Hz i więcej.
Dla oceny mocy widma według kryteriów analizy spektralnej, przyjętych w EKG [1, 5], zastosowano szybkie przekształcenie Fouriera od 0 Hz do 60 Hz (Zborowskij E.I., 1971; Boronojew, W. W. 1999; Czaszczin A.W. 2014). Dla krzywej, odzwierciedlającej mechaniczną aktywność ścianki tętnicznej w procesie kompresji ramienia, oprócz szybkiego przekształcenia Fouriera w paśmie częstotliwości od 0 Hz do 60 Hz, wykorzystano także przekształcenie Hilberta -Chuanga od 0 Hz do 3 kHz. Dla oceny samopodobieństwa fragmentów (fraktalnej wymiarowości) oscylacji wykorzystano metodę Hursta, (Hurst H.E., 1951). Analizę oscylogramów według metody Hilberta-Chuanga wykorzystano także dla oceny momentalnej częstotliwości za pomocą zdefiniowania obszarów Delta 0,4-4 Hz, Teta 4-8 Hz, Alfa 8-13 Hz, Beta 13-25 Hz, 25-60 Hz, 60 Hz i więcej w różnych fazach ucisku ramienia mankietem. W tych samych odstępach czasowych obliczono obszar dla stwierdzenia mocy fazy momentalnej. Dla analizy wykorzystano najczęściej używany tętniczy oscylogram. Według poziomu odchylenia od średnich znaczeń (-1 - +1) wskaźniki analizy spektralnej zgrupowana w 10 kategoriach (od -5 do -1 i od 1 do 5).

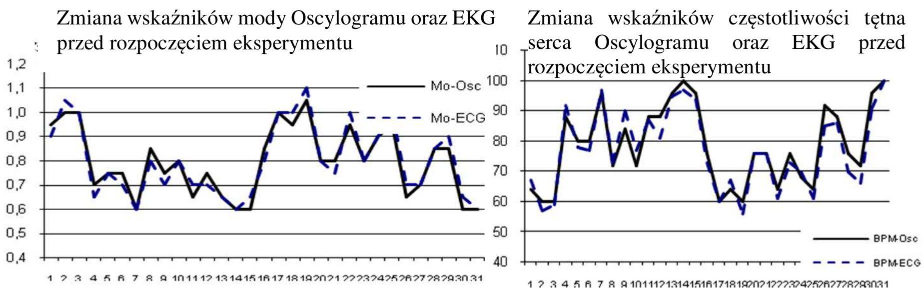
2.4. Analiza korelacji

Realizacja rytmicznej aktywności serca możliwa jest tylko przy występowaniu pewnych fazowych współzależności między oscylacyjnymi procesami mózgowymi i sercowymi (Smirnow K. J., 2010) i, z kolei, gdy powolne (nie oddechowe) wahania rytmu serca korelują sięz analogicznymi falami ciśnienia krwi i pletyzmogramem (Bajewskij R. M., 1991). Analizie koleracyjnej poddano wskaźniki, obliczone na podstawie czasowych i spektralnych metod analizy oscyłogramów: wszystkich grup badanych, jak również **oddzielnie -** zdrowych, chorych; do i po fizycznym obciążeniu, masażu, przeglądu multimiedialnych kompozycji, procedury terapii fizycznej (ćwiczenia) itp. Wybrane znaczenia koleracji poddano analizie skupień (metoda k. przeciętnych, Mirkes E. M. 2011) , obliczono współczynnik korelacji (metoda Pearsona Rodgers J. L., Nicewander W. A., 1988), zgrupowano w 12 klastrach. Ze zgrupowanych w klastry korelat sformowano **portret korelacyjny** według następujących kryteriów: korelaty, które znajdowały się w interwale od 0,9 do 1 i -0,9 do -1; gdzie znaczenie klastra było unikatowym (specyficznym) właśnie dla danego czynnika; ilość łącznych kolerat; ilość znaczących korelat do i po eksperymencie; ilość i wagowa współzależność korelat z bezpośrednią i odwrotną zależnością; znaczenie kolerat, które były obojętne wobec występujących czynników. Klasterową analizę oscylogramów wykorzystano dla znakowania obciążeń i procesów patologicznych oraz dla dalszego porównania zmierzonych sygnałów z wcześniej zidentyfikowanymi portretami korelacji.
Ustalono, że do korelacji, które były charakterystyczne dla wszystkich 446 zbadanych (przed eksperymentami) należą absolutne wartości części widma o wysokiej częstotliwości i ich procentowy udział w sumarycznej częstotliwości mocy zasilania (0,003 Hz - 0,4 Hz), wyznaczonych według przekształcenia Fouriera, jak również korelaty, obliczone na podstawie przekształcenia Hilberta-Chuanga momentalnej częstotliwości (0 Hz - 13 Hz) i momentalnej fazy zarejestrowane w ciągu całej kompresji naczyń ramienia, lub w niektórych jej okresach. Wśród niezmiennych

korelat zdarzały się Delta-fale. Powyższe korelaty miały bezpośrednią więź. Sprzężenie zwrotne rejestrowano pomiędzy mocą Delta rytmu z Alfa i Teta rytmem. Na oscylogramach, zarejestrowanych w czasie pomiarów ciśnienia krwi w stanie spokoju u 110 zdrowych osób, korelacyjne związki odnotowano przeważnie między statystycznymi wskaźnikami oscylogramów: Mo, AMo, NN50, IVR, stopniem dynamiki (mocy) rozszerzenia ścianki naczyń w czasie skurczu, średnioarytmetycznymi i średniokwadratowymi znaczeniami RR-Odstępów, jak również między absolutną i procentową zawartością mocy wysokiej i najpowolniejszej częstotliwości w sumarycznej mocy wszystkich zakresów widma (HF, LF i VLF) w szczególności i między sobą w ciągu całej kompresji naczyń ramienia lub w niektórych jej okresach. Badania poświadczyły skoordynowaną aktywność bardziej niskich poziomów regulacji czynności układu sercowo-naczyniowego.

2.5. Porównawcza analiza synchronicznie zarejestrowanych wskaźników arterialnych oscylogramów i elektrokardiogramu

Przebadano 96 osób w wieku 18 - 29 lat. Oscylogramy i EKG rejestrowano w stanie spokoju i po wpływie każdego z różnocharakterystycznych audiowizualnych czynników (5 rodzajów 650 zapisów). Synchronicznie rejestrowano elektrokardiogram nieprzerwaną metodą w ciągu całego badania u każdego z badanych (20 minut). Ujawniono, że dynamika badanych jednoimiennych wskaźników może mieć silną więź koleracyjną (Mo, *Częstość skurczów serca* (heart rate, HR), rys. 2.6), przeważna ilość wskaźników może mieć silną koleracyjną więź (AMo, RMSSD, LF, waga Alfa fal w widmie od 0 Hz do 60 Hz i inne); może odróżniać się o rzędy wielkości przy zachowaniu poprzedniego przypadku więzi (RR-std ze średniokwadratowym odchyleniem odstępów między sąsiednimi drganiami oscylogramów, VLF, Alfa-rytmem etc.); koleracyjna więź może nie występować. Ostatni fakt świadczy o tym, że bezpośrednia reakcja naczyń ramienia na ich kompresję zależy jak od stanu naczyń, tak i od wielu neuro-refleksowych czynników, dlatego nie zawsze towarzyszą im synchroniczne zmiany poszczególnych wskaźników.



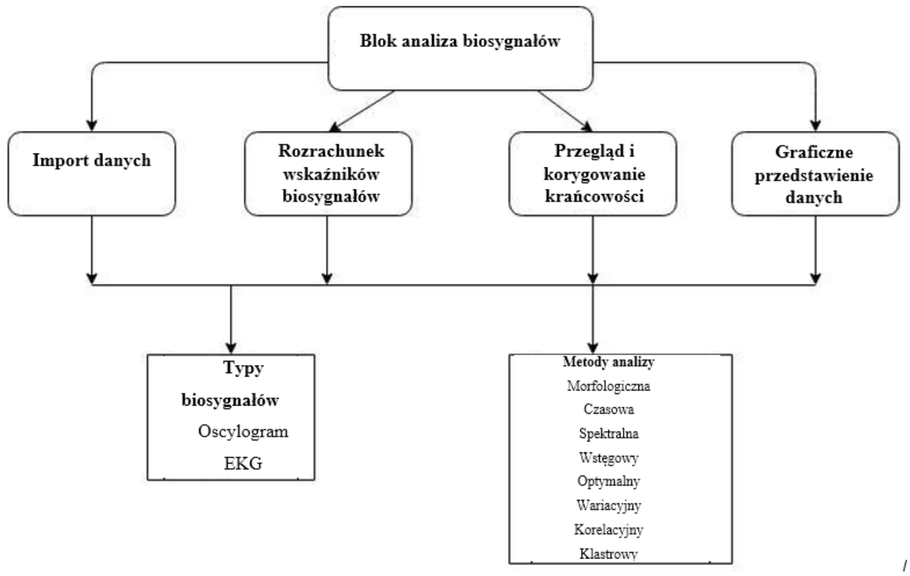
Rysunek 6. Wskaźniki: mody (z lewej strony) i częstotliwości tętno serca (z prawej) oscylogramów i EKG przed rozpoczęciem eksperymentu (reprezentatywny wybór 31 osób)

W ten sposób, korelacja na poziomie 0,97 między wskaźnikami mody, jak i częstotliwości tętna sercowego, obliczonych w oparciu o EKG i AOH, wskazuje na

silną korelację ich w całym doborze i potwierdza wysoką nośność informacyjną wybranych metod badania. Jeżeli uwzględnić to, że Amo charakteryzuje poziom centralizacji zarządzania rytmem serca [16], ta zbieżność jego wskaźników na EKG i AOH pozwala wyciągnąć wniosek, iż jest to nie tylko charakterystyka poziomu centralizacji sterowania rytmem serca, lecz również «pereferyjnego serca». Przypadki silnej koleracji między RMSSD (wskaźnik aktywności parasympatycznego ogniwa wegetatywnej regulacji) świadczy o jednakowym stopniu udziału ПС ВНС w sterowaniu czynnością serca i naczyń obwodowych.
Otrzymane rezultaty potwierdzają wysoką nośność informacyjną wybranych metod.

3. Oprogramowanie dla analizy arterialnych oscylogramów

Metody czasowej, spektralnej, morfologicznej analizy jest realizowano w bloku analizy arterialnych oscylogramów informacyjnego systemu medycznej (fizycznej) rehabilitacji. Dla zapewnienia prawidłowej oceny stanu badanego pacjenta systemu system ekspercki zabezpiecza biocybernetyczną interpretację otrzymanych rezultatów. Blok sprawozdań zabezpieczony jest rozległym wykazem wariantów sprawozdań, co zapewnia maksymalnie pełne odzwierciedlenie rezultatów pomiarów dla różnych pracowników służby zdrowia, pacjentów i kierowników placówek medycznych [4, 13, 14, 15, 16].
Rezultaty zastosowania informacyjnego systemu medycznej (fizycznej) rehabilitacji mogą być wykorzystane zarówno w klinicznej, jak i w eksperymentalnej medycynie dla wyjawienia chorób układu sercowo-naczyniowego, zakłóceń jego funkcjonalnej zdolności i towarzyszyć zdrowym i chorym przy ich fizycznej rehabilitacji, co pomoże zaplanować przedsięwzięcia profilaktyczne i rehabilitacyjne oraz zapobiec rozwojowi patologicznego procesu, co prowadzi w wyniku do znacznej oszczędności środków przy udzieleniu pomocy w szpitalu.
Dla odtworzenia paradygmatu opracowanego bloku analizy biosygnałów informacyjnego systemu medycznej (fizycznej) rehabilitacji skorzystamy z ujednoliconego języka modelowania UML**.** Uogólniona struktura schematu blokowego analizy biosygnałów przedstawiono na rysunku 7.
Dla wprowadzenia zaproponowanej naukowo technicznej wytwórczości niezbędna jest obecność elektronicznych mierników ciśnienia tętniczego z możliwością eksportu zapisanych znaczeń pomiaru, na przykład BAT-41-2 (producent «ИКС-Техно», Ukraina). Zaplecze programowe - «Informacyjny system medycznej (fizycznej) rehabilitacji» z Blokiem analizy arterialnych oscylogramów.



Rysunek 7. Schemat blokowy analizy biosygnałów

4. Wnioski

Analiza źródeł literatury przedmiotu oraz własnych badań potwierdziła aktualność badania stanu naczyń obwodowych. Reakcja naczyń przedramienia na kompresję w stanie spokoju i po okazaniu wpływu różnocharakterystycznych czynników stwarza możliwość oceny stanu regulacji nerwowo-hormonalnej czynności układu sercowo-naczyniowego, poziomu funkcjonowania wegetatywnego układu nerwowego, funkcjonalnej wydolności serca, reflektorowej reakcji układu sercowo-naczyniowego, stanu łożyska naczyń obwodowych (tonus, elastyczność, drożność), aktywności mechanizmów natychmiastowej reakcji na kompresję (baroreceptory, chemoreceptory, refleks na niedokrwienie) itp. Uzyskane rezultaty dają możliwość podnieść zakres informacyjny diagnostyki stanu układu sercowo-naczyniowego drogą analizy arterialnej oscylogramów, zarejestrowanej w procesie pomiarów ciśnienia arterialnego z zastosowaniem morfologicznej, czasowej, klastrowej analizy u każdego pacjenta.

Uogólnienie rezultatów wpływu wymienionych i wszystkich innych wykorzystywanych czynników dała możliwość na stwierdzenie, że reakcja układu krążenia, nawet jeśli początkowy stan względnej spójności i wpływu tych samych czynników, nie jest jednoznaczny, co obiektywnie potwierdza konieczność indywidualnego podejścia do wyboru czynników wpływu.

Badanie uwidoczniły, że stopień i jakość reakcji naczyń na kompresję zależą od prężnie-elastycznych właściwości sprężystych ścianki naczyniowej ściany naczynia, które uwarunkowane są specyfiką ich struktury (indywidualną, wiekową, patologiczną), tonicznym napięciem mięśniowej warstwy naczyniowej ścianki, stopniem biernego napięcia ścianki naczyniowej i podlegają nerwowo-reflektorowym wpływom. Do ostatniego odnieść należy reakcje krążenia pochodzenia nerwowego - baroreceptory, chemoreceptory, refleks na niedokrwienie centralnego układu nerwowego, które kontrolują różne parametry krążenia krwi i stale informują centralny układ nerwowy o zachodzących zmianach (Kurszakow N. A., Pressman L. P., 1954).

Rezultaty przeprowadzonych badań mogą być wykorzystane, jako metody wczesnej diagnostyki chorób, w medycynie klinicznej, eksperymentalnej i sportowej dla wyjawienia chorób układu sercowo-naczyniowego i naruszenia jego funkcjonalnej zdolności, jak też oceny wyników leczenia.

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INFORMATION TECHNOLOGY SECURITY AUDIT OF INFORMATION SYSTEMS OF ELECTRONIC PAYMENTS

Summary: Technology for information security in payment systems is proposed. To ensure information security in payment systems must be used a systematic approach and the stages of systematic analysis of information system security be followed, including: creating a secure environment for handling service and billing system that combines a variety of different countermeasures to any threats.

Keywords:. Electronic payment systems, a systematic approach to information security

AUDYT BEZPIECZEŃSTWA TECHNOLOGII INFORMACYJNYCH W SYSTEMACH PŁATNOŚCI ELEKTRONICZNYCH

Streszczenie: W artykule zaproponowana informacyjną technologię bezpieczeństwo informacji w systemach płatności. W celu zapewnienia bezpieczeństwa informacji w systemach płatności należy stosować podejście systemowe i zachować środki bezpieczeństwa poprzez etapową analizę (krok-po-kroku) bezpieczeństwa systemów informatycznych, co w szczególności obejmuje: tworzenie bezpiecznego środowiska do przetwarzania informacji o usługach i płatnościach w systemie, łączącego w sobie różne środki przeciwdziałania wszelkim zagrożeniom.

Słowa kluczowe: elektroniczne systemy płatności, systemowe podejście do bezpieczeństwa informacji

Introduction

Electronic payment systems more clearly start to become our daily reality, which at least have to be considered. Nowadays, many large firms offer payment for their

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services and goods through electronic payments. One of the advantages is that the consumer in the first place it saves time and does not cause difficulties.

Electronic payment systems (eng. Electronic Payment Systems) – are intended for carrying out payment transactions using the Internet [1].

Free software to open your e-wallet and all the money adapted for mass-market computers, and after a little practice does not cause the average user any problems. Electronic money is becoming more widespread every day, opening more opportunities for someone with access to the Network.

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To ensure information security in payment systems as complex systems, the proposed information technology information security in payment systems that follow the stages of system analysis of safety of payment systems that include: creating a protected environment for service and processing billing information in the system, combining various means of combating any threats [4]. Together with the principles of a systematic approach to perform the analysis of payment systems, is the synthesis of its elements, the direction of solving the problem based on the system model. The analysis is based on the decomposition processes of the payment system. The synthesis stage is the optimal aggregation of components and the functional components for receiving secure electronic payment system.

Information technology security audit of information systems of electronic payments includes the following tasks:

1. Identify the key tasks of electronic payments systems and principles of their functioning, their characteristics.
2. Analysis of the main electronic payment systems.
3. Analysis of threats associated with the use of electronic money.
4. Analysis of security using electronic payment systems.
5. Development of recommendations on the use of electronic payment systems.

The electronic payment system in accordance with the nature of payment are distinguished:

- the system of interbank calculations is intended for payment transactions between banks, payments between its clients;
- intra-Bank payment systems are created to provide the most favorable conditions for the passage of payments between the institutions that belong to the same group;
- the system "client-Bank" are used by banks that offer payment services to its clients based on modern technologies. So, now the increasing distribution receives banking services at home, or "home Bank";
- system of mass payments, which are widely used in developed countries. Despite the fact that traditional non-cash payment instruments (checks, money orders, etc.) are quite common, in recent years increasingly implementing a system of mass (consumer) payments using credit cards.

Interbank electronic payment system (EPS) of Ukraine is the main payment system among banks and institutions of the state Treasury in Ukraine. It was through her going on the bulk of payments between individuals and legal entities in the country. EPS is a closed RTGS system in which money circulate in a closed fiscal space and are under emission control by the National Bank.

In order to make payment via the Internet, electronic store connected to one or more Internet payment systems. In Ukraine with the payments through the Internet are used [5].

Systems based on credit cards.

When connecting to a particular payment system based on credit cards, store will be able to receive payments through the Internet from those customers who have a credit card supported by this payment system. For example, Purse – www.portmone.com.ua – supports payments from major credit cards Visa and MasterCard/Europay such banks, "Nadra", the "Aval", "PrivatBank", "Finance and Credit", etc. However, this system is focused mostly on payment of utility services via the Internet. To see the work of the Ukrainian system of "Purse" can be independently looking at the above website demo.

Systems based on smart cards.

The clients need to have smart card issued by the Bank connected to the system, and for payments via the Internet and additionally use a special device – start-reader and special software. The Ukrainian system based on smart cards is "INTERPLAT" – www.interplat.com.ua).

Internet-banking is designed to provide services for the management of Bank accounts via the Internet (with the receipt of statements on completed transactions). When customers use Internet banking the store does not have to be connected to these systems, it is enough that they accepted cash payments. The client, in order to use the services of Internet banking, shall enter into a respective agreement with the Bank after which you will be able to access their account and make payments via the Internet using a normal browser and under the system of Internet banking procedures. As the examples of the Ukrainian system that allows clients to manage their accounts via the Internet, it can be called such: "Privat-24" PrivatBank www.pbank.com.ua; "HomeBanking", "international Commercial Bank" www.icbua.com/interbanking/; "Internet banking" UkrSibbank https://ib.ukrsibbank.com etc.

System is based on electronic money. In order to use these systems for payments via the Internet, you need to connect to any of them. To install on your computer client software operating system is required; open your account and enter the money (e.g. prepaid cards). In Ukraine there are such systems on the basis of electronic money as. Money www.imoney.com.ua; Webmoney www.webmoney.com.ua. These systems have a list of stores and companies connected to him, that is, unable to pay for goods and services with electronic money. The main question is their safety.

A systematic approach to information security in payment systems should have the following protection mechanisms:

- identification,
- authentication ,
- authorization of all subjects of the payment system,

-control user logon to the system and managing system passwords
-registration, logging and auditing,
- monitoring the integrity, i.e., protection from unauthorized modification of entities in the system,
- control of access.

In the electronic payment systems circulating information in the first place is confidential, which requires protection from viewing, modification and the imposition of false information (availability) [3].

The development of appropriate security technologies, focused on Internet, is causing serious difficulties at the present time. The reason for this is that the architecture, basic resources and technology of the Internet, focused on the organization of access to collecting public information.

After analyzing of many possible common threats to electronic payment systems, it was concluded that electronic payment system is vulnerable to many threats, both accidental and malicious nature, which can be divided into four main groups:
-threats of natural origin;
-threats associated with the area client risks of electronic payment systems;
-the threats associated with the environment interaction (the Internet provider of the client and the Bank);
-threats related to local (or distributed) networks of the Bank.

The main object of attack, the attacker is funding, or rather their electronic alternates - the payment orders circulating in the payment system. In relation to data means an attacker could pursue the following objectives:

1. Theft of funds.
2. The introduction of counterfeit drugs (a violation of the financial balance of the system).
3. The malfunction of the system (technical risk).

Possible implementation mechanisms of the effects are highlighted in the table.

Table 1. Possible implementation mechanisms

The object of the impact	Goal of the impact	Possible implementation mechanisms of the impact.
The HTML page on the web server of the Bank	Substitution with the aim of obtaining information that is entered in the payment order by the customer	Attack on the server, and the substitution of pages on the server. Substitution of pages in the traffic. Attack on the client's computer, and the substitution of pages to the client.
Client information-no page on the server	Obtaining information about customer payments	The attack on the server. The attack on the traffic. Attack on the client computer.
The data of the payment order made by the client in the form	Obtaining information that is entered in the payment order by the customer.	Attack on the client computer. The attack on the order data when forwarding traffic. The attack on the server.

Private information of the client located on the client computer and does not apply to the electronic payment system	Receiving confidential information of the client. Modification of client information. Disabling the client computer.	The whole complex of known attacks on a computer connected to the Internet.
Information of processing center of the Bank.	Disclosure and modification of information processing center and the local network of the Bank.	The attack on the local network connected to the Internet.

Thus the basic requirements which must be met by the system of electronic payments through Internet derive Publisher [6]:

- the system must provide the protection these payment calculations from unauthorized changes and modifications.
- system should lock and not to increase the capabilities of the attacker in launching attacks on the client computer.
- the system must ensure the protection of data located on the server from unauthorized reading and modification.
- the system should provide or support a system of protecting the local network from the effects of the global network.

Nowadays, security systems, electronic payments are caused by using the following protection measures [2]: key management system; electronic signature of documents; encryption of messages during transmission via communication channels; the separation of powers while working with electronic documents; protection level communication protocols; protection of archives from destruction; the organisation of events. During the development of specific systems of information security of electronic payments, the model and the requirements must be overcome in further detail.

Based on the above systemic approach of information security in payment systems must adhere to the following principles:

- the system, the formation of the basic goals and objectives of information security;
- the integrity, which defines system boundaries and allocation from the external environment;
- structuring, builds component elements of the system, influencing factors, analyzing their relationship and the construction of a relevant scheme;
- functionality that involves the establishment of functions, systems, subsystems and their mutual coordination.

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WYBÓR KLASYFIKATORA DO KATEGORYZACJI TEKSTU I USZCZEGÓŁOWIENIA TEKSTÓW ROSYJSKICH

Streszczenie: W artykule omówiono konieczność automatycznej klasyfikacji tekstów poprzez cechy semantyczne, opisano główne etapy procesu klasyfikacji tekstów, w tym funkcji wstępnego przetwarzania tekstu i pracy z tekstami rosyjskimi. Również wykonano przegląd różnych klasyfikacji, porównano i wybrano najbardziej odpowiednie do wykonywania zadanie.
Słowa kluczowe: analiza semantyczna, tonalność, przypadek, klasyfikacja dokumentów, dane, termin, waga wektora, uczenie maszynowe.

SELECTING CLASSIFIER FOR TEXT CATEGORIZATION AND PECULIARITY OF RUSSIAN TEXTS

Summary: This paper discussed the necessity of automatic classification of texts by the semantic features, describes the general steps of the process of classification of texts, including pre-processing text features and work with Russian texts. Also, an overview of different classifications, comparisons and choose the most suitable to perform the task.
Keywords: semantic analysis, tonality, case, documents classifier, data, term, weight vector, machine learning.

1. Intoduction

In the last years content-based document management tasks have gained a prominent status in the information systems field, due to the increased availability of documents in digital form and the ensuing need to access them in flexible ways. Text categorization, the activity of labeling natural language texts with thematic categories

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from a predefined set, is one such task. Text categorization dates back to the early ’60s, but only in the early ’90s it became a major subfield of the information systems discipline, thanks to increased applicative interest and to the availability of more powerful hardware. Text categorization is now being applied in many contexts, ranging from document indexing based on a controlled vocabulary, to document filtering, automated metadata generation, word sense disambiguation, population of hierarchical catalogues of Web resources, and in general any application requiring document organization or selective and adaptive document dispatching.

2. The basic steps of classification process

The first stage of solving the problem of automatic text classification is a document conversion. At this stage, the documents that have a sequence of characters, are converted to a form suitable for machine learning algorithms in accordance with the task of classification. Generally machine learning algorithms deal with vectors in space called feature space.
The second step is building classification function F through training examples. Quality of classification depends on how the documents will be converted to a vector representation, and the algorithm that is used in the second stage. Basic steps to resolve the problem of classification is presented in Figure 1.

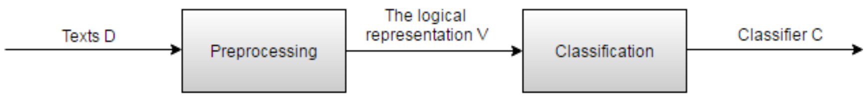

Figure 1. The main stages of classification

Thus, the classic problem of classification can be divided into two main phases:

- pretreatment / indexing - display the document in its logical representation, such as scales vector $\overline{d_j}$, which is then fed to the input classification algorithm [1];
- classification / learning – stage of classification document or study on a set of documents based on a logical representation of the document. Importantly, for the classification and learning can be used general method for preprocessing / indexing texts [2].

Importantly, the methods for transforming text to vector are specific for classification texts problem and may depend on the collection of documents, type of text (simple, structured) and document language. Machine learning methods, used in the second stage is not specific to the job classification and texts used in other areas, for example for pattern recognition tasks [3].
Pretreatment step displays text document in a logical presentation. The text is represented as multisets of terms (words). The set of all terms $T = \{\tau_0, \ldots, \tau_{|T|}\}$. Each of term $\tau_i \in T$ is mapped to some weight w_{ij}, $0 \leq w_{ij} \leq 1$, numerical characteristic frequency of use of the word in the document $d_j \in D$. The word order is generally not considered, only counted the frequency of use of the word in the text and possibly

other symptoms, such as "word met in the header", "word enclosed in tags", etc. Based on these signs every word in the text matched its weight.
Logical representation of document $\overline{d_j}$ in this case can be obtained by extraction of significant terms of all the documents D and appropriation of term each document $\overline{d_j}$ its weight. More formally, each document is the n-dimensional vector $\overline{d_j} = \langle w_{1j}, \ldots, w_{|T|j} \rangle$, where each component w_{ij} is the weight of an i-th term of set of terms T in document $\overline{d_j}$. The resulting n-dimensional vector space called feature space for category D. Each documents is a point in the feature space.
The process of getting $\overline{d_j}$ weights vector for document is called an indexing of document.
Indexation can be represented as three stages (see. Figure 2):

- term extraction – at this point the methods used to find and select the most important terms in the case of documents [4];
- term weighting – determine the significance of the theme of the selected document [5];
- dimensionality reduction – process of reducing the vector space.

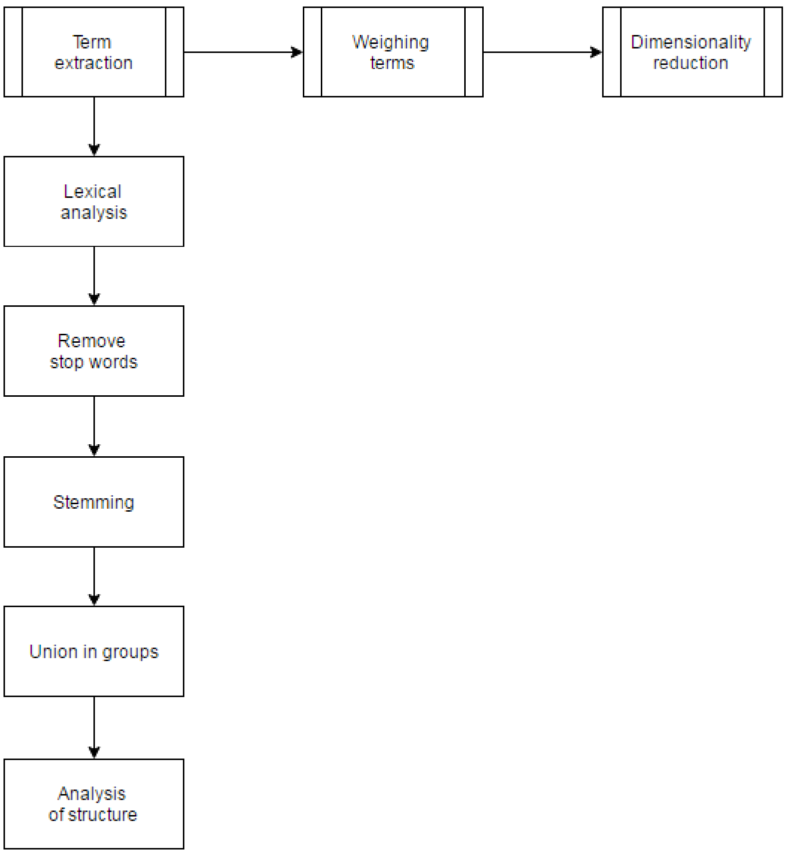

Figure 2. Document indexing

Terms or signs extraction – the process of splitting the text into simpler objects, which also called terms. The result of this process – a set of terms T, which is used for weight characteristics of the document.
Lexical analysis – the first step of extracting terms. At this stage, eliminated all the characters other than letters, for example, punctuation and html-tags.
Removal of stop words. Stop words – words that do not have any independent semantic load. Stop words are prepositions, conjunctions and pronouns. To reduce the dimensionality of space terms indexer ignores stop words and remove them in the analysis. Just stop words strongly influence the selection of keywords. If they are not removed, they clog many terms as are common in text.

3. Peculiarities of the normalization of Russian texts

Russian language belongs to the group of synthetic inflected languages, ie the languages in which the predominant derivation using affixes combining several grammatical meanings, so this allows the use of language Stemming algorithms.
The Russian language has a complex morphological variability of words, which is a source of error when using stemming. Usually stemmer used to search for text with simulated account morphology. Under simulated meant unavoidably large number of errors and irrelevant results that occur if you apply only stemmer. The Russian-language source of error in stemming are all sorts of changes in the root word – fleeting vowels, for example [6].
As a solution to the problem of poor search results with stemmer for the Russian language, you can use two additional modules grammar dictionary – lemmatizer and flexer (declension and conjugation). With lemmatizer you can bring words to basic form, so after matching words with stem can refine the result using lemmatization. The second module – flexer, who can issue all grammatical forms of a word based on the base form. This allows you to refine search results by checking the found fragments recruitment forms keyword.
The most common algorithm is an stemming algorithm of Porter (Porter, 1980). The original version of this algorithm was only for English, but later the project «Snowball» was created, which used the basic idea of the algorithm, implemented stemmer for the majority of Indo-European languages, including Russian.
Lemmatization is one of the disciplines of applied linguistics, it is quite often used for morphological analysis of texts, which are all word forms to their original form. [7] As a result, which removes only inflected endings and returns the primary or dictionary, word form, called lemma.
The Russian language is considered a form of dictionary:

- nouns – nominative case, singular number (книгами – книга);
- verbs – infinitive form (читали – читать);
- adjectives – singular, nominative, masculine (зарубежными – зарубежный).

Stop words are the words which do not carry any independent meaning. To reduce database systems do not include stop words during indexing, replacing a special marker. These include:

- conjunctions;
- pronouns;
- prepositions;

- particles;
- Interjections;
- demonstrative words;
- figures;
- punctuation marks;
- introductory words;
- some nouns, verbs, adverbs (e.g. website, give, always, however, and others.).

Due to continuous development and improvement of existing algorithms of search, classification, clustering, and so on. Database stop words are updated and changed. Discussed ways to improve the performance and reduce the dimension of the problem is not all that exist for processing text information, but in most cases enough for such classification systems.

4. Classifier selection

Most important in solving data classification problem is the choice of classification algorithm and selection of its parameters. For a visual representation costs and benefits of different algorithms presented the schedule of their work under different conditions. The result is shown in Figure 3.

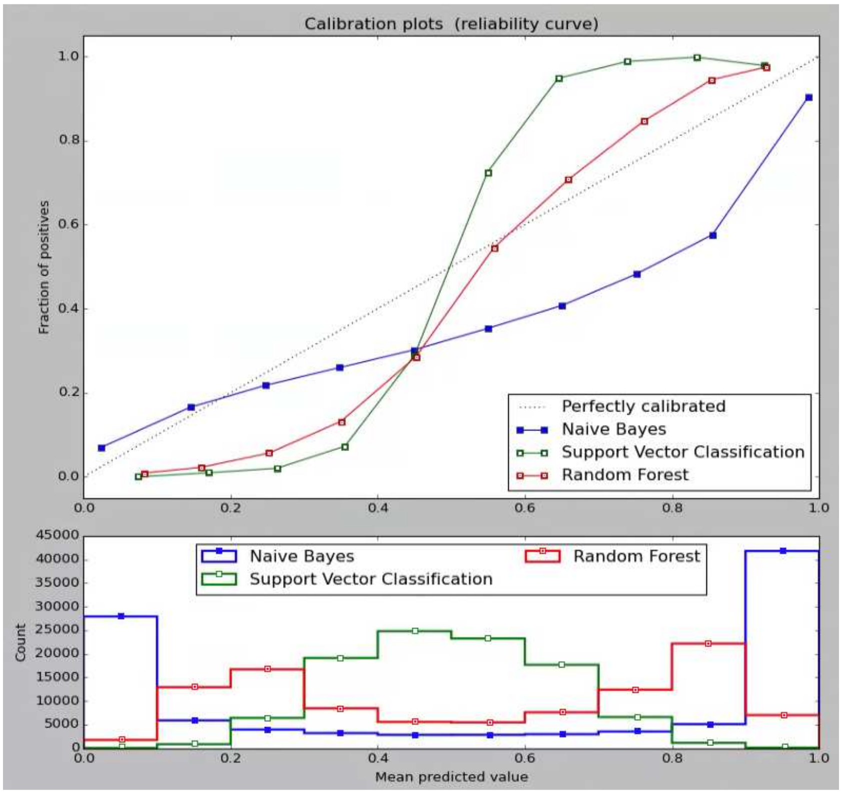

Figure 3. Comparative analysis of classification algorithms

The top chart on the x axis postponed the return value qualifier, and on axis y – real value that would turn perfectly calibrated classifier. Well calibrated classifiers are probabilistic classifiers for which output predict_proba method can be directly interpreted as a confidence level. For example, well-calibrated binary classifier should classify samples so that among the samples, which he gave predict_proba value close to 0.8, – approx. 80% actually belonged to the positive class. As can be seen from the graph, the curve Random Forest classifier closest to the dotted line – perfectly calibrated classifier.
The bottom graph on the x-axis value probabilities delayed the return qualifier, and on axis y – the number of elements which he appropriated this probability. GaussianNaiveBayes seeks to reduce the probability of 0 or 1 [8]. This is primarily because it makes the assumption that the features are conditionally independent in class that is not appropriate for the data set that contains two redundant features [9].
RandomForestClassifier shows the opposite behavior: histograms showing peaks at about 0.2 and 0.9 probabilities and probability close to 0 or 1 are very rare.
Support Vector Classification (SVC) shows a more sigmoid curve than RandomForestClassifier, which is typical for methods of maximizing the border that focus on hard samples that are close to the border decision [10].
After analyzing the Random Forest classifier was selected. Random Forest – machine learning algorithm that uses an ensemble (or committee) decisive trees.

4.1. Classifier learning algorithm

All trees are built independently by following procedure:

1. Generates a random sub-sample of size N repetition of the training set.
2. Construct the final tree that classifies examples of this sub-sample. And in the creation of another tree node will choose a sign on which the partition is made, not all features of M but m only randomly selected.
3. The tree is built to full depletion subsample and difficult procedure of cutting off branches

Classification of objects made by voting every tree object Committee refers to one of the classes, and class wins, who voted for the largest number of trees.

5. Conclusions

This paper has compared three different probabilistic classifiers and chosen the most suitable one - Random Forest. Also we show how to prepare the text and extract features. This article has shown problems that can arise when working with Russian texts.
In future work, we plan to conduct a study as additional information about the text can affect the classification. For example, whether it is appropriate to consider the author's text, the number of texts by the same author, the presence of images or video in the message.
We also plan experiments with varying amounts of training data because we hypothesize that that optimal vocabulary size may change with the size of the training set.

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METODY ANALIZY PORÓWNAWCZEJ PRYMITYWÓW KRYPTOGRAFICZNYCH

Streszczenie: W niniejszym artykule opisano możliwe metody analizy porównawczej prymitywów kryptograficznych oraz określania ich własności. Istniejące, znane metody analizy porównawczej elektronicznych podpisów – są oparte na metodach estymacji dokonywanych przez eksperta, metodach analizy procesów hierarchicznych lub wariacji wskaźników wagowych. Wszystkie wymienione metody zostały przeanalizowane oraz zbadane. Praca kończy się wnioskami oraz zaleceniami jak używać prymitywów kryptograficznych. Zestawiono i omówiono metody ewaluacji.

Słowa kluczowe: analiza prymitywów kryptograficznych, metody analizy porównawczej, wskaźniki wagowe

METHODS OF CRYPTOGRAPHIC PRIMITIVES COMPARATIVE ANALYSIS

Summary: The paper deals with the possible comparative analysis methods of the cryptographic primitives properties. The existing methods of comparative analysis of electronic signatures based on expert estimations methods – analytic hierarchy process and variations of weight indices methods are investigated and analyzed. Conclusions and recommendations on the use of the cryptographic primitives evaluation methods are made and provided.

Keywords: cryptographic primitives, cryptographic primitives analysis, comparison analysis methods, weight indices

1. Introduction

The significant number of standardized electronic signatures (ES) mechanisms [4-6,10] are applied in order to provide in different information technology [3] some

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services [1, 2], in particular electronic trust services, at the international, regional and national levels.

According to the recent researches, in terms of requirements and development of post quantum ES standards, appeared new, both theoretical and practical, problems of substantiation construction methods, analysis and comparative analysis of ES. In this case developers and users of electronic trust services applications have the ability to select ES from the significant number of existing international and national standards, primarily DSTU ISO/IEC 14888-1,2,3 [4, 5], DSTU ISO/IEC 9796-3 [6], DSTU 4145-2002 [10] etc.

So, in our opinion, now so important and, that require the solving, are theoretical and practical issues of methods substantiation and choice, and creation on their base the analysis techniques and comparative analysis of ES mechanisms.

The special importance of solve the above mentioned problems is connected with the deployment of the development and implementation ES works, and other cryptographic primitives, that meet the post quantum period requirements [9]. This is stems from the fact, that to the post quantum cryptographic primitives demands are made not only relatively cryptographic stability, but also it is a significant number of feasibility and technical-operational requirements.

First time, according to our analysis, such analysis techniques and comparative analysis ES were proposed in [7, 11, 13-15] and detailed in [9]. The essence of the suggestions reduced to separation ES evaluating criteria on unconditional and conditional, and then their use to calculate the values of integral conditional and unconditional ES evaluating criteria. In this case offered unconditional criteria and integral unconditional criterion on their base are effective and allow to estimate or compare ES. But methods of calculating integral conditional criterion values based on pairwise comparisons and hierarchies methods, proposed in [7, 9, 11, 13-15], to a large extent depend on the experts competence and objectivity in their evaluations (their subjective opinion). At the same time, there are other methods, including deserves attention method of weight indices and its variations [12, 16-18], and practical guidelines, that support it.

The objective of this work is the methods theoretical substantiation and definition the possibility of practical use for cryptographic primitives comparison [4-6, 9-10].

2. Problem formulation

The analysis of a number of sources [7,9,11,13-15] showed, that an important stage of selection perspective cryptographic primitive is the decision on determine the most perspective cryptographic primitives, and the final stage is their comparative analysis according to determined partial and integral conditioned and unconditioned criteria. In fact, this problem practically not solved relatively cryptographic primitives, the evidence of this is carrying international projects AES, Neisse and SHA-3 [9].

Based on this, the important theoretical and practical problem is the substantiation and choice, according to the requirements, the sets of indicators and assessment criteria, substantiation and choice estimate method or methods and properties comparative analysis, and also the development and practical application of scientifically grounded assessment techniques and comparative analysis cryptographic primitives of certain class.

In our case concentrate on existing and perspective standardized ES mechanisms, that are improved or will be developed for use in post quantum period.
Thereby, the objective of research, which is the subject of the article is analysis and comparative analysis of cryptographic primitives on the totality unconditional and conditional criteria [9], and also separately analysis and development of recommendations on the use methods and technique for specified cryptographic primitives analysis and comparison.

3. The achievements state of the methods and assessment techniques and electronic signatures comparative analysis development and application

From described above follows the necessity and actuality of solving the problem, a great extent, automation and significantly reduce decision-making subjectivity relatively the benefits of the cryptographic primitives certain set, such as ES. The solution of tasks certain components of this problem is contained in [7,9]. In [9] for ES evaluation and comparative analysis are proposed pairwise comparison methods and hierarchy method [7-9,11,13-15,19].
Later in the criterion will understand the sign on which basis is carried out the assessment, anything determination or classification [9], that is, in fact, will understand the measure of evaluation. The previous researches and [9] allow to substantiate the conclusion, that the evaluation and standardized ES algorithms comparison should implement using two sets of criteria: unconditional and conditional [9]. Considering the [9], ES type cryptographic transformations evaluating can be carried out in 2 stages.
On the first stage it is checked the conformity standardized algorithms to unconditional criteria requirements – partial and integral, and in the second, using conditional criteria – partial conditional criteria and integral conditional criterion. It is possible to compare different ES type cryptographic transformation by using partial conditional criteria and integral conditional criterion.

3.1. Electronic signatures mechanisms evaluation by unconditional criteria

Unconditional criteria are the criteria, which implementation for the ES type cryptographic transformations is mandatory, that is unconditional.
Analysis of the application state, development and assessment experience of the ES type cryptographic transformations properties, primarily in a group of elliptic curve (EC) points, the achieved results in the practical solution of cryptanalysis tasks and various attacks implementing, allow as basic to choose the following unconditional evaluation criteria [9]:
$W_{\delta 1}$ – mathematical base reliability, which used in the cryptographic transformations for ES;
$W_{\delta 2}$ – ES type cryptographic transformations against known attacks practical protection;
$W_{\delta 3}$ – ES real protection against all known and the potential cryptanalytic attacks;
$W_{\delta 4}$ – ES type cryptographic transformation statistical safety;
$W_{\delta 5}$ – ES type cryptographic transformation in a group of EC points theoretical protection;

$W_{\delta 6}$ – the absence of ES type cryptographic transformation weak private key;
$W_{\delta 7}$ – the complexity of the direct I_{dir} and reverse I_{rev} cryptographic transformations regarding ES is not higher than polynomial character.

Since the presented partial criteria are unconditional, then the selection criterion is a logical variable yes/no (1/0), so unconditional criterion can be written as [9]:

$$(W_{\delta 1}, W_{\delta 2}, W_{\delta 3}, W_{\delta 4}, W_{\delta 5}, W_{\delta 6}, W_{\delta 7}) \in (1,0). \tag{1}$$

Given the described above partial unconditional criteria $W_{\delta 1}$–$W_{\delta 7}$ and condition (1), cryptographic transformation accordance function can be presented as:

$$f_{af}(\ ) = W_{\delta 1} \wedge W_{\delta 2} \wedge W_{\delta 3} \wedge W_{\delta 4} \wedge W_{\delta 5} \wedge W_{\delta 6} \wedge W_{\delta 7}. \tag{2}$$

Therefore, the quality of ES cryptographic transformation can be estimated using unconditional integral criterion – ES cryptographic transformation accordance function to requirements $f_{af}(\ ) \in (0,1)$ and on $f_{af}(\ ) = 1$ ES cryptographic transformation, that estimated, complies with the requirements.

Introduced thereby integral criterion allows to establish, whether the considered ES type cryptographic transformation complies with considered discussed requirements. If the ES complies with the requirements, it can be reasonably recommended for use. Provided a positive evaluation of ES by integral unconditional criterion, further comparison and evaluation can be made based on the conditional criteria and integral conditional criterion [9].

3.2. Electronic signatures mechanisms evaluation by conditional criteria

Researches have shown that qualitative and quantitative comparison of ES type cryptographic transformations can be carried out using generalized conditional preference criterion [9] or integral conditional criterion.

As the main partial conditional criteria propose to use the following:

W_{y1} – the possibility and conditions of free distribution and use of international or national ES cryptographic transformations standard in Ukraine taking into account Ukraine normative acts to export, import and restrictions on its use, including the provision of electronic trust services;

W_{y2} – the level of trust in international and national cryptographic transformation in a group of EC points standard, that defined by the results of researches and the degree of application extension and recognition in different countries, and internationally recognized systems, including for the provision of electronic trust services;

W_{y3} – the perspective of international or national standard application in Ukraine taking into account recognition and application perspective information and telecommunication systems, cloud computing and other information technology etc.;

W_{y4} – timing and spatial complexity of hardware, software, and hardware and software implementations ES means, and management and key certification, including for the provision of electronic trust services etc.;

W_{y5} – the possibility and conditions for the use of standards with different values of general system settings and keys, methods of making and maintenance public key certificates, including for the providing electronic trust services, etc.;

W_{y6} – ES flexibility degree from the standpoint of use in various applications, by different requirements and restrictions, in different conditions, the unification and standardization degree, including for the providing electronic trust services, etc.;

W_{y7} – the level of protection in the implementation of different types of threats, in different conditions of cryptanalytic attacks and rejection common parameters properties from the defined etc.;

W_{y8} – the possibility and conditions of use in the construction of anonymous signatures for national and international use, and the level of ensuring the anonymity.

It is important to choose the method of clotting the partial conditional criteria to integral conditional criterion in their application. The conducted analysis and practical researches have shown [7-9,11-12,13-19] that as a method of clotting the partial conditional criteria can choose the analytic hierarchy process based on pairwise comparisons and the weight indices determining method.

When using the analytic hierarchy process based on pairwise comparisons, obtained statements expressed in integers taking into account nine-point scale (table 1) [7,9].

Table 1. Relations scale (degree of actions importance)

The importance degree	Definition	Explanation
1	Equal importance	Two actions do the same contribution to achieve the objective
3	Some advantage of one action importance over another (weak importance)	There are understandings in favor of advantage of one of the actions, but these understandings not enough convincing
5	Substantial or strong importance	There are reliable data or logical statements in order to show the advantage of one of the actions
7	Obvious or very strong importance	Convincing evidence in favor of one activity to another
9	Absolute importance	Evidence in favor of the advantage of one action to another supremely persuasive
2, 4, 6, 8	Intermediate values between two adjacent statements	The situation when it is necessary to compromise decision
Inverse values given above non-zero values	If to the actions *i* at comparison with the action *j* is ascribed one of the above mentioned non-zero integers, then to actions *j* at comparison with the action *i* is ascribed the reverse value	If coherence was postulated in obtaining *N* numerical values to form the matrix

4. The analytic hierarchy process based on pairwise comparisons and features of its use for the electronic signature algorithms evaluation

Analytic hierarchy process (AHP) – the systematic approach to the complex problems of making decision mathematical tool. AHP does not prescribe to the decision making person (DMP) any "right" decision, and allows him to interactively find this option (alternative), which the best agrees with its understanding of the problem essence and requirements to its solution [8,13,19].

For use the analytic hierarchy process must choose a conditional criteria system. With such set of indicators, using the conditional criteria can calculate the integral conditional criterion value, and, consequently, make the comparison by integral conditional criterion.

The elements pairwise comparison method [7,9] can be described as follows. The set of paired comparisons matrices is constructed. Paired comparisons are carried out in terms of the dominance of one element over another. Obtained statements are expressed in integers, considering the nine scale in table 1 [7,9].

In pairwise comparison the expert compares investigated objects of their importance pairwise, establishing the most important object in each pair. All possible objects pairs expert represents in a record of each combination (object 1 – object 2, object 2 – object 3, etc.) or in the matrix form [7,9].

Let $E_1, E_2, ..., E_n$ – the plenty of n elements (alternatives) and $\nu_1, \nu_2, ..., \nu_n$ –their weight or intensity respectively. Let compare pairwise the weight or intensity of each element with weight or intensity of any other element of the set relative to common for them property or objective (relative to “father”–element). In this case, the pairwise comparisons matrix $[E]$ is as follows:

$$[E] = \begin{array}{c|c|c|c|c|}
 & E_1 & E_2 & \dots & E_n \\ \hline
E_1 & \nu_1/\nu_1 & \nu_1/\nu_2 & \dots & \nu_1/\nu_n \\ \hline
E_2 & \nu_2/\nu_1 & \nu_2/\nu_2 & \dots & \nu_2/\nu_n \\ \hline
\dots & \dots & \dots & \dots & \dots \\ \hline
E_n & \nu_n/\nu_1 & \nu_n/\nu_2 & \dots & \nu_n/\nu_n
\end{array}$$

The pairwise comparisons matrix has a reverse symmetry property, that is $a_{ij} = 1/a_{ji}$, where $a_{ij} = \nu_i / \nu_j$.

In conducting pairwise comparisons should answer the following questions: which of the two compared elements is more important or has greater impact, which is more probable and which has a greater advantage.

When comparing the criteria, usually ask, which criterion is more important; when comparing alternatives in relation to the criterion – which of the alternatives has more advantages or more probable [7,9].

When constructing a pairwise comparisons matrix for all criteria, it is necessary to determine the consistency ratio [7,9] for each of criterion as follows.

The assessment of eigenvector component is calculated by the formula (3):

$$q_i = (W_{yi} \times W_{yi+1} \times \ldots \times W_{yn})^{\frac{1}{n}} . \tag{3}$$

The normalized assessment of priority vector is calculated by the formula (4):

$$r_i = q_i \div z , \tag{4}$$

where z – consistency matrix ratio, which is calculated using the formula (5):

$$z = \sum_{i=1}^{n} q_i . \tag{5}$$

The consistency matrix ratio value is in the range $[0, \sum_{i=1}^{n} q_{i\max}]$, where $q_{i\max}$ – the maximum possible eigenvector component evaluation value for the selected case.

5. Method and procedure of evaluation and comparative analysis electronic signature algorithms based on weight indices

In the case, when get information about parameters comparable systems importance using informal methods is not possible, necessary to use formalized methods. Among them are methods based on determining the weight indices. There are several such methods [12,16-18].

Let us consider the general problem formulation for ES evaluation technique based on the determining the weight indices method. Let there are [12,16-18]: k systems (ES mechanisms), which is necessary to evaluate; m indicators, according to which systems are evaluated; n experts, that carry out the evaluation.

We define some partial indicators, at which ES mechanisms can be evaluated:

x_1 – the possibility of free distribution and use of international or national ES cryptographic transformations standard in Ukraine;

x_2 – the level of trust in international and national cryptographic transformation in a group of EC points and based on mathematical apparatus of pairing EC points;

x_3 – the perspective of international or national standard application in Ukraine;

x_4 – the timing and spatial complexity of hardware, software, and hardware and software implementations ES means;

x_5 – the possibility of the standards use with different values of general system settings and keys;

x_6 – the ES algorithm flexibility degree from the standpoint of use in various applications, by different requirements and restrictions;

x_7 – the level of protection against the different types of threats in different conditions of cryptanalytic attacks;

x_8 – the possibility of use ES algorithm in the construction of anonymous signatures for national and international use, and the level of ensuring the anonymity.

The specified partial indicators expert evaluation is performed to determine the weight indices value of indicators themselves [9]. For the evaluation, you can use the following weight indices determining methods [12,16-18]: using the Fishburn scale; based on the ranking method; based on the points attribution method; based on the numerical method.
After the weight indices values of indicators themselves determining, it is necessary to make the system expert evaluation by the chosen determining weight indices methods.
For this, for each system it is need to perform the indicators ranking in connection with that, which indicator is the most determined in chosen system, better than other describes it. That is, arrange the indicators in relation to the chosen system, from more significant to least significant.

6. The electronic signature mechanisms according to DSTU ISO/IEC 14888-3:2014 by unconditional criteria evaluation

Table 2 shows the results of comparative analysis regarding unconditional criteria for ES mechanisms according to DSTU ISO/IEC 14888-3:2014.

Table 2. Results of comparative analysis regarding unconditional criteria

ES criterion / ES algorithm	$W_{\delta 1}$	$W_{\delta 2}$	$W_{\delta 3}$	$W_{\delta 4}$	$W_{\delta 5}$	$W_{\delta 6}$	$W_{\delta 7}$	W_{δ}
DSA	0	1	0	1	0	1	1	0
KCDSA	0	1	0	1	0	1	1	0
Pointcheval/Vaudenay	0	1	0	1	0	1	1	0
SDSA	0	1	0	1	0	1	1	0
EC-DSA	1	1	1	1	1	1	1	1
EC-KCDSA	1	1	1	1	1	1	1	1
EC-GDSA	1	1	1	1	1	1	1	1
EC-RDSA	1	1	1	1	1	1	1	1
EC-SDSA	1	1	1	1	1	1	1	1
EC-FSDSA	1	1	1	1	1	1	1	1
IBS-1	1	1	1	1	1	1	1	1
IBS-2	1	1	1	1	1	1	1	1

Further comparison and evaluation based on conditional criteria and integral conditional criterion will be carried out for all standard ES mechanisms, other than DSA, KCDSA, Pointcheval/Vaudenay and SDSA ES mechanisms, that is mechanisms, based on the finite fields mathematical apparatus.

7. The electronic signature mechanisms according to DSTU ISO/IEC 14888-3:2014 by conditional criteria evaluation

At first consider the practical application of the analytic hierarchy process based on pairwise comparisons on the example of ES mechanisms according to standard DSTU ISO/IEC 14888-3:2014 [4,5].

Comparing ES algorithms relatively conditional criteria, construct for this objectives tree (fig. 1).

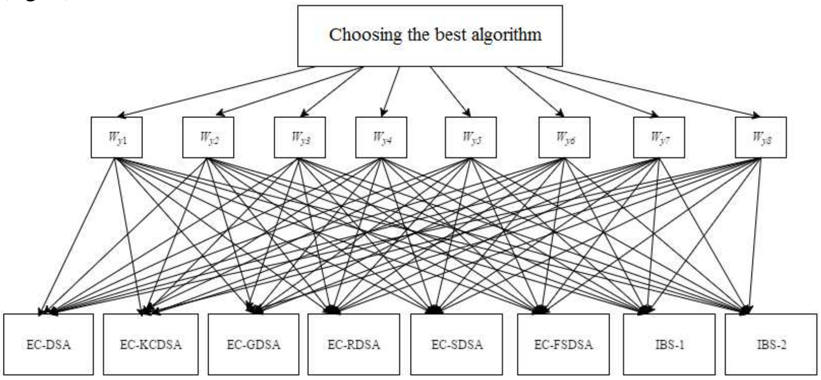

Figure 1. Objectives tree

After this do the evaluation of each criterion. For this construct the pairwise comparisons matrix relative to the compared ES algorithms for each criterion, using formulas (3)–(5) [7,9].

To calculate the resulting priorities vector multiply the level 1 priority vector and the level 1 acquired values matrix (fig. 2).

$$v := \begin{pmatrix} 0.048 \\ 0.198 \\ 0.053 \\ 0.031 \\ 0.048 \\ 0.097 \\ 0.456 \\ 0.069 \end{pmatrix} \qquad M := \begin{pmatrix} 0.201 & 0.087 & 0.082 & 0.076 & 0.166 & 0.21 & 0.051 & 0.205 \\ 0.201 & 0.169 & 0.165 & 0.061 & 0.166 & 0.229 & 0.102 & 0.19 \\ 0.201 & 0.124 & 0.165 & 0.103 & 0.166 & 0.192 & 0.086 & 0.19 \\ 0.029 & 0.025 & 0.021 & 0.05 & 0.049 & 0.027 & 0.02 & 0.028 \\ 0.067 & 0.054 & 0.06 & 0.08 & 0.099 & 0.043 & 0.036 & 0.047 \\ 0.067 & 0.054 & 0.06 & 0.08 & 0.099 & 0.043 & 0.036 & 0.047 \\ 0.118 & 0.244 & 0.233 & 0.275 & 0.128 & 0.129 & 0.334 & 0.147 \\ 0.118 & 0.244 & 0.233 & 0.275 & 0.128 & 0.129 & 0.344 & 0.147 \end{pmatrix}$$

$$V2 := M \cdot v \qquad V2^{T} = \begin{pmatrix} 0.099 & 0.144 & 0.125 & 0.025 & 0.048 & 0.048 & 0.256 & 0.256 \end{pmatrix}$$

Figure 2. The priorities resulting vector calculation

Let us consider the obtained numerical results. The investigated ES algorithms based on the transformation of group of EC points and pairing EC points can arrange the places, that they occupied on the results of comparison (1 – the best, 8 – the worst): IBS-1 – 0,256; IBS-2 – 0,256; EC-KCDSA – 0,144; EC-GDSA – 0,125; EC-DSA – 0,099; EC-SDSA – 0,048; EC-FSDSA – 0,048; EC-RDSA – 0,025.

Thereby ES IBS-1,2 have the greatest advantages by an integral indicator. The ES algorithm EC-RDSA has the worst result, that is substantiated by the attacks implementation on the algorithm and the inability to use nationally.

It should be noted, that the obtained results cannot be taken for use, most likely, this is the ES comparison technique. For real use you'll need to choose conditional criteria and conduct researches.

Now consider the practical application of the determining weight indices method variations [12,16-18]. According to each of specified weight indices method variants [12,16-18], we conduct the ES mechanisms according to DSTU ISO/IEC 14888-3:2014 evaluation [4,5]. We construct all specified in methods tables under the relevant rules [12,16-18]. We obtain the following results after the evaluation (table 3).

Table 3. ES mechanisms evaluation results

Methods for the weight indices determining			
using the Fishburn scale	based on the ranking method	based on the points attribution method	based on the numerical method
IBS-1 – 0,159	IBS-1 – 0,147	IBS-1 – 0,137	IBS-1 – 0,15
IBS-2 – 0,159	IBS-2 – 0,147	IBS-2 – 0,137	IBS-2 – 0,15
EC-DSA – 0,15	EC-KCDSA – 0,143	EC-RDSA – 0,132	EC-DSA – 0,144
EC-GDSA – 0,147	EC-GDSA – 0,142	EC-FSDSA – 0,128	EC-GDSA – 0,141
EC-KCDSA – 0,142	EC-DSA – 0,139	EC-DSA – 0,127	EC-KCDSA – 0,138
EC-FSDSA – 0,118	EC-FSDSA – 0,115	EC-SDSA – 0,127	EC-FSDSA – 0,126
EC-SDSA – 0,117	EC-SDSA – 0,111	EC-GDSA – 0,126	EC-SDSA – 0,123
EC-RDSA – 0,106	EC-RDSA – 0,103	EC-KCDSA – 0,124	EC-RDSA – 0,109

8. The analysis of electronic signature researches results according to DSTU ISO/IEC 14888-3:2014

For chosen ES mechanisms evaluation methods were obtained results, that are shown in previous chapters. ES mechanisms comparison was made based on expert evaluations. After that, calculations were made by aforementioned methods.

One can assume, that the results of the evaluation ES mechanisms according to DSTU ISO/IEC 14888-3:2014, by different methods have been obtained almost identical – almost the same ES mechanisms arrangement from the best to the worst. Numeric scatter of weight indices values for one algorithm is almost negligible, only numeric values for IBS-1,2 ES mechanisms in the analytic hierarchy process based on pairwise comparisons differ from weight indices values for these ES mechanisms according to other evaluation methods, that is substantiated by more strong influence of the subjective experts opinion.

Figure 3 graphically shows the results of the ES mechanisms evaluation by different evaluation methods.

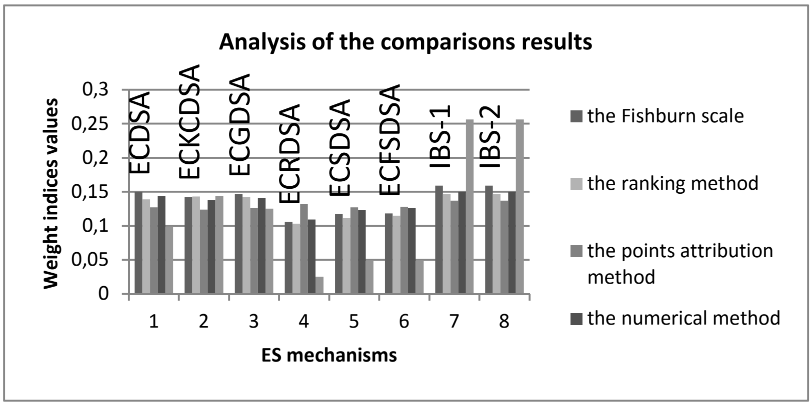

Figure 3. The results of the ES mechanisms evaluation by different methods

9. Conclusions

1) In connection with the specific requirements for cryptographic transformations, including for ES, the main criteria should be divided into two classes: conditional and unconditional. As the main criterion for integral evaluation can be and is recommended to use the integral unconditional criterion, that is derived by partial unconditional criteria.
2) The research results allow to conclude, that in terms of evaluation objective the best use the variations of weight indices determining method, because the experts subjectivity has the a significant impact to the result in the analytic hierarchy process based on pairwise comparisons.
3) The the comparative analysis results of standardized ES algorithms DSTU ISO/IEC 14888-3:2014 allowed to make the following conclusions and recommendations: the maximum integral conditional criterion value for DSTU ISO/IEC 14888-3:2014 has been achieved for algorithms IBS-1 and IBS-2 by all evaluation methods. According to all evaluation methods in the first place are ES mechanisms IBS-1 and IBS-2, and in the last place – ES mechanisms EC-RDSA (only for the determining the weight indices method based on the points attribution method on the last place based ES mechanism EC-KCDSA).
4) To obtain more precise evaluation results and for obtaining approximately same evaluation results by different evaluation methods, it is necessary to perform the evaluation procedure several times and carefully approach to the choice of experts that will conduct the evaluation.

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OCENA ZAGROŻEŃ BEZPIECZEŃSTWA PLATFORM HANDLU ELEKTRONICZNEGO JAKO ELEMENT DZIAŁAŃ TYPU TZW. TRAFFIC ARBITAGE

Streszczenie: W niniejszej pracy omawiane są problemy handlu elektronicznego (wybranych platform) oraz procesy tzw. traffic arbitrage czyli zakupu i odsprzedaży dóbr. Ponadto, w niniejszej pracy, zestawiono najbardziej popularne narzędzia (platformy) do prowadzenia handlu elektronicznego. Przeprowadzono statystyczne analizy danych odnoszących się do najbardziej znaczących zagrożeń bezpieczeństwa tychże platform. Zaproponowano własny model EPC (skrót na postawie nazwy w języku angielskim: Event-driven Process Chain) w jaki sposób zagrożenia (wirusy itp.) uzyskują dostęp do paneli administratorów sieci. Opracowano metodę oceny zagrożeń na podstawie estymacji prawdopodobieństwa zrealizowania skutecznego ataku hackerskiego.

Słowa kluczowe: sklep internetowy, handel elektroniczny, działania typu traffic arbitrage, zagrożenia, bezpieczeństwo, model EPC

ASSESSMENT OF SECURITY THREATS RELEVANCE OF E-COMMERCE PLATFORM AS COMPONENT OF TRAFFIC ARBITRAGE

Summary: The process of traffic arbitrage and e-commerce platform as one of its component are considered in this paper. The most popular tools of online store implementation were identified. The research of statistical data of the most significant security threats on the chosen tools was conducted. EPC-model of threat of getting access to admin-panel of site was constructed. The approach to assessment of threat relevance was build based on estimation of probability of successful threat realization.

Keywords: online store, e-commerce, traffic arbitrage, threats, security, EPC-model

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1. E-commerce platform and its security

E-commerce typically refers to the purchase and sale of different stuff online, but there is more to it than that. Actually e-commerce is a set of economic relations between the agents with the goal to exchange or distribute goods and/or services. The development of this sector is a logical outcome of technological progress, caused by the usage of computer technologies, and profound changes in the structure of global consumption.

Internet traffic is an important component of e-commerce, it can be considered as the flow of potential customers. Modern information technologies in the field of market communications can be used for management of this flow by buying and selling some certain activities (clicks, registration etc.). This process is known as "traffic arbitrage". Roughly, it can be described as buying traffic at the minimum price and reselling it at the maximum price. The purchase process takes place in traffic sources and resale occurs into Internet stores. The illustration of this scheme is given on Figure 1. The figure shows that traffic arbitrage consists of two main parts: the source of traffic and online store (e-commerce platform). Breaking one of the components destroys the entire arbitrage process and brings financial losses.

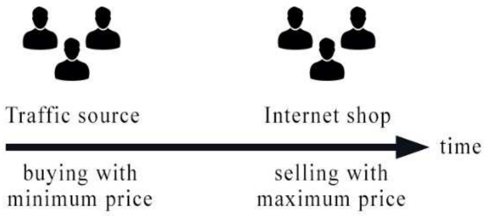

Figure 1. Structural scheme of the traffic arbitrage process

The security of e-commerce platform is extremely important in the traffic arbitrage process because in case if it is broken (not accessible or corrupted), then have been bought web-traffic would not be sold. As e-commerce platform merges together information means and technical tools to ensure interaction between the buyer and seller through electronic channels of communication. Study of the most popular tools of online store implementation was conducted. CMS WordPress with e-commerce module WooCommerce was recognized to be the most common prototype of system for online store implementation as a result of conducted research. Statistic data of attacks on Internet shop based on CMS WordPress were studied by authors [1-9]. The threat of getting access to the admin panel belongs to the most significant threats with severe impacts.

2. Design of EPC-model of threat. Assessment of threat relevance based on developed model.

Idea of EPC-modeling of threats was suggested in [10]. The EPC is a type of flowchart with events as key elements connected in logical sequences using logic operations (OR, XOR, AND). EPC-models of threats allows to estimate cause-effect relations between possible vulnerabilities of e-commerce platform and their negative consequences for the security of the system. Although estimation of the probability of threats was done under the assumption that all mutually exclusive events are equally likely to happen.

The EPC (Event-Driven Process Chain) was used for modelling threats of information security of e-commerce platform in this paper. Threat of getting access to the admin panel was used as the example. A structural model of the events, that lead to the successful attack was devsigned based on expert data. The EPC-model of threat that attacker get access to the admin panel is shown in Figure 2.

It was assumed that risk of getting access to admin panel involves two main threats:
- unauthorized access to the admin panel;
- discrediting admin account.

Each of above threats were subdivided into logical chain of possible outcomes including:
- Stealing a set of session keys.
- Cracking password by Bruteforce.
- Accessing to files from a administrator PC.
- Phishing.

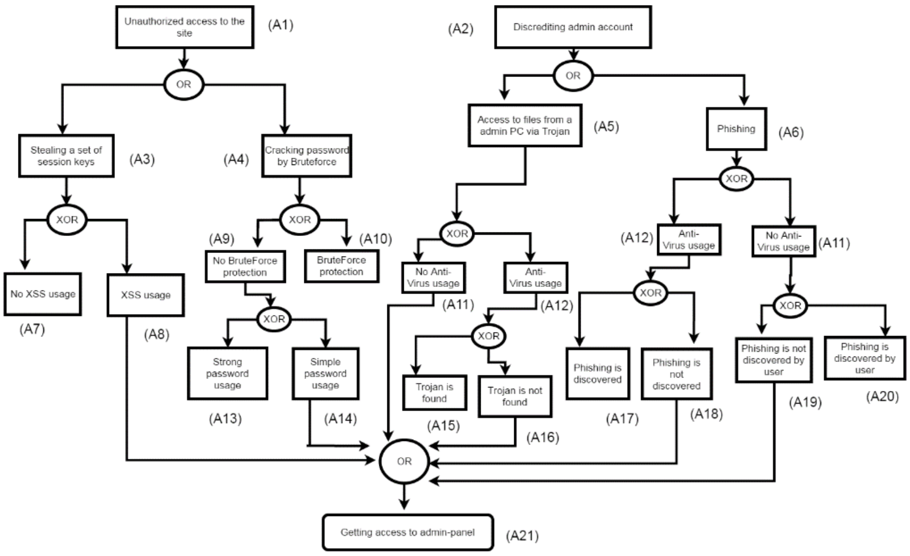

Figure 2. EPC-Model of threat - attacker get access to the admin panel

The probability of each event in chain was estimated based on general known rules and theory of probability. Initially the calculations were done under assumption that there is no statistical data and all mutually exclusive events are equally likely to occur.

Table 1. Calculation of probability events under assumption of equally likely

Event	Probability
Unauthorized access to the site	P(A1) = 0,5
Discrediting admin account	P(A2) = 0,5
Stealing a set of session keys	P(A3) = 1 - √ 0.5 = 0.29
Cracking password by Bruteforce	P(A4) = 1 - √ 0.5 = 0.29
Access to files from a admin PC via Trojan	P(A5) = 1 - √ 0.5 = 0.29
Phishing	P(A6) = 1 - √ 0.5 = 0.29
No XSS usage	P(A7) = 0.29 * 0.5 = 0.145
XSS usage	P(A8) = 0.29 * 0.5 = 0.145
No BruteForce protection	P(A9) = 0.29 * 0.5 = 0.145
BruteForce protection	P(A10) = 0.29 * 0.5 = 0.145
No Anti-Virus usage	P(A11) = 0.29 * 0.5 = 0.145
Anti-Virus usage	P(A12) = 0.29 * 0.5 = 0.145
Strong password usage	P(A13) = 0.145 * 0.5 = 0.073
Simple password usage	P(A14) = 0.145 * 0.5 = 0.073
Trojan is found	P(A15) = 0.145 * 0.5 = 0.073
Trojan is not found	P(A16) = 0.145 * 0.5 = 0.073
Phishing is discovered by Anti-Virus	P(A17) = 0.145 * 0.5 = 0.073
Phishing is not discovered by Anti-Virus	P(A18) = 0.145 * 0.5 = 0.073
Phishing is not discovered by user	P(A19) = 0.145 * 0.5 = 0.073
Phishing is discovered by user	P(A20) = 0.145 * 0.5 = 0.073
Getting access to admin-panel	P(A21) = 1 - (1 – 0.145) * (1 – 0.073) * (1 – 0.145) * (1 – 0.073) * (1 – 0.073) * (1 – 0.073) = 0.46

The study of available data of probability of successful attacks was conducted. The authors of [3] write that old versions of WooCommerce has a XSS-vulnerability dealt with metadata of images. At the same time, statistics [2] show, that 37% of users are still using the old version of WooCommerce module.

The data of Trojan attacks are taken from Kaspersky Security Bulletin 2015 [4]. In 2015, there were 1966324 registered notifications about attempts of malware infections. In order to evaluate the popularity of malware among cybercriminals and the risk of user computers to be infected by Trojans, Kaspersky Lab calculated the percentage of users who encountered this type of threat during the reporting period. Kaspersky Lab divides statistics by geolocation. The maximum value of percentage is 11.6%. The authors of [5] states that 50-60% of users of Windows do not use any Anti-Virus program.The Av-Comparatives was tested 18 Anti-Virus programms for detecting Trojan malware software [9]. An average statistcal value 83.3% was calculated.

The authors of [1] write that 81% of sites have not any BruteForce protection. The difficulty of user passwords is discussed in [6]. According to the data provided in the article, 13.5% of Gmail users, 13.4% of Yandex users and 9.6% of Mail users uses a simple password, that could be successfully cracked by BruteForce with standard dictionaries. The average was used for further calculations.

In second quarter 2016, the Anti-Phishing system of Kaspersky Lab was triggered 32363492 times on the computers of Kaspersky Lab users. Overall, 8.7% of users were attacked by phishers in second quarter of 2016 [7]. Results of the test [8] show,

that the percentage of blocked phishing websites is 94.4% by Kaspersky Lab, 93.6% by Bitdefender and 93.2% by ESET. We use an average value for calculations.
The calculation of the probability of events using statistical data presented in Table 2.

Table 2. Calculation of probability events based on available information about some events occurrence

Event	Probability
Unauthorized access to the site	P(A1) = 0,5
Discrediting admin account	P(A2) = 0,5
Stealing a set of session keys	P(A3) = 1 - √ 0.5 = 0.29
Cracking password by Bruteforce	P(A4) = 1 - √ 0.5 = 0.29
Access to files from a admin PC via Trojan	P(A5) = 1 - √ 0.5 = 0.29
Phishing	P(A6) = 1 - √ 0.5 = 0.29
No XSS usage	P(A7) = 0.29 * 0.63 = 0.183
XSS usage	P(A8) = 0.29 * 0.37 = 0.107
No BruteForce protection	P(A9) = 0.29 * 0.81 = 0.235
BruteForce protection	P(A10) = 0.29 * 0.19 = 0.055
No Anti-Virus usage	P(A11) = 0.29 * 0.55 = 0.156
Anti-Virus usage	P(A12) = 0.29 * 0.45 = 0.131
Strong password usage	P(A13) = 0.235 * 0.87 = 0.204
Simple password usage	P(A14) = 0.235 * 0.13 = 0.031
Trojan is found	P(A15) = 0.131 * 0.83 = 0.109
Trojan is not found	P(A16) = 0.131 * 0.17 = 0.022
Phishing is discovered by Anti-Virus	P(A17) = 0.131 * 0.94 = 0.123
Phishing is not discovered by Anti-Virus	P(A18) = 0.131 * 0.06 = 0.008
Phishing is not discovered by user	P(A19) = 0.156 * 0.50 = 0.078
Phishing is discovered by user	P(A20) = 0.156 * 0.50 = 0.078
Getting access to admin-panel	P(A21) = 1 - (1 – 0.107) * (1 – 0.031) * (1 – 0.156) * (1 – 0.022) * (1 – 0.008) * (1 – 0.078) = 0.35

The probability of successful realization of threat of getting access to admin-panel was calculated twice. The probability equals 0.46 under assumption that all mutually exclusive events are equally likely and 0.35 while using available statistical data. The difference is rather significant, moreover the last value is more close to real data. It means that we can underestimate or overestimate the real likelihood of risks while using the equal probabilities for mutually exclusive events in EPC-diagram.

Approach of estimation probabilities of successful realization of threat based on constructed EPC-model of threat can be used in risk management. The results of analysis of probability values could be considered as assessment of threats relevance while designing complex of technical and organizational means to protect the ecommerce platform.

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SYMULACJA DYNAMIKI ORGANIZMU PRZYPOMINAJĄCEGO ROBAKA ZA POMOCĄ MOBILNEGO AUTOMATU KOMÓRKOWEGO

Streszczenie: W pracy przedstawiono symulację działania organizmu przypominającego robaka. W szczególności symulowano podsystemy mechaniczne oraz neuronowe, które sterują jego poruszaniem się za pomocą mobilnego automatu komórkowego.

Słowa kluczowe: mobilny automat komórkowy, organizm przypominający robaka, algorytm ewolucyjny

SIMULATION OF THE DYNAMICS OF WORM-LIKE ORGANISMS USING THE MOVABLE CELLULAR AUTOMATA

Summary: There is a simulation of the worm-like organism's mechanical and neuron subsystems that control their locomotion using the movable cellular automata.

Keywords: movable cellular automata, worm-like organism, evolutionary algorithm

1. Introduction

Biological systems are complex things. As understanding of how organisms work has increased, it is evident how much more there is still to be understood. Behaviour, anatomy, cellular functions, neural systems, gene sequences: all these components that make up a living being are the subjects of massive fields of research with thousands of people worldwide working to unravel the elaborate mysteries set us by nature. Given the difficulty of these problems, it makes sense to choose a relatively simple example to work with. For this reason worm-like organisms were chosen as the object of research.

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Nowadays the only representative of this class is a nematode Caenorhabditis elegans, whose nervous system's structure is completely studied and its connectome was obtained in the first approximation. First C. elegans was studied by Sydney Brenner in 1974 for using as a model organism for genetic research [1]. Choosing a worm, Brenner said "we want a multicellular organism which has a short life cycle, can be easily cultivated, and is small enough to be handled in large numbers, like a micro-organism. It should have relatively few cells, so that exhaustive studies of lineage and patterns can be made". The article [2] points out that many characteristics make it an almost ideal research animal, but particularly significant is that the worm is made up of few cells and has a very simple nervous system. The website OpenWorm [3] is an open source project dedicated to creation of the world's first virtual organism in a computer, a C. elegans nematode.

2. Formulation of the problem

The aim of this work is to simulate the worm-like organism's subsystems that controls its locomotion The method of movable cellular automata (CA) [4] was chosen as a method for modeling. A simulation object is divided into two subsystems - mechanical and neural.

Mechanical subsystem represents the corresponding fragments of the body of organisms and simulate muscle contraction (transversal and longitudinal) [5]. As transversal muscles contract, the corresponding fragments of body become longer and narrower, and as longitudinal muscles contract, their length decreases with increasing of thickness. The signal for muscle contraction is the state of corresponding "nerve ending" of neuron subsystem that is associated with corresponding CA.

During the simulation of a neuron subsystem the elementary analogues of artificial neurons (perceptrons) are implemented. Their basic task, similar to that of biological neurons, is to form output signals according to the set of input signals, their state, and the function of transformation.

3. Mechanical subsystem

The mechanical subsystem represents the corresponding fragments of the body of organisms and simulates the contraction of transversal and longitudinal muscles. The structure of the cellular automata set fragment of the designed object (mechanical subsystem) is represented in the Fig. 1. Every CA can have no more than four neighbours. If at least one neighbor is absent, it is considered to be boundary (white circles with absent neighbouring connections, shown with dotted lines in Fig. 1).

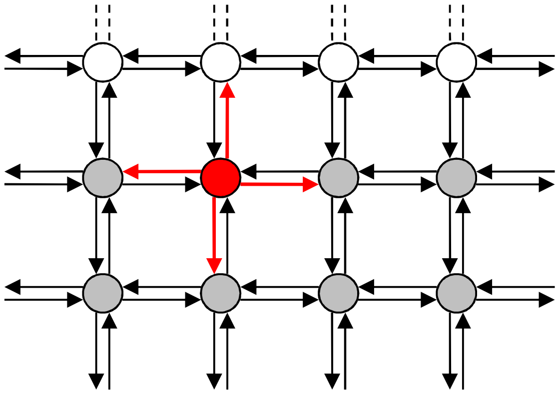

Figure 1. The fragment of cellular automata set of the modeled system and CA chosen for interaction (red CA)

Horizontal connection with the neighbours corresponds to longitudinal muscles, and vertical connection corresponds to transversal muscles. As transversal muscles contract, the corresponding fragments of the body become longer and narrower, and as longitudinal muscles contract, their length deacreases with increasing of thickness. The scheme of cellular automata algorithm is asynchronous. It provides a random convenience sampling of one CA (marked in red in fig.1) from the set and the appropriate modification of its state and the state of its nearest neighbours according to the rules of interaction. After interaction finishes another CA is chosen randomly and the process is repeated.

The core of cellular automata interactions consists in establishment of some distances between corresponding CA under the influence of corresponding signals. A signal for muscle contraction is the state of the corresponding "nerve ending" of the neuron subsystem that is associated with corresponding CA.

Fig. 2 represents the examples of mutual location of CA during the interaction. Fig. 2.a) illustrates the state of CA either when the signals of muscle contraction is absent for the chosen cell, or when both muscles (longitudinal and transverse) are contracted. Fig. 2.b) shows the state of CA in case of the signal of longitudinal muscle contraction, and fig. 2.c) - in case of the contraction of the transversal muscle.

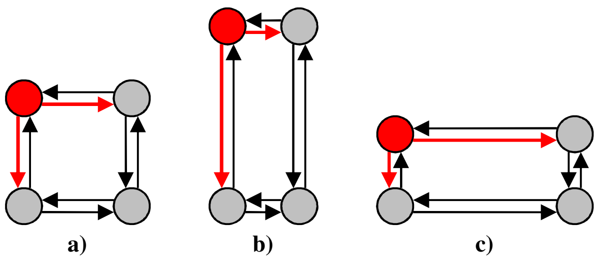

Figure 2. Examples of mutual location of CA during the interaction

In the process of simulation it is necessary to adhere to the principle of non-compression of the body fragments of the designed organisms, according to which the volume of the fragments doesn't change during the arbitrary deformations. In case of two-dimensional model the question is about permanence of the fragments' areas. In case of elementary rectangular approach of fragments reflection, it is necessary to set not only corresponding distances between two interactive CA but also between diagonal CA, i.e. with the neighbour of the chosen CA's neighbour (fig. 3.a) - 3.c)).

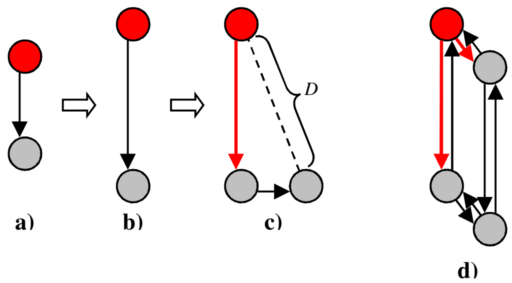

Figure 3. Schematic representation of results CA interaction

Thus, if a neighbour is longitudinal, then the neighbour's neighbour is transversal, and vice versa. If it is not predicted, then the violation of the principle of non-compression (fig. 3.d)) cannot be avoided.

4. Neural subsystem

While simulating the neural subsystem elementary analogues of artificial neurons (perseptrons) are designed. For every separate CA the coordinates of remote fragments of the designed organism are pointed out, the states of which are input signals for the corresponding neuron. Thus, input connections appear chaotically. The amount of connections is fixed for all CA. The simplified schematic image of the neural subsystem's organization is shown in fig. 4.

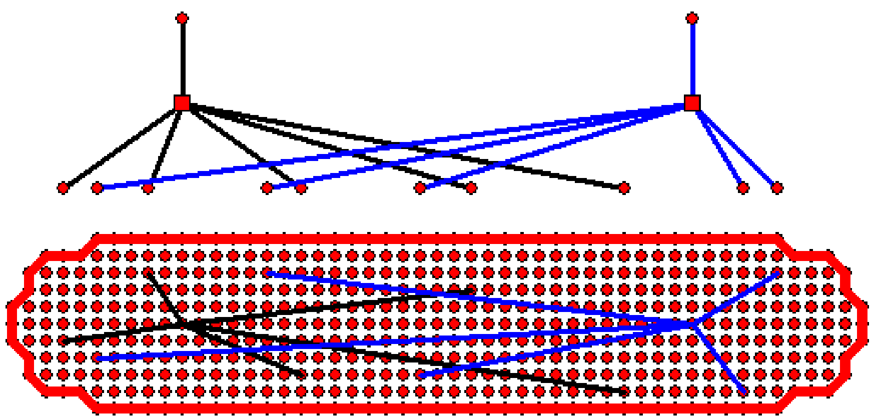

Figure 4. Simplified schematic image of the neural subsystem's organization.

There are two artificial neurons with five connections. Chaotic geometry of connections is shown at the bottom of the image, and corresponding model of neurons is shown at the top (input receptors are at the bottom, output managing signals are at the top). The basic task, similar to that of biological neurons, is to form output signals according to the set of input signals, input state, and the function of transformation. In our case the input state is one of three variants of the CA interposition shown in fig. 2.

As the transformation function there is a function, which forms one of three values: 0 – no signal, 1 –longitudinal muscle contraction, 2 – transverse muscle contraction. These values depend on the values of thebsum of input signals of x_i (x_i = 0, 1, 2), multiplied by the weight coefficients of w_i ($w_i \epsilon [0 \dots 1]$):

$$y = \begin{cases} 0,\ if \quad 0 \leq \sum_{i=1}^{K} x_i w_i < 2K/3, \\ 1,\ if \ \ 2K/3 \leq \sum_{i=1}^{K} x_i w_i < 4K/3, \\ 2, if \quad 4K/3 \leq \sum_{i=1}^{K} x_i w_i < 2K, \end{cases} \qquad (1)$$

where K is a maximum amount of connections for neurons.

It is necessary to notice that the value of weight coefficients and the order of location of the conditional statements in a formula (1) can change. It is a feature of a separate CA. Algorithm of changes of weight coefficients and the order of location of conditional statements in a formula (1) is evolutionary. Arbitrary evolutionary algorithm [6,7] shows the random changes (mutations) of parameters and estimation of influence of these changes on the dynamics of the system according to a corresponding criterion. If a criterion is satisfied, changes are fixed, otherwise they are rejected, that is the complete analogue of natural selection

The criterion of evolutionary selection in this case is the minimization of the changes of initial values of neurons at the high speed of motion of worm-like organism. The changes of initial values of neurons represent the energy that is spent by an organism. Obviously, the more often muscles contract, the more energy is spent by an organism. Thus, it is rational to reduce the power expenses at the maximum possible speed of motion. The separate aspect of implementation of the organism´s dynamics under the rule of the neuron signals' streams is the introduction of the concept of inertia. A time parameter that determines the speed of the muscles contraction while switching the corresponding managing signals and limits the maximum possible speed of motion is examined.

Talking about the organization of the organism's motion, the analogue of one-sided motion of worms provided by a presence of specific hair on the surface of the body, was simulated. These hair easily slide while moving in one direction, but sliding in an opposite direction becomes complicated because friction increases. The simplest way of simulation of the one-sided dynamics is the prohibition of the motion of the boundary CA (white circles in fig. 1), that coincides with the location of the left neighbour (while moving the organism to the right) or vice versa.

The described algorithm needs the presence of corresponding index array that contains such parameters of cellular automata :

1) the type of the CA (boundary, internal, etc.);
2) the coordinates of CA in space;
3) the state of the signal neuron;
4) the indexes of the neighbouring CA (mechanical subsystem);
5) the indexes of the remote CA (neuron subsystem);

6) the parameters of the formula (1).

5. Conclusion

As a result of the simulation of the worm-like organisms, it should be noted that an organism arbitrarily steers to the state of maximum effective motion (minimum energy at the maximum speed) from the initial random chaotic state (fig. 5) due to the self-organization of the signals in the chaotic neural network.

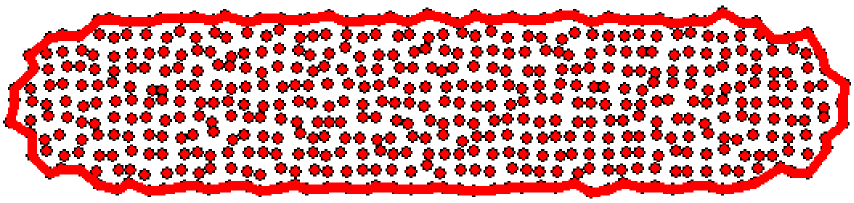

Figure 5. Initial random chaotic state

The dynamics of this process is arbitrary: from simple stretches-clenches and to highly organized motion such as segment compression, “Nematode“ movement and other (Fig.6, 7):

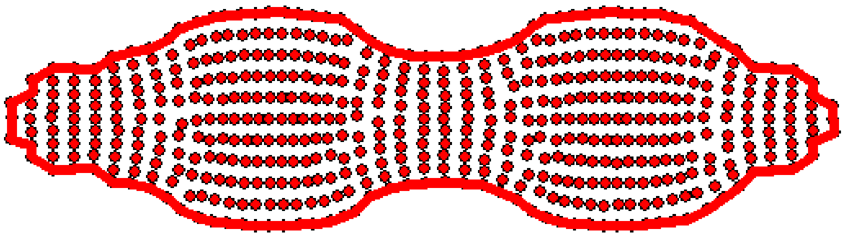

Figure 6. Segment compression

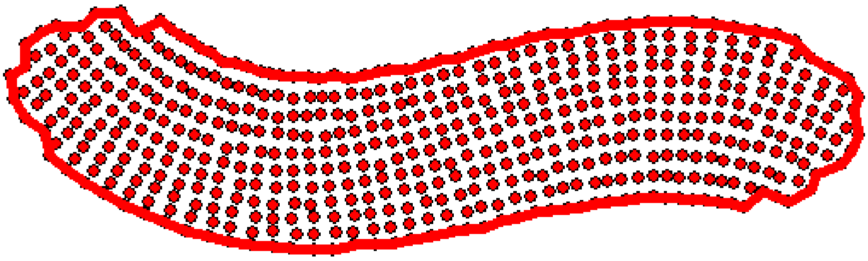

Figure 7. “Nematode“ movement

As a result it is possible to simulate both worm-like and more complex organisms, collect the data and study their behavior. Of course this will be possible only with the development in this area and a more detailed analysis of the subject area. But it gives significant impetus to future research.

Development in this branch can give important results, which require a lot of time of development and research in both biology and programming. This study presents a rather primitive algorithms of the nervous system's simulation, but further development of hardware enables simulation of much more complex examples and gaining the speed of signal transmission at the level of human neural network.

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TRANSFORMACJA WIEDZY MODELOWANEJ W TECHNOLOGII MONITORINGU WIELOPOZIOMOWEGO

Streszczenie: Podejmowanie decyzji w wielu dziedzinach czy sytuacjach nie jest czynnością trywialną. Odwrotnie, wymaga ono analizy oraz przetwarzania danych – wielkich zasobów informacji – dochodzących z zewnątrz systemu tak aby decyzja była uzasadniona. Zatem, automatyzacja podejmowania decyzji jest ważnych zadaniem w dążeniu do rozwoju jakiekolwiek system sztucznej inteligencji. W rzeczywistości, oznacza ona kompleksową analizę istniejących rozwiązań działania podobnych systemów. W szczególności, należy przeanalizować jak takie systemy transformują wiedzę oraz jak tworzą jej reprezentację. Okazuje się, że model reprezentacji wiedzy definiuje architekturę, parametry, własności takiego systemu, metody akwizycji wiedzy oraz jej przetwarzania. Uwzględniając powyższe zasady, w niniejszym artykule zaproponowano rozwiązania praktyczne. Mianowicie, rozwinięto nowe ujęcie konceptualizacji wiedzy aby zbudować bazę danych wiedzy. To ujęcie obejmuje inne (niż dotychczas) zasady archiwizacji wiedzy dla jej indukcyjnego modelowania. Dzięki temu uproszczono procedurę akwizycji nowej wiedzy.

Słowa kluczowe: podejmowanie decyzji, konceptualizacja wiedzy, baza danych wiedzy, model reprezentacji wiedzy, model indukcyjny, technologia monitorowania wielopoziomowego

TRANSFORMATION OF MODELING KNOWLEDGE IN MULTILEVEL MONITORING TECHNOLOGY

Annotation: Decision-making in many areas is not a trivial task that requires analyzing and data processing a large quantities of information coming from the outside to argumentation this process. Therefore the automation of decision-making is the important task for development any intellectual system, because it means a complex analysis of existing approaches to work with the knowledge and models of their representation. The model of knowledge representation defines the architecture, features, properties of the system, acquisition of knowledge methods and work with them. Therefore, the actual practical task whose solution is proposed in this paper is development a new approach to the knowledge conceptualization for knowledge base create. This approach involves other principles of knowledge saving for inductive modeling that will simplify the procedure of new knowledge acquisition.

Key words: decision-making, knowledge conceptualization, knowledge base, knowledge representation model, inductive modeling, multilevel monitoring technology

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1. Setting the problem

The rapid development of modern information technologies and increasing level of intelectual nature of computer systems in the end of the first and the beginning of the second decade of the 21 century are the result which is directly connected with the development of society and its growing demand for analytical processing of large amount of data collected in different areas of human life.
The notion of "intelligent system" in the classical theory of artificial intelligence is entirely related to the concept of "knowledge." Thus, any system containing a database of knowledge is taken as intellectual.
However, knowledge alone is an extremely specific resource. It is difficult to be identified (you can select only explicit knowledge (explicit knowledge), which in turn is associated with implicit (tacit knowledge)), poorly measured (both qualitatively and quantitatively) and formalized, so the process of working with knowledge is connected with numerous difficulties. The latter is identified, studied and eliminated by one of the areas of artificial intelligence, knowledge engineering.
Within the sphere of knowledge engineering there is the term "work with knowledge", the term links the concept of "knowledge" and the process of working with it. It is generally accepted to define the term extensionally by enumerating the subprocesses that determine it. These subprocesses typically include: production and acquisition of knowledge as well as its presentation and manipulation using knowledge. The sphere of aspects of knowledge alongside with subprocesses mentioned above include methods and tools that promote the subprocesses. In addition, any of subprocesses mentioned are based on the model of knowledge presentation; the latter in its turn affects the structure of the knowledge database of intelligent system and determines possible methods and tools to work with the system.
Besides, it should be born in mind that modern intelligent systems should primarily be adaptive as knowledge is not a constant notion and is increasing its volume due to the emergence and development of new aspects of scientific research. Therefore the contradiction arises as follows: the construction of knowledge database on tha basis of approaches developed earlier does not promote the level of adaptivity of intelligent systems which in its turn prevents the creation of new and more effective means to automate a rather laborious and long process of integration of the abstract knowledge in the chosen subject area.

2. Analysis of recent research and publications

The conceptual paradigm of working with knowledge is formulated and described by V. Hlushkov [1]. Also a significant contribution in this area was made by D. Pospelov, N. KHomsky, M. Minsk, T. Gavrilova, A. Tarsky, D. Davidson, N. Leontieva, E. Popov, V. Shirokov and many others. In addition, the chosen area also may include many of the works in other areas of artificial intelligence within the problem of modeling complex objects, including mathematical logic [2-7].

3. Pointing out the unsolved aspects of the problem

Despite the fact that scientists have developed a lot of models of knowledge presentation [8-11], among which widely used are logic, networking, productive, frame and formal ones, the scientific community still has no agreement on the rational application of this or that model to solve practical problems. Thus within the given research the scientific problem is to develop a new approach to the conceptualization of knowledge that will help to improve work with knowledge using new perspective and more effective methods of knowledge formalizing that will enable to modify easily knowledge database according to the given task as well as to create adaptive automated tools for building knowledge database in the chosen subject area.

4. The aim of the article

One of the most significant signs of theorizing knowledge in any field is its methodological nature that is aiming the research not only at the object but also at the means of its cognition [12]. The right aiming of methodological research influences the right cognition of general laws and helps to identify the laws of development of studied objects, processes and phenomena, also the efficiency of scientific research and its strict dedication. That is why the aim of this work is to develop a new methodology of work with knowledge that includes the formulation of general principles of conceptualization of knowledge and consequently its storage methods for further modelling and usage. This approach will enable us to simplify the procedure of obtaining new knowledge using methods of artificial intelligence.

5. Results

Monitoring is one of the constituent parts of the process of supporting deision making in the management of any complex objects. The main method of diagnosing the state of the object monitored is the collection, processing and analysis of information about it. Thus, due to monitoring the process of decision making under uncertainty is provided with new knowledge about the object by means of transforming the information.

In this paper, the process of transforming information will be viewed as a combination of a set of object models of the same level of monitoring, according to the presented in [13] methodology of automated systems of multilevel transformation of information. The methodology provides a combination of methods and means of forming a hierarchy of multi-parameter models, where each model solves a separate local task of data transformation.

That means data are separate facts or figures (in qualitative or quantitative form) that are required for initial superficial acquaintance with the object at a certain moment. Based on available data it is possible to get information about the main features and properties peculiar to the object and to draw some conclusions about its peculiarities. The condition is understood as a vector of values of object properties that are changed in the monitoring process.

Knowledge is always based on the data, as it represents information on trends which are observed for the studied object at a certain time interval and which are quantitatively or qualitatively reflect object's properties and their change under the influence of external factors. In fact, knowledge characterizes the dynamics of the object.

Thus, forming the database of model knowledge is the process of transforming a set of knowledge based on existing images. Each image is a combination of knowledge to describe new properties of the object under study. That is, the image contains the structure of relationships between knowledge, which enables to form a field of knowledge at each level of the hierarchy of representation model. In the process of ascending synthesis of multi-level model [13] a new image is generated, making it possible to represent the tendencies to changes on the referential field of knowledge and to formulate hypotheses about the nature and character of the object under study. That's why each image is a complex combination of new knowledge about the studied object, process or phenomenon.

Therefore, under the new approach proposed in this paper, the global goal of artificial intelligence is implemented by forming multi-level stratified structure of the knowledge database. Each individual stratum contains a single field of knowledge that generates several images of the object and is a combination of multi-parameter models, which solve the local tasks of transformation of information at a given level of the hierarchy. That means knowledge database is built in the form of a hierarchical combination of images generated by the fields of knowledge, which form the local functional dependence in which the relationship between input and output variables of the model is represented as Volter's functional series or its discrete analog, which is known as Kolmogorov-Gabor's log [14]. It will be reasonable to create a global functional dependence whenever there is a strategy of its synthesis γ, which enhances the adequacy of mapping connections between input signals of local models:

$$(\forall\gamma)(\forall x)\{[P(x, D_i(\gamma)\ i\ K(u^\gamma)) = u] \rightarrow P(\pi_\Delta(x), D)\} \qquad (1)$$

where: γ – a strategy of synthesis of a global functional dependence;
x – the output signals of the previous layer models;
$D_i(\gamma)$ – the tasks of transforming the information of the given stratum;
D – global tasks of transforming information;
u^γ – a set of connections, reflected in the structure of multi-layer model;
u – a set of valid connections.

A strategy of synthesis of a global functional dependence γ provides completing the condition:

$$(\forall\gamma)(\forall x)(\forall y)\{[P(x, D_i(\gamma)\ i\ G(x,y) \in G(\gamma))] \rightarrow P(\pi_\Delta(x), D)\} \qquad (2)$$

where: y – output sygnals of the next layer models;
$G(x,y)$ – the function of quality assessment of a global functional dependence;
$G(\gamma)$ – the given function of quality assessment.

The task which includes both coordination of models of monitored objects as the main structural elements within a particular field of knowledge and coordination of interaction of fields of knowledge while shaping the global functional dependence is solved by applying the basic principles of self-organizing systems, which are realized by means of artificial intelligence methods including:

- The interlocutory nature of making decisions. Nowadays making a decision should be done in such a way as to provide to ensure maximum freedom of choice for making future decisions at every step of selforganization [15].
- External addition. It is based on the theorem by K. Gedel [16] and means that only external criteria of a model quality based on new knowledge, can synthesize adequate model of complex object, process or of the studied phenomenon, hidden in initial noisy data.
- A method of mass selection offered by A. Ivakhnenko [17] which is meant to provide a gradual self-organized complication of the model structure so that its quality criteria passed through its minimum.

Analysis of knowledge within the database of model knowledge formed in this way supposes formation of strategies of using images by application systems while solving the given tasks with the help of expert analyst (Fig. 1).

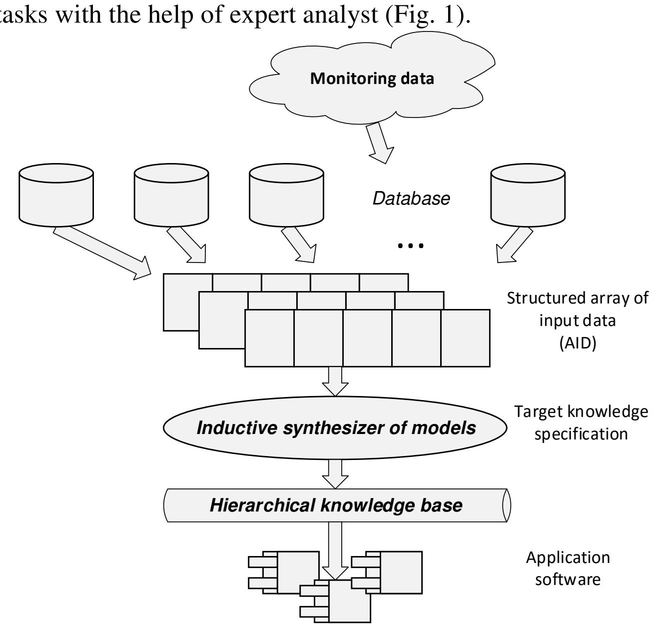

Figure. 1. Architecture of intellectual analysis system.

6. Conclusions and suggestions

Thus a new approach to building knowledge databases of intelligent systems capable of learning and adapting was offered. According to this approach knowledge about the object is formed by means of a hierarchical combination of images, which in their turn form the fields of knowledge of multidimensional models based on the principles of the interlocutory nature of making decisions, external addition and mass selection. Further research will focus on the development of adaptive methods of forming the structure of knowledge images.

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NAUKOWE I METODOLOGICZNE PODEJŚCIE DO MODELOWANIA, PRZETWARZANIA I KOMPUTEROWEJ SYMULACJI SYGNAŁÓW Z SERCA

Streszczenie: W artykule, opisano metodologię badań serca. Przedstawiano uogólnioną strukturę oraz integralne ujęcie naukowo-metodyczne w celu modelowania oraz metod przetwarzania cyklicznie zmiennych, rejestrowanych sygnałów serca. Rozpatrzono sygnały różnego typu tj.: elektryczne, magnetyczne i mechaniczne (akustyczne) poprzez odpowiednie systemy komputerowego monitoringu dla kardiologii. Na tej podstawie możliwe jest przewidywanie i optymalna koordynacja terapeutyczna (rehabilitacja, profilaktyka) stanu czynnościowego serca i układu krążenia w organizmie ludzkim.

Słowa kluczowe: modelowanie, metody przetwarzania sygnałów, systemy komputerowe dla kardiologii

SCIENTIFIC AND METHODOLOGICAL APPROACH TO MODELING, PROCESSING AND COMPUTER SIMULATION OF HEART SIGNALS

Summary: The paper gives the reasoning for actuality and presents the generalized structure of integral scientific-methodological approach to modeling and methods of processing the wide range of cyclic heart signals of electric, magnetic and mechanical (acoustic) nature in the systems of computer diagnosis, prediction and optimal therapeutic coordination (rehabilitation, prophylactic) of functional state of heart and cardiovascular system in human organism.

Keywords: modeling, signal processing methods, computer systems for cardiology

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1. Introduction

Modern systems and technologies of computer diagnostics, prediction and optimal therapeutic control (rehabilitation, prevention) over functional state of heart and cardiovascular system of human organism are widely used in clinical practice that significantly intensified and increased the efficiency of diagnostics and making therapeutic solutions by cardiologist. However, despite significant advances of cardiometric computer systems introduction, their use in the cardiology practice is characterized by insufficient accuracy, reliability, informability (according to statistics 20% of diagnoses are inadequate) automated diagnosis of the heart and cardiovascular system of the human body functional state, that in its vast majority is caused by the lack of development of software and some inadequate mathematical models of cyclic signals. Existing approaches to the developing models and methods for processing, simulation of cyclic heart signals mostly are not holistic and systematic enough due to several reasons including:

1. A number of contradictions and inconsistencies in the processed cardio-signals' interpretation due to the considerable variety of their analysis standards (methods) and different medical research peculiarities including the ambiguity of the interpretation of many fundamental concepts in cardiography, which greatly complicates the development of algorithms for automated analysis of cardio-signals.
2. Despite the similarity in space-time structure of different cyclic heart signals types (electrocardiosignal, phonocardiosignal, magnetic-cardiosignal, reocardiosignal, photopletizm-cardiosignal etc.) there are significant differences (and sometimes contradictory) in their structure and properties of known mathematical models, processing techniques and computer simulation.
3. Development of software for different cargiodiagnostics types (portable, stationary, and telemedical systems, for population research to study patients at rest and subject to load) based on different mismatched principles and approaches.
4. Mathematical tools of modeling and working out cardiac fields, totality of synchronously registered and individual cardiosignal and as well as tools for simulation and analysis of morphological characteristics and cardiosignal rate characteristics are poorly coordinated among themselves and sometimes are contradictory.
5. In the process of models' building and justification, heart signals processing methods, it is difficult to consider previous experience in this area of research because there is no single piece of scientific and methodological approach to mathematical modeling and computer simulation study which greatly complicates the implementation of this process and reduces quality.

Above mentioned drawbacks need the known approaches to mathematic modeling, computer simulation and processing of heart signals to be improved. In particular, it is necessary to develop generalized unified science and methodological access that would take into account positive aspects of existing concepts of modeling and processing the heart signals as well as to eliminate the named disadvantages. Developed science and methodological approach should serve as theoretic background for expert system of decision making in tasks of projecting software of different purposes, functions, types of processed signals, accuracy requirements (reliability, informability) to computer systems for diagnosis, prediction and optimal therapeutic coordination (rehabilitation, prophylactic) of functional state of heart and cardiovascular system in human organism.

2. Developing of scientific and methodological approach to modeling, processing and computer simulation of heart signals

This work is dedicated to improving the scientific and methodological approach to building and justification of mathematical models, methods of working out and computer simulation of cardio signal is in systems of computer diagnosis, prognosis and optimal management of the heart and cardiovascular system's functional state. Before developing a new approach, the main demands to it will be formulated, which will give the possibility to clearly specify the required properties for the task of creating appropriate mathematical software.

2.1. Requirements for the developed scientific and methodological approach to modeling, processing and computer simulation of heart signals

1. The developed scientific and methodological approach to building and justification of mathematical models, processing methods and algorithms, computer simulation of cardio-signals should:
2. Be applied for modelling a broad class of cyclic heart signals of different physical nature, namely of electrical, magnetic and acoustic ones.
3. Be applicable (adapted) to solve problems of development and improving the set of diverse systems for computer diagnosis, prognosis and optimal therapeutic control (rehabilitation, preventive) over the functional state of human heart and cardiovascular system. In other words, it should be applicable for diagnostic systems in hospital and outpatient conditions for patients were in resting state and subject to strain (physical, psychological, action agents) for express cardiometric systems and for integrated multifunctional diagnostic systems, Telemedicine and for population biometric studies using metacomputing, in particular, grid technologies.
4. Have coordinated tools for modeling and processing of vector and scalar cardiac fields, aggregate of synchronous and individual registered cardio signals, have means of modeling and analysis of its morphological characteristics and rhythm charcteristics, be suitable for solving tasks of analysis, prediction, identification and optimization (correction) the functional state of heart and cardiovascular system.
5. Give a possibility to select the level of detail, completeness, adequacy of describing the space-time heart signal's structure concerning phenomenologically identified properties of cyclical heart signals, namely, from their "rough" (total) to more "detailed" (more accurate) indication that will provide a necessary for cardiological practice level of reliability and informability of functional heart diagnosis.
6. Have means to take into account the biophysical cardiosignals' mechanisms of electric, magnetic and mechanical (acoustic) nature within a single theoretical and methodological approach as a heart signals have similar space-time structure

and mechanisms of their formation, caused by interconnectedness, consistency between an electrical and mechanical biophysical processes in the heart.

2.2. Requirements for the developed scientific and methodological approach to modeling, processing and computer simulation of heart signals

We will give generalized abstract formulation of the fundamental principles of the structure proposed in the scientific and methodological approach to modeling and computer simulation study of cyclical heart signals.

Step-by-step principle of software development. This principle sets the overall consistency of software development: 1) formulation the set of requirements to software, based on the total set of requirements to cardiomrtric system developed; 2) giving reasons for the choice of mathematical models, methods and computer simulation study based on the best match of their properties to formulated requirements; 3) the reasonable choice of specific algorithms that implement the relevant models and methods; 4) parametric identification of algorithm processing and computer simulation of heart signals; 5) verification of mathematical models, methods and algorithms (see. Figure 1).

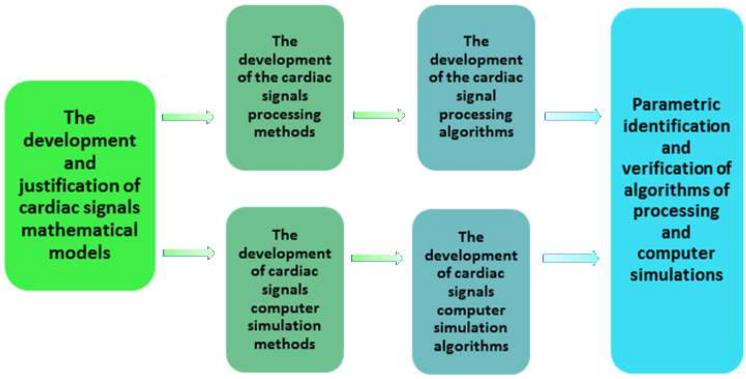

Figure 1. Sequence of stages of justifying and choosing mathematical models, processing methods and computer simulation of cyclical heart signals

Principle of priority of motivative choosing the existing heart signal model over development of a new one.

Considering the large number of existing mathematical models of heart signals, their great diversity, software developer has no need to develop a new mathematical model and methods of processing the cyclical heart signals "from scratch" but more appropriate is to reasonably choose and adapt (adequately to studied signal structure and study objectives) mathematical model from the existing totality that will significantly increase the efficiency (significantly simplify and speed up) the development of designed information system software.

Principle of integrity, coordination, and partial arrangement of mathematic models by the degree of considering heart signals' characteristics

Despite the large number of mathematical models of heart signal including deterministic models, stochastic periodic model (additive model, cyclic standard correlated random processes, linear periodical random functions), stochastic processes with band-cyclic structure, the cyclic casual process and vector of cyclical rhythm floor ' related stochastic processes, conventional cyclic random process [1], there is their common feature – their recurrence. The presence of this models' common property gives a possibility to apply developed mathematical tools of cyclical functional relations theory [2] as a theoretical foundation that unites and coordinates structurally different mathematical models of heart signals. Partial arrangement of heart signals mathematical models should be carried out according to their ability to show defining characteristics of cyclic signals structure and possibility, effectiveness of their use for solving applications design software of the automated information systems of processing and simulation (generation) cyclical heart signals.

Principle of maximum coordination of requirements for software and models' (methods').

For correct and motivated choice of mathematic model and heart signal processing methods, it is necessary to outline the class of cyclic signals' mathematic models and to determine the list of characteristics by which they will be compared to the requirements. It is necessary to briefly and clearly present data concerning peculiar characteristics of present mathematic models, the efficiency of their use for solving appropriate tasks, e.g.as in [3]. Also, the important task is to specify a set of possible requirements for automated information modeling systems and processing of cyclic heart signals software.

Principles of automation the procedure of choosing models and methods

Despite a large amount of known cardio-signals mathematic models, the process of their developing will be constant for the reason of information inexhaustibility of the object, permanent need for improving cardiometric systems and new tasks of cardiology. For automation purpose, it is reasonable to implement science-methodological approach with the use of expert computer support system of taking model solutions in the task of developing software for automated information cardiometric systems (see Figure 2).

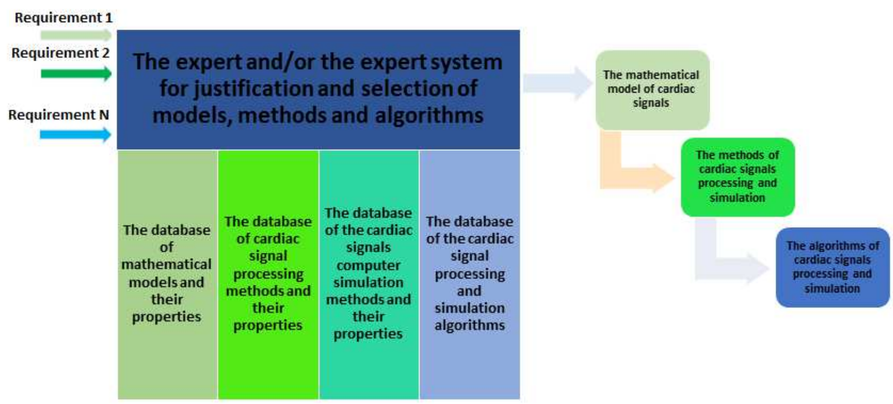

Figure 2. Generalized scheme of functioning of expert system for motivation and selection of mathematic models, method of processing and computer simulation of heart signals

3. Conclusions and prospects of further research

1. The topicality of the development is reasoned and the requirements to new generalized science-methodological approach to modeling and building out the method of processing the wide range of cyclic heart signals being electric, magnetic and mechanical (acoustic) by nature in computer diagnosis systems, prognosis and optimal therapeutic coordination (rehabilitation, prophylactics) of functional state of heart and cardiovascular system in human organism.
2. Structure and general principles of scientific-methodological approach to modeling, processing and computer simulation of cyclic heart signals were proposed, that opened prospects of building the interactive information expert system for reasoning and choosing the mathematic models of processing methods and computer simulation of heart signals, which takes into account a set of requirements for cardiometric system being developed.
3. In further scientific research it is necessary to develop the parameters of the degree of correspondence between models (methods), demands and heart signals' characteristics, as well as to develop the architecture of expert system for reasoning the choice of mathematic models, methods of processing and computer simulation of heart signals.

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Projektowanie, badania i eksploatacja

Designing, researches and exploitation

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OCENA ZMIAN CIŚNIENIA PALIWA W ZASOBNIKU W WARUNKACH PODAWANIA DZIELONEJ I NIEDZIELONEJ DAWKI WTRYSKU

Streszczenie: W artykule przedstawiono wyniki analizy zmian ciśnienia paliwa w zasobniku układu zasilania Common Rail. Do pomiarów wykorzystano fabryczny czujnik ciśnienia. Rejestrowano zmiany ciśnienia paliwa przy wtrysku dzielonej i niedzielonej dawki. Zadawano parametry wtrysku odpowiadające pracy silnika samochodowego podczas jazdy w mieście. Porównano zadane i zmierzone, w oparciu o przebiegi ciśnienia, czasy wtrysku oraz wyznaczono zmiany ciśnienia wynikające z procesu podawania paliwa.

Słowa kluczowe: tłokowy silnik spalinowy, układ zasilania w paliwo, Common Rail

ASSESSMENT OF THE FUEL PRESSURE IN THE RAIL DURING DIVIDED AND UNDIVIDED FUEL DELIVERY

Summary: In the article the results of the analysis of pressure changes in the fuel supply system Common Rail were presented. For measurements the manufacturing pressure sensor was used. Changes in fuel pressure with divided and undivided fuel injection dose were recorded. Injection parameters corresponding to the operation of the car engine when it driving in the city were set. The set and measured on the basis of waveforms pressure injection times were compared. Changes in pressure resulting from the fuel delivery process were designated.

Keywords: internal combustion engine, fuel supply system, Common Rail

1. Wstęp

W każdym silniku spalinowym bardzo ważny jest proces przygotowania mieszaniny palnej. Na jakość tego procesu w dużej mierze wpływa praca układu zasilania w paliwo. Szczególne znaczenie ma praca układu w silniku o zapłonie samoczynnym (ZS), z uwagi na brak układu inicjującego zapłon. Należy bowiem w każdych

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warunkach pracy silnika wytworzyć mieszaninę, która samoczynnie ulegnie zapłonowi. Tworzenie mieszaniny znacząco zależy od ciśnienia paliwa doprowadzanego do komory spalania.
Obecnie prawie we wszystkich pojazdach wyposażonych w silnik spalinowy o zapłonie samoczynnym stosuje się system zasilania w paliwo typu Common Rail. System ten został wprowadzony do produkcji w 1997 roku. Umożliwia zmiany parametrów procesu wtrysku, a tym samym kształtowanie natężenia wypływu paliwa z rozpylacza. Jego zaletami są zapewnienie mniejszego zużycia paliwa oraz ograniczona emisja szkodliwych substancji w spalinach, umożliwiające spełnienie przez silnik aktualnych norm z zakresu toksyczności spalin. Układ sterowania takiego układu zasilania składa się z szeregów czujników, których sygnały są wysyłane do sterownika silnika spalinowego. Podczas pracy układu Common Rail bardzo ważna jest kontrola ciśnienia w zasobniku paliwa, które zmienia się w zależności od wielkości i formy podawanej dawki wtrysku.

2. Cel i zakres pracy

Celem pracy była analiza przebiegu ciśnień w zasobniku paliwa oraz określenie czasów wtrysku w przypadku podawania dzielonej i niedzielonej dawki paliwa. Ponadto próbowano odpowiedzieć na pytanie, czy jest możliwa analiza procesu wtrysku w oparciu o zarejestrowane zmiany ciśnienia paliwa w zasobniku. Wybrano takie parametry pracy układu zasilania, które odpowiadają eksploatacji samochodu w warunkach jazdy miejskiej. Analiza zmian ciśnienia rejestrowanych za pomocą fabrycznego czujnika w warunkach jazdy miejskiej jest zadaniem stosunkowo trudnym. Wynika to z mniejszej czułości i dokładności użytego przetwornika w odniesieniu do laboratoryjnego czujnika oraz małych wartości zadawanych czasów sterowania wtryskiwaczami. Te czynniki wywołują relatywnie małe zmiany analizowanych przebiegów. Ponadto na rejestrowane wartości nakładają się zakłócenia, co powoduje konieczność przeprowadzania dodatkowych zabiegów związanych z analizą.

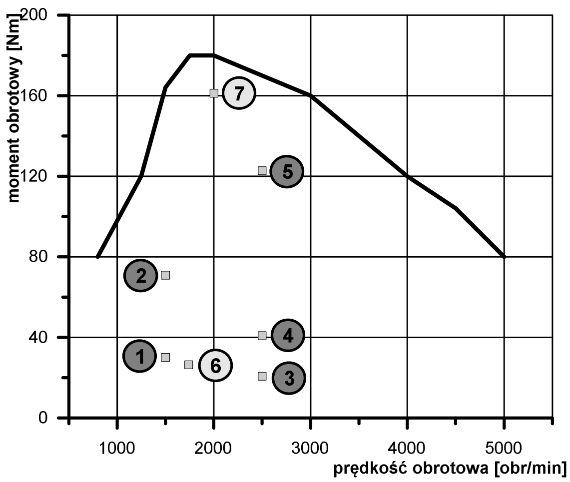
3. Program badań

Na program badań składa się 7 różnych przypadków pomiarowych. Wartości zadanych czasów wtrysku wyznaczono w oparciu o wyniki badań silnika 1,3 SDE 70 KM, przeprowadzonych na hamowni silnikowej. Wyznaczone punkty pomiarowe przedstawiono na rysunku 1 na tle charakterystyki zewnętrznej silnika 1,3 SDE. Jak wspomniano, wybrano punkty w obszarze odpowiadającym pracy silnika w warunkach jazdy miejskiej. Ciemnoszarym tłem zaznaczono punkty, w których występuje dzielona dawka paliwa, a jasnoszarym tłem – niedzielona.
Ponieważ dane odczytane z rejestratorów hamowni nie zawierały zadawanych czasów przerw między częściami dawki, należało je wyznaczyć. Wykorzystano tutaj wartości wielkości wyznaczone podczas hamownianych pomiarów, a mianowicie:
PIL_PRE – czas przerwy między pierwszą, a drugą częścią dawki, KINJPIL_OBD – kąt wyprzedzenia wtrysku pierwszej części dawki, KINJPRE_OBD

- kąt wyprzedzenia wtrysku drugiej części dawki, RPM – prędkość obrotowa wałka pompy wysokiego ciśnienia, TINJPIL_OBD – czas wtrysku pierwszej części dawki, PRE_M – czas przerwy między drugą, a trzecią częścią dawki, KINJM_OBD – kąt wyprzedzenia wtrysku trzeciej części dawki, TINJPRE_OBD - czas wtrysku drugiej części dawki, i ujęto w zależności (1) i (2).

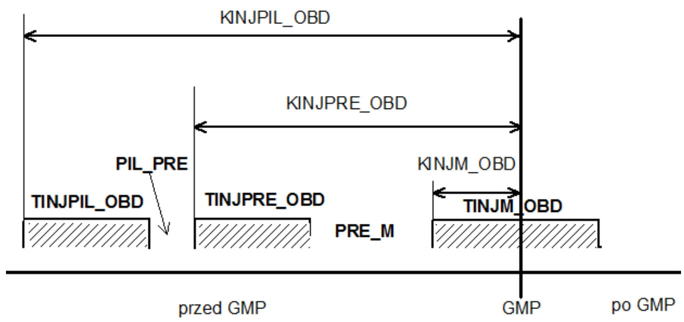
$$PIL\_PRE = \frac{KINJPIL\_OBD - KINJPRE\_OBD}{6\ RPM} - TINJPIL\_OBD \tag{1}$$

$$PRE\_M = \frac{KINJPRE\_OBD - KINJM\_OBD}{6\ RPM} - TINJPRE\_OBD \tag{2}$$



Rysunek 1. Punkty pomiarowe na tle charakterystyki zewnętrznej silnika 1,3 SDE

Sposób wyznaczania czasów części dawek oraz czasów przerw między dawkami został zilustrowany na rys. 2.



Rysunek 2. Schemat do obliczania czasów przerw między częściami dawki

Wyznaczone wartości zadanych czasów wtrysku i przerw stanowiły podstawę do opracowania programu badań, którego podstawowe założenia zestawiono w tab. 1.

Tabela 1. Ramowy program badań przebiegów ciśnienia paliwa w zasobniku

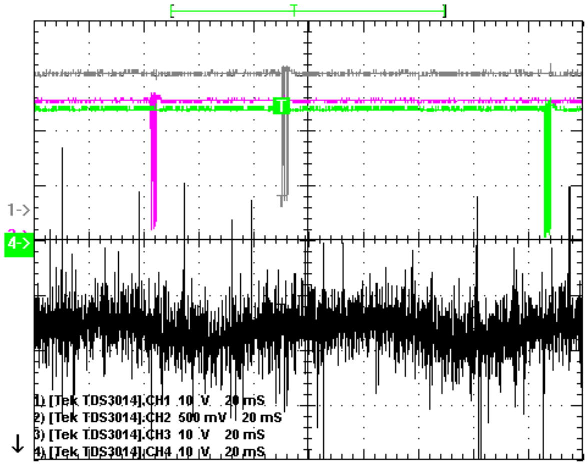
Lp.	Liczba części dawki wtrysku	Czas wtrysku pierwszej części dawki [µs]	Przerwa między pierwszą, a drugą częścią dawki [µs]	Czas wtrysku drugiej części dawki [µs]	Przerwa między drugą, a trzecią częścią dawki [µs]	Czas wtrysku trzeciej części dawki [µs]	Ciśnienie paliwa w zasobniku [bar]	Temperatura paliwa w zasobniku [°c]	Całkowity czas wtrysku °/µs
1	3	282	274	291	154	503	564	31,35	1504
2	3	277	167	289	267	695	595	31,56	1695
3	3	270	196	278	188	421	702	31,68	1353
4	3	225	308	272	195	482	826	31,18	1482
5	2	272	261	533			912	31,26	1066
6	1	538					612	31,02	538
7	1	1002					1008	31,12	1002

4. Stanowisko pomiarowe

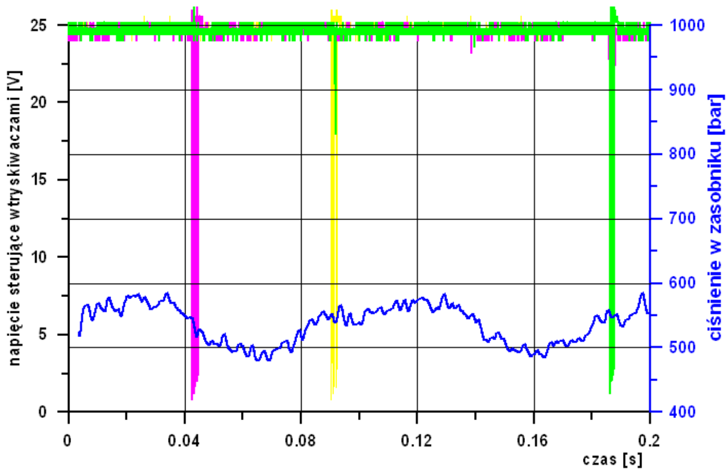
Badania przeprowadzone zostały na stole probierczym STAR 8, który został zmodyfikowany w celu umożliwienia prowadzenia badań układu Common Rail. Na stanowisku pomiarowym jest możliwość badania podzespołów wspomnianego układu np. wtryskiwaczy czy pompy wysokiego ciśnienia. Praca stanowiska jest nadzorowana za pomocą komputera, na którym zaimplementowano specjalne oprogramowanie, umożliwiające zarówno zadawanie, jak i rejestrację badanych wielkości. Do komputera są wprowadzane następujące dane: zadane czasy wtrysku poszczególnych części dawki paliwa, czasy przerw między częściami dawki, ilość części dawki oraz jest zadawane ciśnienie w zasobniku. Zmiana ciśnienia następuje za pomocą zaworu regulacyjnego, przez zmianę wypełnienia sygnału PWM. Dane z komputera wysyłane są do sterownika, a następnie do elementów wykonawczych. Sterownik odczytuje z badanego układu zasilania takie wielkości jak: prędkość obrotowa, ciśnienie w zasobniku, temperatury paliwa mierzone na zasobniku i w zbiorniku paliwa. Stanowisko pomiarowe wyposażono w oscyloskop cyfrowy Tektronix TDS-3014. Został on podłączony do sterownika, a tym samym umożliwiono równoczesne wyświetlanie i rejestrację przebiegów sterujących z trzech wtryskiwaczy oraz z fabrycznego czujnika wysokiego ciśnienia umieszczonego w zasobniku. Rejestracja przebiegów następowała w oparciu o specjalistyczne oprogramowanie oscyloskopu WaveStar.

5. Wyniki badań

Wynikami badań są sygnały napięciowe wtryskiwaczy oraz napięciowy sygnał z czujnika wysokiego ciśnienia w zasobniku. W celu przeprowadzenia dokładnej analizy zmian ciśnienia, jego przebiegi zostały przekształcone. Wstępna analiza wykresów wykazała, że sygnały z czujnika ciśnienia charakteryzują się licznymi zakłóceniami, a bardzo krótkie czasy wtrysków dawek paliwa oraz czasy przerw nie pozwalają na odczytanie dokładnych wartości. W celu uzyskania dokładniejszych wyników przebiegi z czujnika ciśnienia poddano filtracji. Do filtrowania zmierzonych przebiegów ciśnienia w zasobniku paliwa zastosowano dolnoprzepustowy filtr Czebyszewa. Wykorzystano aplikację wbudowaną w programie MATLAB. W procesie filtracji należało dopasować cztery parametry filtra, to jest: rząd, częstotliwość odcięcia, częstotliwość próbkowania i falistość. Optymalne wyniki uzyskano stosując filtr o następujących parametrach: rząd filtra - 3, falistość 0,1 dB, częstotliwość odcięcia 500 Hz, częstotliwość próbkowania 50000 Hz.



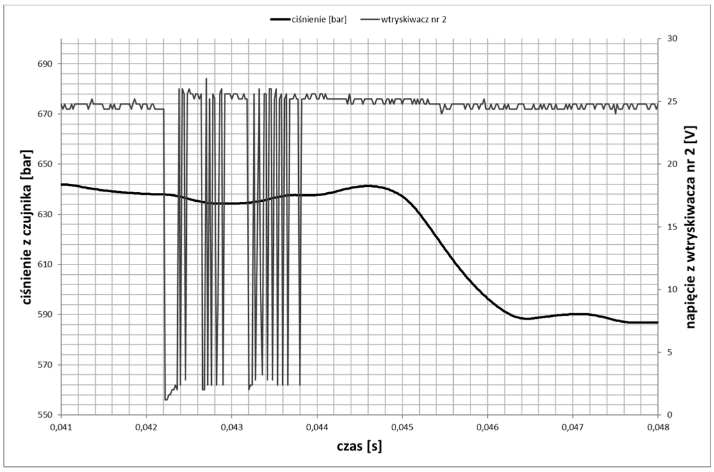
Rysunek 3. Przykład rejestrowanych przebiegów sterujących wtryskiwaczami oraz przebiegu ciśnienia



Rysunek 4. Przykład sygnału napięciowego z czujnika ciśnienia po filtracji

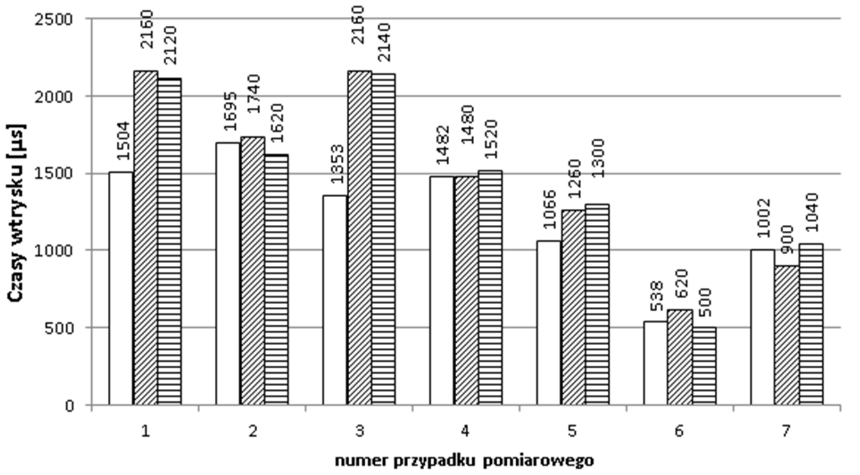
Ponieważ badano układ zasilania, w którym pompa wysokiego ciśnienia współpracowała z czterema wtryskiwaczami, zmiany ciśnienia wywołane wtryskiem dla pierwszego i trzeciego wtryskiwacza istotnie różnią się od zmian wywołanych pracą drugiego i czwartego wtryskiwacza. Dlatego konieczne było przeprowadzenie rozważań dotyczących zmian ciśnienia dla tych dwóch grup. Wybrano wtryskiwacze pierwszy i drugi. W rezultacie konieczna była analiza 14 różnych przypadków pomiarowych.

Wytypowano trzydzieści wielkości, głównych i pomocniczych, które stanowiły podstawę rozważań: czas początku wtrysku, czas końca wtrysku, czas początku wtrysku pierwszej części dawki, czas końca wtrysku pierwszej części dawki, czas początku wtrysku drugiej części dawki, czas końca wtrysku drugiej części dawki, czas początku wtrysku trzeciej części dawki, czas koniec wtrysku trzeciej dawki, całkowity czas wtrysku, czas wtrysku pierwszej części dawki, czas wtrysku drugiej części dawki, czas wtrysku trzeciej części dawki, czas przerwy między wtryskiem pierwszej, a drugiej części dawki, czas przerwy między wtryskiem drugiej, a trzeciej części dawki, początek zmniejszenia ciśnienia wywołanego wtryskiem, koniec zmniejszenia ciśnienia wywołanego wtryskiem, początek zmniejszenia ciśnienia wywołany wtryskiem pierwszej części dawki, koniec zmniejszenia ciśnienia wywołanym wtryskiem pierwszej części dawki, początek zmniejszenia ciśnienia wywołany wtryskiem trzeciej części dawki, koniec zmniejszenia ciśnienia wywołany wtryskiem trzeciej części dawki, całkowity czas zmian ciśnienia wywołanych wtryskiem, czas zmniejszenia ciśnienia wywołany wtryskiem pierwszej części dawki, czas zmniejszenia ciśnienia wywołany wtryskiem trzeciej części dawki, czas narastania ciśnienia odpowiadający przerwie pomiędzy kolejnymi częściami dawki, zmniejszenie ciśnienia wywołane wtryskiem całej dawki, zmniejszenie ciśnienia wywołane wtryskiem pierwszej części dawki, zmniejszenie ciśnienia wywołane wtryskiem trzeciej części dawki, przyrost ciśnienia zarejestrowany podczas przerwy pomiędzy kolejnymi częściami dawki, zwłoka czasowa między zakończeniem sygnału sterującego wtryskiem, a początkiem zmniejszania ciśnienia.



Rysunek 5. Przykład napięciowego przebiegu sterującego wtryskiwaczem i odpowiadający mu przebieg zmian ciśnienia w zasobniku

Na rys. 6÷8 przedstawiono wybrane parametry wtrysku odczytane z przebiegów ciśnienia paliwa w zasobniku. Kolorem białym zaznaczono zadane parametry, ukośnymi liniami dane z pierwszego wtryskiwacza, a poziomymi liniami dane z drugiego wtryskiwacza. Na osi poziomej podano numery przypadków odpowiadające zadanym parametrom zamieszczonym w tabeli 1.
Rysunek 6 przedstawia porównanie całkowitych czasów wtrysku, zadanych za pomocą sterownika, z czasami wyznaczonymi z przebiegów ciśnienia. Wyraźnie dają się zauważyć różnice czasów wtrysku, zwłaszcza dla podziału na trzy części. Największa różnica wynosi 807 µs (59,6 %) dla pierwszego wtryskiwacza i trzeciego przypadku pomiarowego. Najmniejsza różnica wynosi 2 µs (0,13 %) dla wtryskiwacza pierwszego i czwartego przypadku pomiarowego.



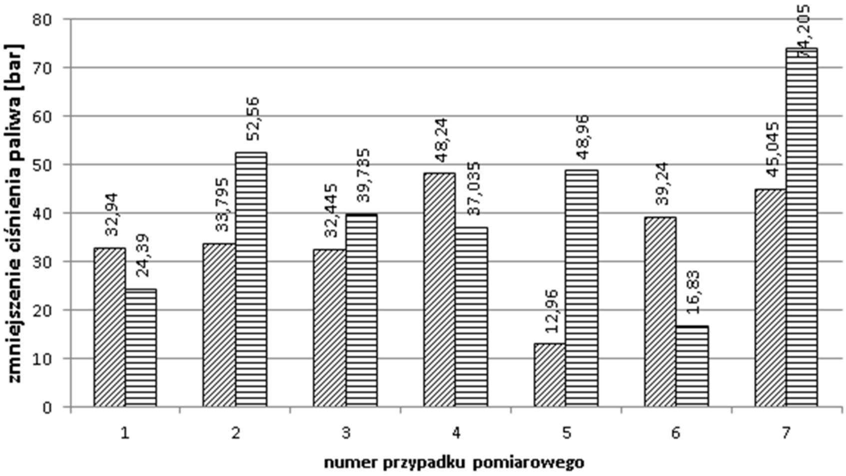
Rysunek 6. Porównanie czasów wtrysku

W tabeli 2 przedstawiono ogólną ocenę wpływu czasu wtrysku na zmiany ciśnienia w zasobniku wywołane procesem podawania paliwa.

Tabela 2. Ocena wpływu procesu wtrysku na przebieg ciśnienia paliwa w zasobniku

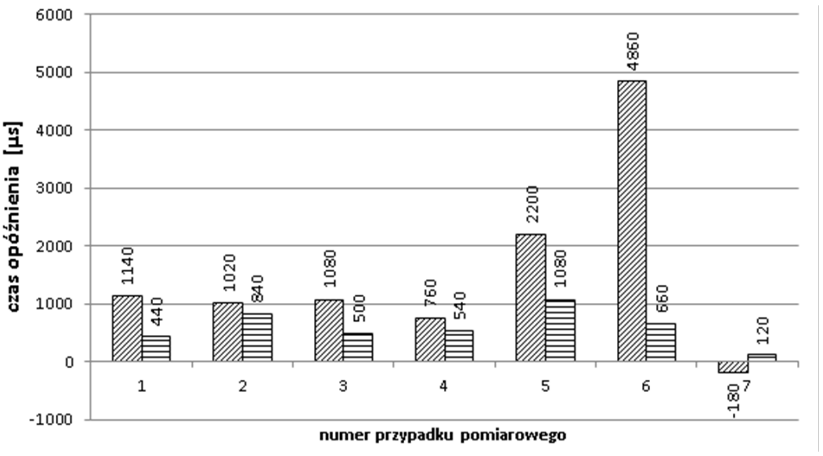
	wtryskiwacz	
ciśnienie [bar]	1	2
570	+++	++
600	++	+++
612	+++	++
708	+++	+
840	++	+
908	+	+++
1008	++	+++
+++ - znaczący wpływ ++ -średni wpływ + - niewielki wpływ		

Natomiast na rys. 7 przedstawiono zmniejszenie wartości ciśnienia paliwa w zasobniku wywołane wtryskiem. Z uwagi na niejednoznaczne wartości, w celu uogólnienia, zastosowano średnią arytmetyczną. Średnia wartość zmiany ciśnienia dla pierwszego wtryskiwacza wynosi 35 barów, natomiast dla drugiego wtryskiwacza 42 bary.



Rysunek 7. Zmniejszenie wartości ciśnienia paliwa wywołane wtryskiem

Z kolei rys. 8 przedstawia czasy między zakończeniem sygnału sterującego wtryskiem, a początkiem zmniejszania ciśnienia paliwa (czas opóźnienia zmniejszania ciśnienia). We wszystkich przypadkach czas opóźnienia dla pierwszego wtryskiwacza jest większy, za wyjątkiem przypadku 7, kiedy zmniejszanie ciśnienia zaczyna się już podczas wtrysku.



Rysunek 8. Czas opóźnienia zmniejszania ciśnienia w czasie wtrysku

6. Podsumowanie

Analiza procesu wtrysku prowadzona w oparciu o przebiegi ciśnienia zarejestrowane na stanowisku probierczym, a generowane przez fabryczny czujnik ciśnienia jest zagadnieniem trudnym. Jej wyniki nie zawsze dają się jednoznacznie zinterpretować.

Mają na to wpływ przede wszystkim niewielkie wartości zadawanych czasów i będące ich wynikiem niewielkie zmiany ciśnienia paliwa w zasobniku. Na podstawie przeprowadzonych pomiarów sformułowano przedstawione niżej wnioski i uwagi końcowe.

Istnieje zależność miedzy wtryskiem paliwa, a ciśnieniem w zasobniku. Wyniki pomiarów związanych z oceną tej zależności mogą być obarczone błędem, ponieważ każdy element układu zasilania pracuje z pewnym opóźnieniem czasowym, którego nie można dokładnie wyznaczyć. Każdemu procesowi wtrysku paliwa towarzyszy zmniejszenie ciśnienia w zasobniku. Z analizy rozważanych przebiegów ciśnienia paliwa w zasobniku wynika, że większe zmniejszanie ciśnienia ma miejsce dla wtryskiwaczy nr 2 i 4, a mniejsze dla wtryskiwaczy nr 1 i 3. Wynika to przede wszystkim z konstrukcji układu zasilania, w którym zastosowano trzysekcyjna pompę wysokiego ciśnienia współpracującą z czterema wtryskiwaczami. Dlatego proces podawania paliwa przez wtryskiwacze nr 1 i 3, który jest realizowany podczas tłoczenia, charakteryzuje się mniejszymi spadkami ciśnienia, w odróżnieniu od procesu dla wtryskiwaczy nr 2 i 4, dla których wtrysk przypada na fazę stabilizacji ciśnienia w pompie. Maksymalne zmniejszenie ciśnienia po wtrysku zanotowano dla piątego przypadku i dla wtryskiwacza nr 2 wynosiło 36 barów.

Przy wykonywaniu pomiarów stosowano 4-kanałowy cyfrowy oscyloskop, dzięki czemu można było jednocześnie rejestrować sygnał z czujnika ciśnienia, jak i z trzech wtryskiwaczy. Wykorzystanie fabrycznego czujnika ciśnienia umożliwia prowadzenie analiz z mniejszym nakładem pracy i można je zrealizować w krótszym czasie.

Istnieje konieczność przeprowadzania filtracji analizowanych przebiegów. Do procesu filtracji przebiegów napięciowych z czujnika ciśnienia wybrano filtr Czebyszewa. Wynikało to z przeprowadzonej wcześniej analizy różnych rodzajów filtrów. Umożliwiło to dokładną analizę przebiegów.

Znajomość charakterystyki czujnika ciśnienia pozwoliła na obliczenie wartości ciśnień w zasobniku, dzięki czemu możliwe było obliczenie wartości zmniejszania ciśnienia wywołanych wtryskiem.

Największą procentową różnicę między zadanymi, a zmierzonymi czasami pierwszej części dawki odnotowano dla wtryskiwacza nr 1 i niedzielonej dawki (1002 μs). Wynosiła ona 10,2 %. Prawdopodobnie wynika to z dużych wartości zadanych czasów. Z kolei najmniejszą procentową różnicę między tymi wielkościami dla wtryskiwacza nr 2 i dzielonej dawki (277 μs). Wynosiła ona 1 %.

Największą procentową różnicę między zadanymi, a zmierzonymi czasami drugiej części dawki odnotowano dla wtryskiwacza nr 2 i czwartego przypadku pomiarowego (272 μs). Wynosiła ona 25 %. Prawdopodobnie wynika to z oddziaływania zadanych czasów. Najmniejszą procentową odnotowano czwartego przypadku pomiarowego (272 μs), dla wtryskiwacza nr 1. Wynosiła ona 2,9 %.

Największą procentową różnicę między zadanymi, a zmierzonymi czasami trzeciej części dawki odnotowano dla wtryskiwacza nr 1 i trzeciego przypadku pomiarowego (421 μs). Wynosiła ona 76 %. Prawdopodobnie wynika to z dużych wartości zadanych czasów i przerw. Najmniejszą procentową różnicę między zadanymi, a zmierzonymi czasami odnotowano dla wtryskiwacza nr 2 i czwartego przypadku pomiarowego (482 μs). Wynosiła ona 3,7 %. Również i tutaj miały wpływ relacje między procesami zwiększania ciśnienia w pompie i wtrysku we wtryskiwaczu.

Nie jest możliwa jednoznaczna ocena wpływu czasów przerw między częściami dawki na proces wtrysku. Rozważane przypadki znacząco różnią się między sobą. Na przykład różnica między zadaną (154 µs), a zmierzoną przerwą wynosi aż 250,6 %. Z kolei zadany czas 167 µs różni się od zmierzonego oi 4,2 %. Prawdopodobnie najistotniejszy wpływ mają tutaj zjawiska falowe występujące w zasobniku paliwa.
Na podstawie analizy wszystkich przypadków pomiarowych można zauważyć, że od zakończenia podawania sygnału sterującego wtryskiem do początku zmniejszania ciśnienia występuje pewne opóźnienie czasowe. Największe wyniosło 4860 µs dla pierwszego wtryskiwacza i szóstego przypadku. W większości przypadków czas ten był większy dla wtryskiwacza nr 1, a mniejszy dla wtryskiwacza nr 2.
Czas zmniejszania ciśnienia wywołany wtryskiem jest dla większości przypadków większy podczas wtrysku realizowanego przez drugi wtryskiwacz. Największy czas zmniejszania ciśnienia wynosił 3360 µs, natomiast najmniejszy 1020 µs. Krótkie czasy zmniejszania ciśnienia występują w przypadkach podawania dawki dwuczęściowej i jednoczęściowej, co wynika z mniejszych wartości zadanych czasów.
W celu potwierdzenia przedstawionych spostrzeżeń należy przeprowadzić podobne badania z zastosowaniem jednotłoczkowej pompy wysokiego ciśnienia, w której wytwarzanie ciśnienia jest zawsze skorelowane z procesem wtrysku.
Podsumowując należy stwierdzić, że na obraz procesu wtrysku w zasobnikowym układzie wtryskowym wpływa szereg czynników, z których - z punktu widzenia przeprowadzonej analizy - najważniejszymi są: relacja między procesem tłoczenia, a procesem wtrysku, przebieg prądu sterującego elektromagnetycznym wtryskiwaczem, zjawiska falowe w zasobniku wysokiego ciśnienia oraz indywidualne cechy wtryskiwaczy. Zatem ocena procesu wtrysku w oparciu o przebieg ciśnienia w zasobniku, szczególnie podczas podawania małych dawek wtrysku, wymaga starannej analizy i doświadczenia.

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WSTĘPNY PROJEKT STANOWISKA DO POMIARU SYGNAŁÓW W UKŁADZIE STEROWANIA SILNIKA

Streszczenie: Artykuł przedstawia opis prac związanych z przygotowaniem wstępnego projektu stanowiska laboratoryjnego, które ma umożliwić wykonywanie pomiarów sygnałów w układzie sterowania silnika o zapłonie iskrowym. W wstępnym projekcie wykorzystano jednostkę sterującą Motronic MP3.1. wraz z wiązką elektryczną silnika 1.4 dm^3, pochodzącego z samochodu Peugeot 106. Parametry były rejestrowane za pomocą cyfrowego oscyloskopu, a ich wyniki przedstawione w formie wykresów.

Słowa kluczowe: oscyloskop, zapłon iskrowy

PRELIMINARY DRAFT OF THE RESEARCH STAND TO MEASUREMENTS OF SIGNALS IN THE ENGINE CONTROL SYSTEM

Summary: The article presents the description of the work related to the preparation of the preliminary draft of the research stand, which is able to perform measurements of signals in the spark ignition engine control system. In the preliminary draft was used control unit Motronic MP3.1. and the electrical harness with the 1.4 dm^3 engine from the Peugeot 106. Parameters were recorded with a digital oscilloscope, and their results were presented in the form of graphs.

Keywords: article, template

1. Wstęp

Tłokowy silnik spalinowy jest najbardziej rozpowszechnioną maszyną zamieniającą energię chemiczną na pracę mechaniczną, wykorzystywaną jako źródło napędów pojazdów mechanicznych. Stale rosnąca liczba samochodów wpływa bardzo znacząco na środowisko oraz, co najgorsze, przyczynia się do zanieczyszczenia powietrza. Dlatego zostały wprowadzone ciągle zaostrzane normy emisji spalin,

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mające na celu ochronę środowiska. W konsekwencji wprowadzenia rygorystycznych norm emisji nowoczesne samochody są wyposażone w różnego rodzaju filtry cząstek stałych oraz reaktory katalityczne. Jednak najważniejszym czynnikiem wpływającym na skład spalin jest przygotowanie mieszaniny paliwowo-powietrznej oraz cały proces jej spalania. Na te dwa procesy głównie wpływają układy zapłonowe i wtryskowe oraz algorytmy sterowania tymi układami. W celu zmniejszenia zużycia paliwa, a dzięki temu zmniejszenia szkodliwych substancji w spalinach firma Bosch w drugiej połowie lat 60 wprowadziła elektronicznie sterowany układ wtryskowy oraz elektronicznie sterowany układ zapłonowy. Dzięki połączeniu tych dwóch układów w 1973 roku powstał projekt Motronic. Zaowocowało to zwiększeniem mocy silnika, znacznym obniżeniem zużycia paliwa, a co za tym idzie, zmniejszenie szkodliwych substancji w spalinach. Elektronicznie sterowany zapłon umożliwił zmianę wyprzedzenia kąta zapłonu, który jest zależny od warunków pracy silnika.
Pierwszy układ Motronic był wykorzystywany od 1979 roku w samochodzie BMW 732i. Głównym elementem układu Motronic jest mikroprocesor i pamięć, w której znajdują się algorytmy sterujące pracą silnika. Odpowiadają one za odpowiednie dawkowanie paliwa oraz właściwy kąt wyprzedzenia zapłonu. Początkowo do zbierania danych o pracy silnika system Motronic wykorzystywał czujniki takie jak: prędkość obrotowa wału korbowego, temperatura silnika oraz ilość dostarczonego powietrza do silnika. Dane te były dostarczane z częstością 100 Hz. W nowoczesnych układach Motronic wykorzystywane jest znacznie więcej danych, dzięki proces spalania jest dokładniej sterowany i odpowiedni do warunków pracy silnika. Motronic pozwolił również na połączenie sterowania układu zapłonowego i wtryskowego w jednym urządzeniu, dzięki czemu czujniki są wykorzystywane do obliczania dawki paliwa jak i do ustalenia kąta wyprzedzenia zapłonu. Ciągłe doskonalenie sterowania pracą silnika przyczynia się do zmniejszenia szkodliwych substancji w spalinach, jak i do usprawnienia procesu spalania.

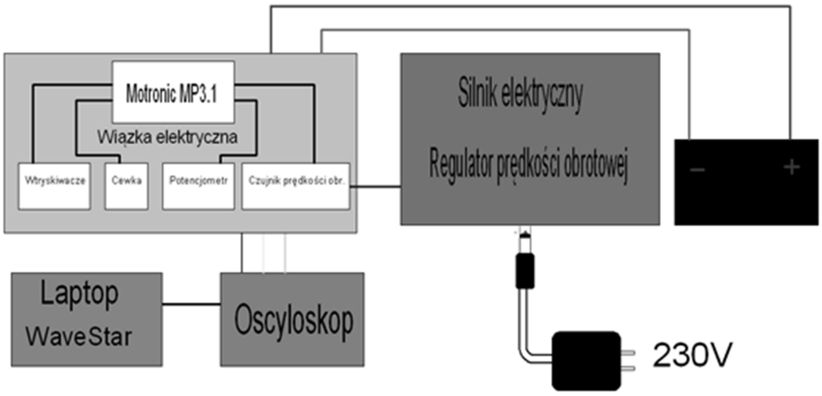
2. Cel i zakres pracy

Celem pracy był projekt i wykonanie pierwszej wersji stanowiska pomiarowego do badania sygnałów sterujących silnikiem spalinowym. Założono również przeprowadzenie wstępnej serii pomiarów, która miała na celu sprawdzenie czy jest możliwe badanie sygnałów napięciowych w układzie sterowania silnika przy wykorzystaniu jedynie fragmentu samochodowej instalacji elektrycznej. Sygnały rejestrowano za pomocą cyfrowego oscyloskopu bezpośrednio ze sterownika. Wyniki zostały przeanalizowane pod kątem zgodności z danymi producenta oraz zobrazowane na wykresach.

3. Opis projektowanego stanowiska

Projektowane stanowisko będzie służyć do pomiarów sygnałów w układzie sterowania tłokowym silnikiem spalinowym o zapłonie iskrowym.
Pierwszą znaczącą trudnością, która pojawiła się na początku prac była konieczność odpowiedzi na pytanie, czy jest możliwe działanie układu sterowania silnikiem odizolowanego od pojazdu. Powszechnie wiadomo, że wiązki elektryczne

w pojazdach produkowane są jako całość i wydzielenie fragmentów, w celu zapewnienia ich prawidłowej pracy, wymaga daleko idącej analizy funkcjonalnej. Początkowe prace sprowadziły się więc do prób uruchomienia sterownika zamontowanego w samochodzie. Próby zostały przeprowadzone na samochodzie marki Peugeot 106, wyposażonego w silnik o pojemności skokowej 1,3 dm^3, którego układ sterowania jest podobnie zbudowany jak analizowany układ sterowania Motronic MP3.1 silnika 1,4 dm^3.
Doświadczenie polegało na demontażu czujnika prędkości obrotowej wału korbowego z pojazdu, który jest umieszczony przy kole zamachowym. Następnie przy włączonym zasilaniu elektrycznym (zapłonie) generowano sygnał na czujniku przez przyłożenie do jego czoła koła zębatego zamocowanego na wirniku dodatkowego silnika elektrycznego. Jednak zastosowane koło zębate z silnika 1,8T 20v powodowało, że nie była to praca ciągła, układ działał okresowo. Po wymianie koła zębatego na koło pasowe z silnika 1,1 dm^3 pochodzącego z silnika FIAT FIRE, które posiada taką samą liczbę zębów jak koło zamachowe z silnika samochodu Peugeot oraz wycięte dwa zęby, wtryskiwacze oraz cewka zaczęły pracować cały czas, do momentu odsunięcia czujnika od koła. Kolejnym krokiem było przygotowanie i skompletowanie elementów układu Motronic MP3.1 oraz zapoznanie się ze stanem połączeń instalacji elektrycznej i połączeniami. Elementy wykorzystywane do budowy stanowiska pochodziły z samochodu eksploatowanego przez dłuższy czas, więc nie wszystkie zespoły pracowały prawidłowo. W wiązce elektrycznej stwierdzono kilka braków, które zostały sprawdzone i uzupełnione. Ponadto do wiązki była podłączona deska rozdzielcza samochodu z licznikiem, stacyjką oraz skrzynką bezpieczników. Kilka prób uruchomienia układu wymontowanego z samochodu ze stacyjką i deską rozdzielczą nie przyniosło rezultatów. Należało ponownie dokładne prześledzić budowę sterownika Motronic MP3.1 oraz przeanalizować schemat przyłaczeńposzczególnych pinów. Wykorzystano tu specjalny schemat przedstawiający przyłącza sterownika. Po analizie stwierdzono, że jest wymagane podłączenia do sterownika dodatkowego zasilania (przyłącze plus) w miejsce określone na schemacie jako zasilanie. Dzięki wprowadzeniu dodatkowego zasilania do sterownika stacyjka oraz deska rozdzielcza nie była wymagana, a układ działał prawidłowo bez tych elementów.
Problemy z prawidłowym podłączeniem zasilania do sterownika skłoniły autora do stwierdzenia, że należy je podać wyłącznie na przekaźnik podwójny, a ten został zwarty na stałe. Układ działał prawidłowo, tzn. słychać było charakterystyczne efekty akustyczne pracy cewki i wtryskiwaczy. Wyeliminowanie stacyjki deski oraz innych elementów przyczyniło się do znaczącego uproszczenia instalacji elektrycznej stanowiska. Stwierdzenie czy proponowany układ pracuje prawidłowo nie jest możliwe bez wykonania specjalistycznych pomiarów. Dlatego po skompletowaniu elementów i zabudowie na stole pomiarowym podłączono układ do akumulatorowego zasilania. Do pomiaru sygnałów sterujących wykorzystano cyfrowy oscyloskop Tektonix TDS 3014 wraz z komputerem rejestrującym (rysunek 1). Do przesyłania danych z oscyloskopu ich rejestracji wykorzystano specjalistyczne oprogramowanie WaveStar firmy Tektonix.



Rysunek 1. Schemat blokowy stanowiska badawczego

4. Plan badań

Na plan badań składało się kilkunastu przypadków pomiarowych, z których po analizie wybrano 8 najlepiej obrazujących przebiegi napięciowe sygnałów sterujących układem Motronic (tabela 1).

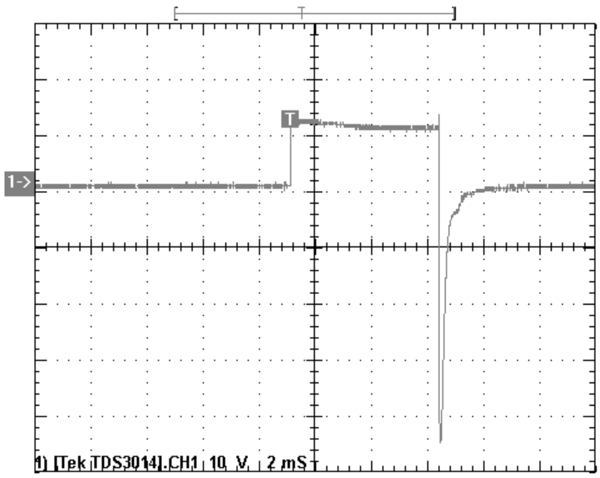
Tabela 1. Przypadki pomiarowe i nastawy oscyloskopu

Numer przypadku	Badany element	Nastawy oscyloskopu
1	Wtryskiwacze	Napięcie 10 V, rozdzielczość 2 ms
2	Cewka (duża prędkość obrotowa)	Kanał 2 i 3: Napięcie 10 V, rozdzielczość 20ms
3	Cewka (mała prędkość obrotowa)	Kanał 2 i 3: Napięcie 10 V, rozdzielczość 20 ms
4	Prędkość obrotowa	Napięcie 1 V, rozdzielczość 20 ms
5	Prędkość obrotowa	Napięcie 2 V, rozdzielczość 10 ms
6	Przepustnica	Napięcie 2 V, rozdzielczość 2 ms
7	Cewka	Kanał 2 i 3: Napięcie 1 V, rozdzielczość 10 ms
8	Prędkość obrotowa i wtryskiwacze	Kanał 2: Napięcie 2 V, rozdzielczość 20 ms, Kanał 3: Napięcie 10 V, rozdzielczość 20 ms

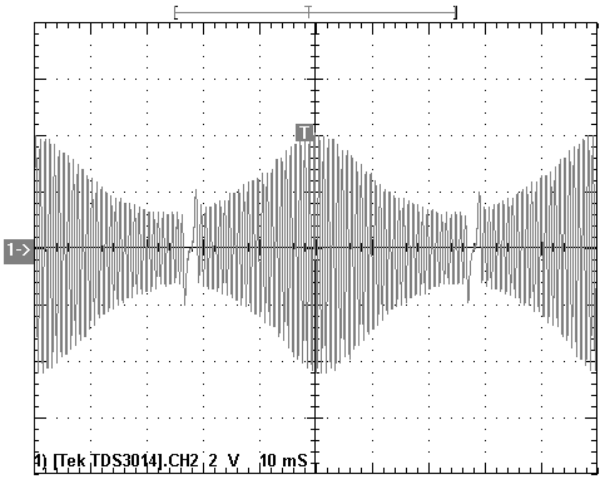
5. Wyniki badań

Przeprowadzone próby były pierwszymi pomiarami przeprowadzanymi z wykorzystaniem projektowanego układu. W toku analiz stwierdzono, że w celu uniknięcia pomyłek należy sondy oscyloskopu podłączać do przyłączy sterownika. Tego typu pomiary są stosunkowo trudne ze względu na możliwość niewłaściwego podłączenia przyrządów pomiarowych do instalacji, co może spowodować uszkodzenie drogiego sprzętu pomiarowego. Wynikami badań były sygnały napięciowe zobrazowane na ekranie oscyloskopu, które zostały specjalnie przygotowane w celu dalszej analizy w programie MS Excel. Niektóre z nich przedstawiono na rys. 2÷5.

Rys. 2 przedstawia sygnał sterujący wtryskiwaczami dla silnika pracującego bez obciążenia, przy zamkniętej przepustnicy oraz nieznacznej prędkości obrotowej.

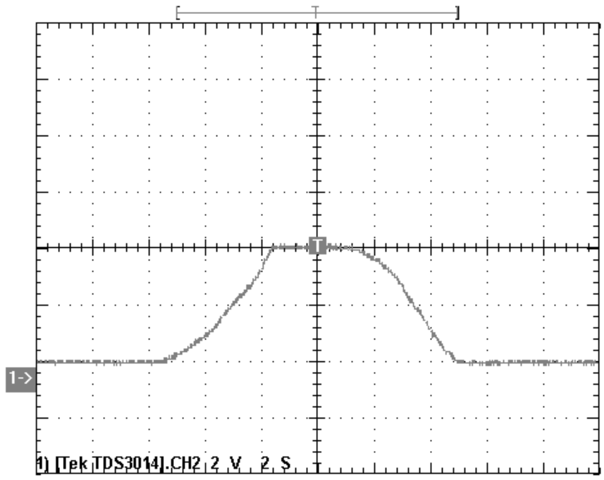


Rysunek 2. Przebieg sygnału sterującego wtryskiwaczem

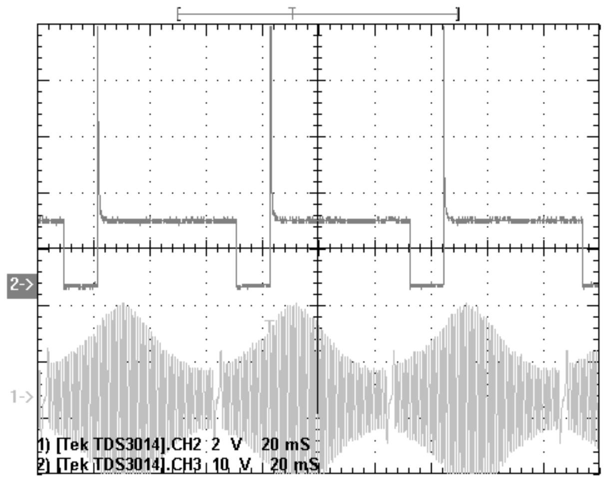


Rysunek 3. Przebieg sygnału z czujnika prędkości obrotowej

Ze względu na synchroniczne działanie wtryskiwaczy nie było konieczności podpinania każdego z nich z osobna. Symulowano również zmianę obciążenia silnika przez oddziaływanie na czujnik ciśnienia bezwzględnego MAP Sensor (za pomocą pompy podciśnienia), który jest zabudowany w sterowniku. Następowała wyraźna zmiana czasu trwania impulsu – zwiększone podciśnienie powodowało zmniejszenie czasu sterowania wtryskiwaczem.
Rys. 3 przestawia typowy sygnał z reluktancyjnego czujnika prędkości obrotowej. Jak można zauważyć, współpracuje on z kołem, które umożliwia określenie charakterystycznego położenia wału korbowego (brak części zębów). Widać istotne, chwilowe zmiany prędkości obrotowej.



Rysunek 4. Przebieg sygnału z czujnika położenia przepustnicy



Rysunek 5. Wzajemne relacje sygnału sterującego wtryskiwaczami i czujnika prędkości obrotowej silnika

Rys. 4 przedstawia typowy przykład wolnozmiennego przebiegu, zarejestrowany na przykładzie czujnika położenia przepustnicy. Ujmuje pełny zakres zmian położenia tego elementu układu sterowania.
Z kolei na rys. 5 zawarto przykład synchronicznych przebiegów wtryskiwaczy i położenia wału korbowego. Mogą stanowić podstawę do oceny parametrów pracy układu zapłonowego.

6. Podsumowanie

Dzięki badaniom przeprowadzonym na wstępnie zmontowanym stanowisku badawczym oraz analizie wyników pomiarów można sformułować następujące wnioski i uwagi końcowe.
Stanowiska badawcze umożliwiają pomiar parametrów układów sterowania oraz analizy sygnałów sterujących, co przyczynia się do ich udoskonalania.
Zrealizowane w ramach pracy podłączenie wiązki elektrycznej i sterownika do stanowiska pomiarowego pozwoliło na stwierdzenie, że jest możliwa budowa pełnego stanowiska badawczego układów sterowania, a generowane sygnały mają prawidłowy przebieg i można je odczytywać i zapisywać.
Największą trudność stanowiło przystosowanie układu elektrycznego do pracy autonomicznej. W badaniach nie wykorzystano całej wiązki elektrycznej, gdyż nie każda jej część ma wpływ na sygnały sterujące pracą silnika. Dążono przy tym do możliwie największego uproszczenia układu.
Do poprawnego działania całego stanowiska konieczne jest przede wszystkim zapewnienie prawidłowych warunków pracy czujnika prędkości obrotowej, na przykład przez wykorzystanie odpowiedniego stołu z silnikiem elektrycznym umożliwiającym płynną zmianę prędkości obrotowej.
Niezwykle istotne są źródłowe informacje i schematy układu zamontowanego w pojeździe. Stanowią one podstawę wszelkich czynności projektowych. Właściwy dobór koła impulsowego, odłączanie stacyjki, czy wykonanie zastępczego zasilania sterownika nie byłoby możliwe bez oryginalnej dokumentacji instalacji elektrycznej.
Wykonane wstępne pomiary i szczegółowa analiza wszystkich przypadków pomiarowych potwierdziły prawidłowość przyjętych rozwiązań i możliwości stanowiska. Możliwa jest więc budowa autonomicznego stanowiska umożliwiającego pomiar sygnałów sterujących pracą całego układu Motronic 3.1.
Uwagi szczegółowe:
Analizując zarejestrowane przebiegi sygnałów sterujących wtryskiwaczami można stwierdzić, że wartość napięcia na wtryskiwaczach się nie zmienia. Podczas wtrysku napięcie rośnie do ok 10 V, następnie zmniejsza się do wartości ok. 2 V. Stwierdzono, że podczas symulacji zmiany obciążenia silnika zmianie ulega sygnał sterujący wtryskiwacza.
Pomiar napięcia na cewkach zapłonowych przy wysokiej i niskiej prędkości obrotowej (przypadki trzeci i czwarty) wykazał, pomiary należy wykonywać z największą starannością, właściwie dobierając miejsca pomiaru. Stwierdzono, że czasy trwania ładowania cewek zapłonowych są prawidłowe.
Przypadki nr 4, 5 i 8 to pomiary sygnału sterującego z czujnika prędkości obrotowej mierzonego bezpośrednio ze sterownika. Dokładnie obrazują wartości napięcia

z czujnika i przyjmują prawidłowe wartości. Można także wskazać fragment przebiegu stanowiący odniesienie, względem którego wyznaczany jest GMP.
Pomiar szósty, czyli pomiar napięcia z potencjometru przepustnicy pozwala określić wartości przy pełnym zamknięciu (ok. 0,5 V) oraz przy pełnym otwarciu przepustnicy. Tu wynosi ono ok. 5 V. Pomiar ten jest prawidłowy i zgodny z danymi serwisowymi.
Kolejne pomiary wartości napięcia na cewkach zapłonowych zostały wykonane bezpośrednio na sterowniku. Można zaobserwować naprzemienną pracę cewek zapłonowych. Napięcie na cewkach gdy nie pracują jest równe zeru, a podczas zapłonu dochodzi do ok 2,5 V. Czas trwania impulsu wynosi ok 3 ms, co jest również zgodne z danymi serwisowymi.
Ostatnia próba to wspólny pomiar napięcia z czujnika prędkości obrotowej oraz napięcia na wtryskiwaczach. Sondy oscyloskopu podłączono bezpośrednio do sterownika. Na wykresie widać dokładnie, że na jeden obrót wału korbowego przypada jeden wtrysk paliwa.
Podsumowując przeprowadzone prace oraz badania można stwierdzić, że istnieje możliwość budowy stanowiska dydaktycznego do pomiarów sygnałów biorących udział w działaniu systemu Motronic MP3.1. Najistotniejszą rzeczą w tych badaniach jest odpowiednie podłączenie przyrządów pomiarowych oraz odpowiednia aparatura. Bardzo ważnym elementem jest również sterownik oraz wiązka elektryczna, które powinny być kompletne oraz w pełni sprawne. Przed przystąpieniem do pomiarów należy dokładnie sprawdzić połączenia przewodów oraz sprawdzić stan elementów wchodzących w jego skład. Budowa takiego stanowiska jest możliwa, jednak jest pracochłonna i wymaga pewnego doświadczenia.

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PODNIESIENIE NIEZAWODNOŚCI REDUKTORÓW PLANETARNYCH

Streszczenie: W artykule rozważa się koncepcję elementów redundantnych w mechanizmach. Wskazuje się na ich wpływ na działanie przekładni planetarnych. Ponadto, przeprowadzono obliczenia różnych przekładni planetarnych oraz mechanizmów z uwzględnieniem elementów redundantnych..

Słowa kluczowe: przekładnia planetarna, niezawodność, elementy redundantne

INCREASING OF RELIABILITY OF PLANETARY REDUCERS

Summary: The article discusses the concept of redundant links in the mechanisms shown their influence on the operation of the planetary gear. There were also counted various planetary gears and mechanisms on redundant links.

Keywords: planetary gear, reliability, redundant communication

1. Introduction

At present the task of improvement of quality and reliability of drives which more are responsible for operation of drives is particularly acute for mechanical engineering.
Many researchers specify rationality of application in drives of machines of planetary reducers. Planetary transmissions are transmissions having cogwheels with the moving geometrical axes which are applied in agricultural machinery, etc. mechanisms. Modern managing on the ground almost in all spheres of an agricultural industry does not do without use of agricultural machinery. Its satellites are rolled on the central wheels having external or internal gearing. Axes of satellites are fixed in planet carrier and rotate together with it around the central axis. [1]
Planetary transmissions have wide areas appointment and applications:

1. Reduction of speed - power transmission with small size and weight, the kinematic transmission with large transmission ratios.

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2. Addition and decomposition of movement, including automatic speed control in machines, vehicles and especially tracked vehicles, multi-stage planetary gearbox, driven alternately braking of units, closed planetary gear with integrated stepless transmission, etc.

Benefits of planetary transmissions will be explained by the following regularities:

a) the distribution of load between the satellites, so the load on the teeth is less in several times;
b) a large transmission ratio in one stage, which often allows not to use complex multi-stage transmission;
c) the wide use of the gear with internal gearing has increased bearing capacity.

The above factors allow to obtain the minimum weight and small dimensions.

In addition, planetary gears operate with less noise than simple which is associated with increased smoothness of internal gearing, smaller wheels, locking of forces in the mechanism and the transmission of smaller forces on the body. If we compare the planetary transmission with transmission with fixed axles, planetary transmissions demand the increased production accuracy, have, as a rule, the larger the number of parts and a complex assembly. Designs of planetary ranks are rather various. They consist of a small central wheel (sun) which is in fixed gearing with the gear wheels called by satellites. Satellites can rotate concerning the axes established in planet carrier. The cogwheel of internal gearing called by a big central wheel (an epicycle, a crown) is in fixed gearing with satellites and surrounds all design. It should be noted that the small central wheel, carrier and a big central wheel rotate concerning one general axis while satellites of planetary transmission rotate rather own axes and together with planet carrier rather general axis. At the same time the satellites of the planetary gear are an integral part of the carrier.

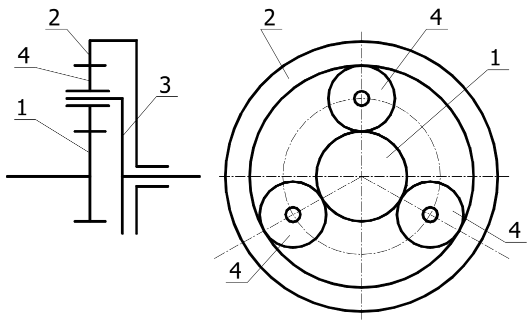

Figure 1. Kinematic scheme of the planetary transmission: 1 - small center wheel; 2 – the epicycle, the crown gear; 3 - carrier; 4 – satellites

The name of this mechanism comes from satellites which it is similar to planets, rotate concerning the axes and at the same time around a small central wheel (sun). The main parameter determining the properties of the planetary gear is the internal gear ratio. In general, any planetary gear set is characterized by six internal ratios. However, in practice, only one is usually used, a defined as the relation of rotating speed of a small the big central wheel, central to rotating speed, in case of the stopped carrier:

$$i_{1\,2} = \left.\frac{\omega_1}{\omega_2}\right|_{\omega_3=0} \tag{1}$$

Where: 1 - the index of the small central wheel; 2 - the index of the large central wheels; 3 - the index of the carrier.
How the central wheels at stopped rotate carrier, the internal transmission relation of a planetary row can be either positive, or negative. All gear is depending on the sign of internal transmission ratios are defined at stopped carrier, are classified on two classes:

1. The planetary series with positive internal gear ratio.
2. The planetary series with negative internal gear ratio.

2. The statement of the research problem

The solution to the problem of improving the reliability and durability of agricultural vehicles at first is to improve the reliability and durability of the limiting nodes, which include the planetary rotation mechanism (PRM).

3. Ways of realization

A significant increase of quality indicators of the planetary gear is achieved by eliminating redundant links. It is important to choose the scheme of the mechanism so that the requirements for accuracy of links were small. This satisfies the mechanisms, statically determinate, i.e. without a redundant (passive) links, links which are established themselves. [2]
Redundant (passive) links are those connections, the removal of which does not increase the mobility of the mechanism.
However, the sizes of links can change during operation owing to sag of the base, wear and adjustment of a gap of kinematic couples, elastic deformations, (for example, deflections of shaft), expansions from heating, and also mistakes at repair and assembly (for example if have mixed inserts of bearings). Change of the sizes of links doesn't influence statically definable mechanism. Therefore, statically determinate mechanisms not only reduce the labor intensity, but also increase the reliability. [3]
Redundant links in the mechanism are harmful, as they increase the complexity of manufacturing and operating mechanisms and reduce their reliability.
Check the mechanism for redundant links by counting them according to the formula of Malyshev A. P.:

$$q = w - 6n + \sum_{i=1}^{i=5} ip_i \tag{2}$$

From here or in expanded form:

$$q = w - 6n + 5p_V + 4p_{IV} + 3p_{III} + 2p_{II} + p_I \tag{3}$$

Where: q – the number of excess relations; n – number of mobile links; w – the mobility of the mechanism; pi – the number of kinematic pairs of the i-th class that imposes i*pi conditions.

Check for redundant links differential rotation mechanism of the tractor, the formula is shown in Fig.2, left drawing, right structural scheme:

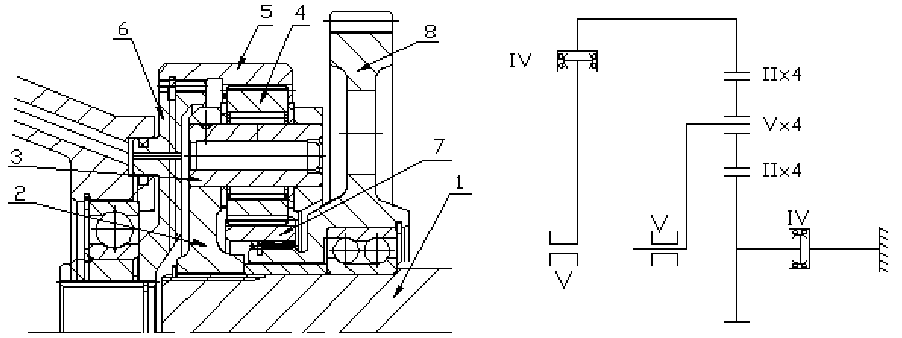

Figure 2. The rotation mechanism (DRM) of tractor

Planetary rotation mechanism (PRM) 6C315 works by rectilinear motion in the following manner with the rear axle shaft (1), is transmitted to the carrier (2), in which the axles (3) are four of the satellite (4). Satellites (4) run in the sun gear (7), mounted on a gear (8), are stopped by the hydraulic motor and transmit torque to the crown gear (5), mounted on the drum (6) which transmits torque to the final transmission. In this mechanism is the floating sun and ring gear, having a splined connection (cardan on the block diagram):

$$q=1-6\cdot8+(5\cdot6+4\cdot2+2\cdot2\cdot4)=1-48+54=7 \quad (4)$$

For comparative analysis to test for redundant links conventional planetary rotation mechanism[1,2] is used for DT-75 Kazakhstan (PRM DT-75) with 3 and 4 satellites of formula 4 and the mechanism of Shatkus [1,2] with 3 and 4 satellites (Fig. 3 right), formula:

$$q=1-6\cdot5+(5\cdot5+2\cdot2\cdot3)=1-30+37=8 \quad (5)$$

$$q=1-6\cdot6+(5\cdot6+2\cdot2\cdot4)=1-36+46=11 \quad (6)$$

$$q=1-6\cdot6+(5\cdot2+4\cdot1+3\cdot3+2\cdot2\cdot3)=1-36+35=0 \quad (7)$$

$$q=1-6\cdot7+(5\cdot2+4\cdot1+3\cdot4+2\cdot2\cdot4)=1-42+42=1 \quad (8)$$

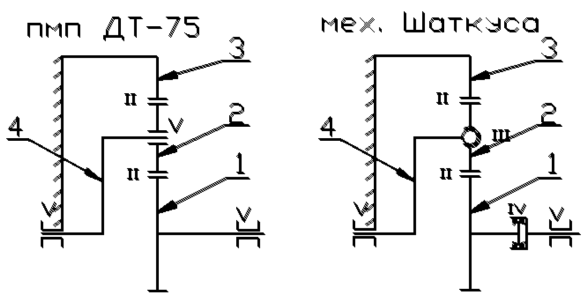

Figure 3. PRM DT-75 and the modified mechanism of Satkus: 1-sun gear, 2-satellite, 3 - ring gear, 4 - carrier.

Consider a PRM in which the carrier is made in the form of a bracelet. Check on the excess when the formula (6):

$$q=(1+1+3)-6\cdot 11+(5\cdot 5+4\cdot (3+3)+2\cdot 2\cdot 3)=5-66+61=0 \quad (9)$$

$$q=(1+1+4)-6\cdot 14+(5\cdot 5+4\cdot (4+4)+2\cdot 2\cdot 4)=6-84+78=0 \quad (10)$$

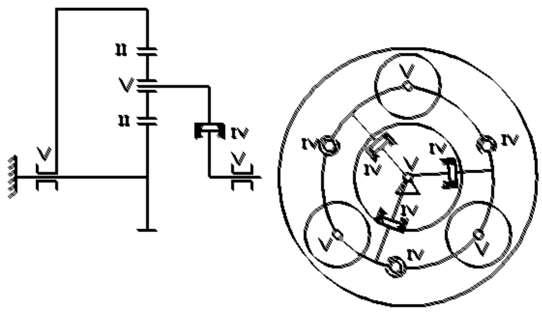

Figure 4. PRM in which the carrier is made in the form of a bracelet

Apparently PRM DT-75 has the large number of redundant links, 11 at 4 satellites, DRM 6C315 has 4 less, that is 7, due to execution of a crown and solar gear wheel floating. The modified mechanism of Shatkus has no redundant links at 3 satellites and one redundant links at 4 satellites that is reached due to execution of a solar gear wheel mobile and installation of satellites on spherical bearings. PRM in which drove is executed in the form of a bracelet has no redundant links at the 3rd and 4th satellites.

4. Conclusion

For reduction of the number of redundant links in the Chetra 6C315 mechanism, and reducing their impact on the mechanism, it is recommended to use a technical solution of Shatkus or PRM «bracelet», however it is not possible because the dimensions of the satellites are small for installation of the spherical bearing. Besides, this planetary transmission has no potential of self-installation of a carrier with satellites under the influence of the radial and tangential forces arising in gearings of satellites with the central wheels that reduces its reliability and durability.

5. Inference

The using of the PRM "bracelet" on the tractor will relieve the mechanism from redundant links, which will increase the resource, durability and save it from unwanted breakdowns during exploitation.

Summing up, the least amount of redundant links were received in the mechanism of Shatkus, even despite of their flaws it is good technical solution that help to improve the reliability and service life of the planetary units of machines.

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PROJEKT I BADANIE AUTONOMICZNEGO SYSTEMU STEROWANIA DO MODELU POJAZDU

Streszczenie: Artykuł został napisany na podstawie własnych prac dyplomowych. Zawiera krótki opis elementów jakie wchodzą w skład układu do autonomicznego sterowania modelem, sposób działania algorytmu sterującego oraz uzyskane wyniki z przeprowadzonych badań.

Słowa kluczowe: autonomiczny, algorytm sterujący

PROJECT AND ANALYSIS AUTOMATIC SYSTEM CONTROL FOR MODEL VEHICLE

Summary: This article was written based on author's own dissertation. It contains a brief describtion of elements that are part of the autonomic control model behavior, a describtion of working method of behavior control algorithm and the results of the study.

Keywords: autonomic, control algorithm

1. Wstęp

W dzisiejszych czasach, w których technologia cyfrowa oraz motoryzacyjna rozwija się w zawrotnym tempie, coraz częściej mówimy o pojazdach autonomicznych. Pojazdem takim można nazwać samochód, który ma zdolność do poruszania się po drodze bez konieczności działań występujących ze strony kierowcy. Oznacza to, że algorytm sterujący, sam kieruje pojazdem po zadanej trasie. Dzięki wykorzystaniu zaawansowanej technologii zawartej we współczesnej elektronice, marzenia o tego typu pojazdach stały się realne.

Innym aspektem dotyczącym sterowania pojazdów są badania stateczności ruchu dużych rozmiarów pojazdów o wysoko położonych środkach ciężkości, dla których stosuje się

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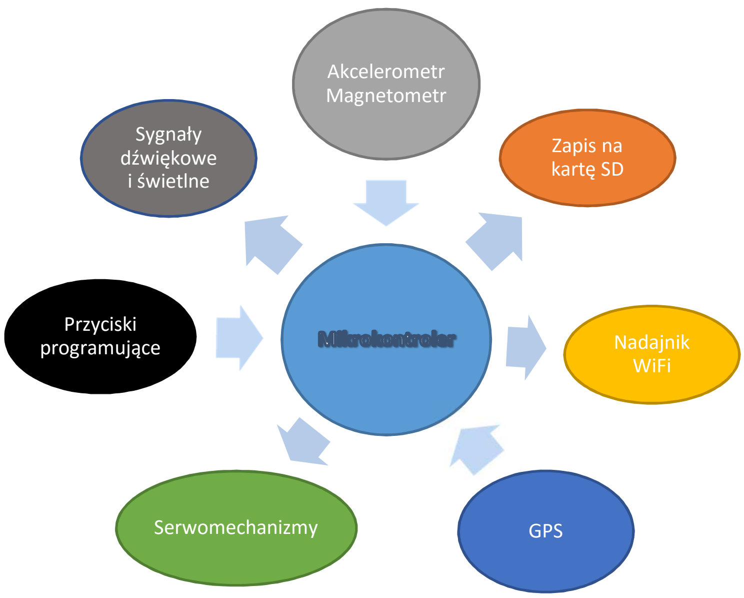
testy badawcze ujęte normami ISO. Realizacja tych testów niesie ze sobą pewne zagrożenia dla badaczy, gdyż samochody tego typu przy dużych przyśpieszeniach bocznych mają tendencję do przewracania się. Spowodowane jest to powstawaniem dużej siły bocznej. W samochodach osobowych problem ten nie występuje, gdyż przy spotykanych wysokościach położenia środka ciężkości i współczynniku przyczepności poniżej jedności samochody te ulegają poślizgowi bocznemu.

W Katedrze Silników Spalinowych i Pojazdów Akademii Techniczno-Humanistycznej w Bielsku-Białej powstał projekt zastosowania do testów stateczności mobilnego modelu pojazdu wykonanego z zachowaniem podobieństwa w stosunku do pojazdu rzeczywistego. Wymaga się, aby model prócz zachowania odpowiedniej konstrukcji (spełnienie warunków podobieństwa) realizował tor ruchu przewidziany normami.

2. Zestawienie elementów do budowy układu sterującego

Do budowy układu sterującego zostały wykorzystane poniższe moduły. Zostały one dobrane na podstawie zdobytego doświadczenia w zakresie programowania mikrokontrolerów firmy „Arduino”.

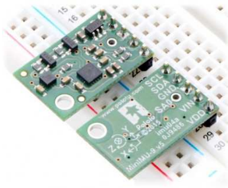


Rysunek 1. Schemat relacji pomiędzy mikrokontrolerem a podłączonymi do niego modułami

Rysunek nr 1 przedstawia uproszczony schemat połączenia oraz relacji pomiędzy dobranymi elementami, a jednostką sterującą „Arduino”. Ponadto układ sterujący został wyposażony w panel do programowania pojazdu, składający się z przycisków monostabilnych. Podczas programowania użytkownik informowany jest o stanach pracy programu poprzez sygnały dźwiękowe oraz świetlne.

2.1. MinIMU-9 v5 - akcelerometr, żyroskop i magnetometr IMU 9DOF I2C

Moduł pozwalający na pomiar przyśpieszenia, pola magnetycznego oraz prędkości kątowej w trzech kierunkach. Umożliwia określenie kierunku względem północy.



Rysunek 2.. MinIMU-9 v5 [1]

2.2. Moduł GPS NEO-6M uBlox UART z anteną

Moduł GPS umożliwiający lokalizację modelu, wyznaczenie przebytej trasy, autonomiczne sterowanie.

Rysunek 3. Moduł GPS NEO-6M uBlox [2]

2.3. Moduł WiFi ESP-01 ESP8266

Moduł pozwalający na bezprzewodową komunikację pomiędzy układem sterującym zainstalowanym w modelu, a komputerem lub telefonem.

Rysunek 4. Moduł WiFi ESP-01 [3]

2.4. Buzzer z generatorem

Brzęczyk informujący o wciskanych przyciskach, stanach pracy sterownika oraz odliczaniu czasu do wystartowania modelu.

Rysunek 5. Brzęczyk wysokotonowy [4]

2.5. Konwerter USB-UART FTDI FT232

Konwerter umożliwiający komunikację pomiędzy portem USB, a magistralą UART. Wykorzystywany do programowania modułu WiFi oraz przeprogramowania parametrów modułu GPS.

Rysunek 6. Konwerter USB-UART [5]

2.6. Arduino Due ARM Cortex

Domyślnie wykorzystany jako główny moduł sterujący, który umożliwia odczyt parametrów z wyżej wymienionych modułów. Na podstawie uzyskanych wyników i wgranego programu do pamięci wewnętrznej wydaje sygnały sterujące na serwonapędy sterujące modelem.

Rysunek 7. Arduino Due [6]

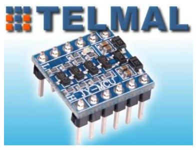
2.7. Przetwornica step-down LM2596 3,2V-35V 3A

Przetwornica impulsowa „step-down" umożliwiająca konwersję napięcia z wyższego na niższe, wykorzystywana do zasilania modułów z akumulatorów zainstalowanych na modelu.

Rysunek 8. Przetwornica step-down [7]

2.8. Konwerter poziomów logicznych 3.3 V – 5 V

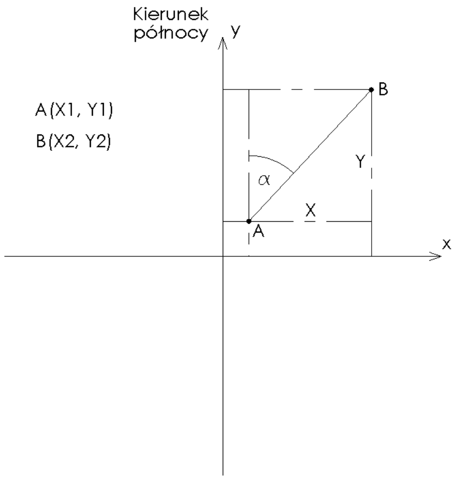
Moduł umożliwiający konwersję napięć sygnałów sterujących z 3.3V na 5V i odwrotnie. Pozwala na podłączenie modułów do jednostki sterującej na prawidłowym poziomie napięcia dla obu stron.



Rysunek 9. Konwerter poziomów logicznych [8]

3. Opis programu sterującego

W pierwszej kolejności program sterujący na podstawie uzyskiwanych wartości z magnetometru i akcelerometru oblicza kąt względem północy, który w programie został nazwany kątem „beta". Prawidłowe przeprowadzenie kalibracji magnetometru jest bardzo istotnym czynnikiem do prawidłowego działania systemu, ponieważ to od niej zależy poprawność wskazywania kierunku północy. Kolejnym krokiem jest obliczenie kąta pomiędzy prostą, która reprezentuje kierunek północy, a odcinkiem jaki zostaje utworzony z punktu, w którym model obecnie się znajduje i punktu, do którego ma podążać. Kąt ten nazwany został jako kąt „alfa".



Rysunek 10. Rysunek przedstawiający sposób obliczenia kąta „alfa"

Punkt „A" reprezentuje obecne położenie modelu, zaś punkt „B" miejsce, do którego model ma podążać. Oba punkty posiadają współrzędne geograficzne. Aby wyliczyć kąt „alfa", należy obliczyć długości odcinków X i Y. Poniżej zostały przedstawione zależności.

$$X = X_2 - X_1$$
$$Y = Y_2 - Y_1$$

Na podstawie obliczonych długości odcinków X i Y można wyliczyć kąt „alfa" stosując odpowiednią funkcję trygonometryczną. Została ona zapisana poniżej w języku zrozumiałym dla układu „Arduino".

$$alfa = atan2(X, Y) \cdot \frac{180}{PI}$$

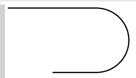
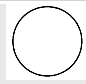
Końcowym etapem obliczeń jest wyznaczenie kąta „gama", który reprezentuje kąt skręcenia kół kierowanych. Wyliczany jest on na podstawie dwóch poprzednich kątów - „alfa" oraz „beta".

Rysunek 11. Zainstalowany układ sterujący na modelu

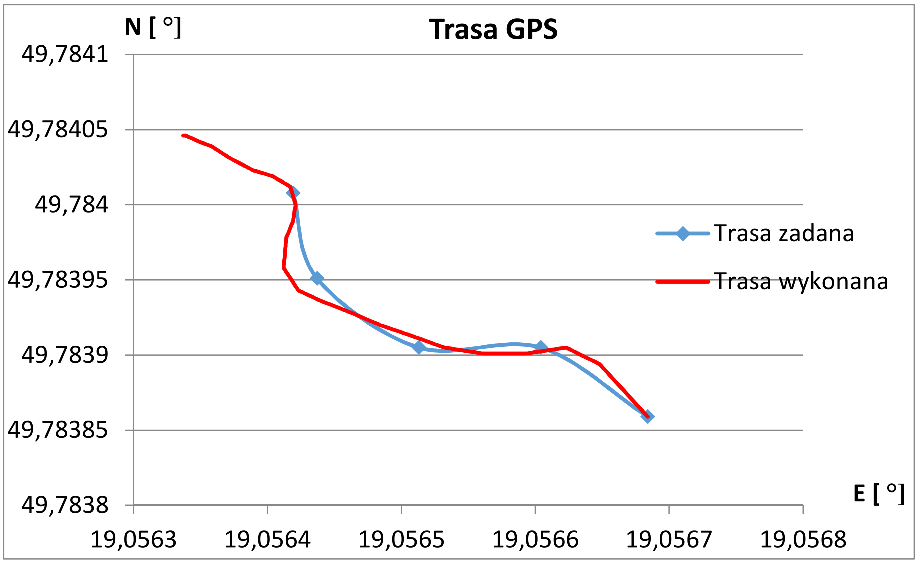
4. Badania funkcyjne autonomicznego układu sterowania

Po skompletowaniu, połączeniu oraz zaprogramowaniu prezentowanego autonomicznego układu sterowania zostały przeprowadzone badania mające na celu sprawdzenia jego skuteczności i prawidłowości działania. Badania polegały na wytyczeniu punktów na mapie ,przy użyciu modułu GPS, wyznaczających trasę którą powinien przebyć model oraz zapisaniu otrzymanych wyników na kartę pamięci SD. Użyte tory ruchu zostały przedstawione w Tabeli 1.

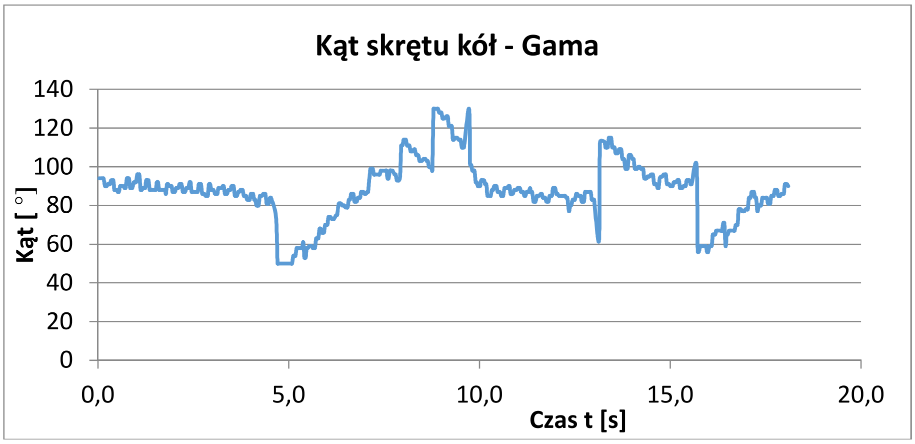
Tabela 1. Zastosowane testy w badaniach skuteczności autonomicznego systemu sterowania modelu pojazdu specjalnego

Nazwa testu	Tor ruchu pojazdu
Prosta trasa	
Ominięcie przeszkody	
Trasa J-Turn	
Jazda po okręgu	

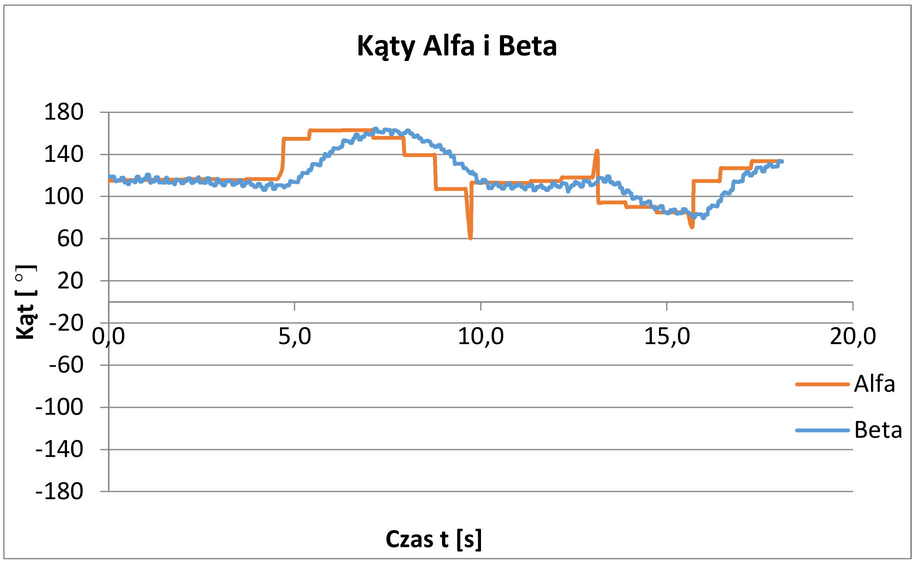
Poniżej zostały przedstawione przykładowe wyniki otrzymane podczas przeprowadzonych badań.



Rysunek 13. Zestawienie trasy zadanej i wykonanej przez model pojazdu



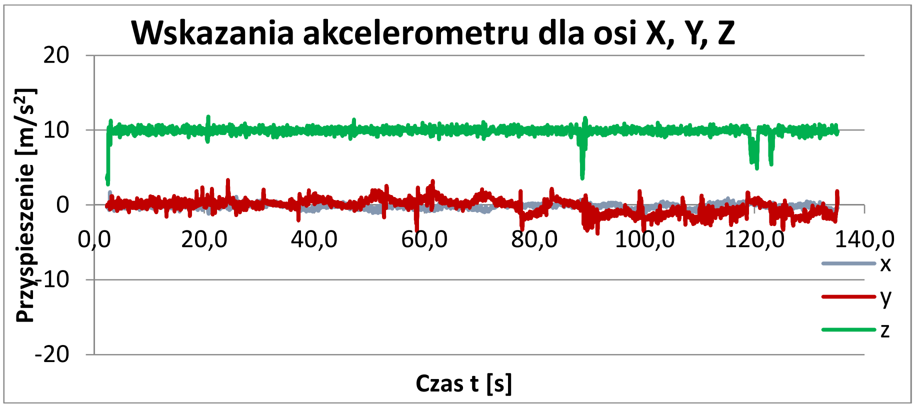
Rysunek 14. Wyznaczony kąt skrętu kół



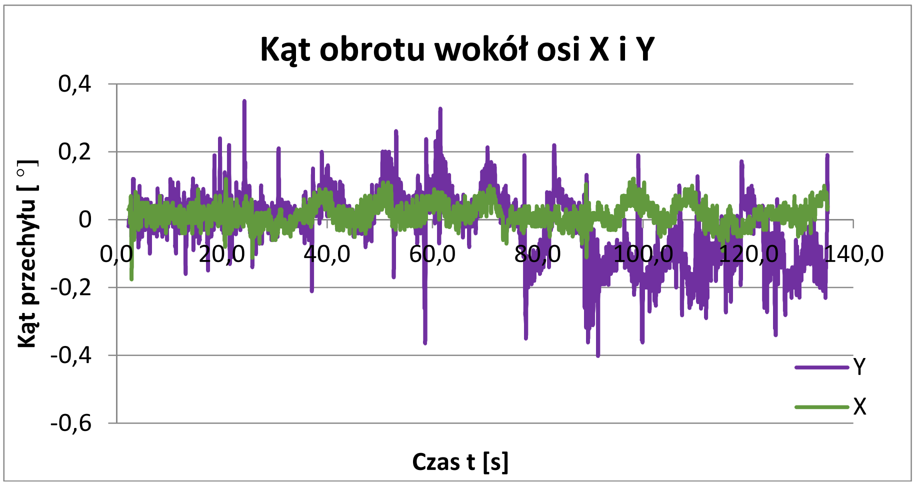
Rysunek 15. Kąty α i β dla realizowanej próby

Rysunek 14 przedstawia wartości kątów zadawanych przez sterownik na serwomechanizm odpowiedzialny za skręt kół pojazdu, wartości 50, 90 i 130 oznaczają kolejno maksymalny skręt w prawo, koła w pozycji do jazdy na wprost oraz maksymalny skręt w lewo. Zmiany wartości kąta „gama" są wynikiem obliczeń różnic pomiędzy kątami „alfa" i „beta" przedstawionymi na wykresie nr 3.

Podczas każdego przejazdu sterownik zapisywał na karcie pamięci nie tylko otrzymane wyniki z moduły GPS i kompasu elektronicznego ale również wartości przyspieszeń rejestrowanych przez akcelerometr oraz przechyły wzdłużne i boczne poruszającego się modelu. Wyniki tych pomiarów zostały przedstawione na wykresach numer 4 i 5. Z powodu małej prędkości pojazdu, z przyczyn bezpieczeństwa i ograniczonej przestrzeni, zarejestrowano niewielkie zmiany przyspieszeń i kątów obrotu.



Rysunek 16. Zmierzone przyśpieszenie wzdłuż osi X, Y i Z



Rysunek 17. Zarejestrowane kąty przechyłu dla realizowanej próby

5. Podsumowanie

Głównym założeniem projektu było skonstruowanie układu sterującego pozwalającego na autonomiczne prowadzenie określonych pojazdów mechanicznych. Pojazdy tego typu mają za zadanie przemieszczanie się po wyznaczonej trasie, bez osoby odpowiedzialnej za jej manualne kierowanie. Urządzenia o takiej specyfikacji mogą zostać wykorzystane w takich dziedzinach jak: transport lądowy, powietrzny i wodny. Transport ten może służyć do przewozu osób, a także ładunków.

Wszystkie przeprowadzone testy dowiodły skuteczności powiązanych elementów. Model pojazdu specjalnego po zaprogramowaniu wyznaczonej trasy pokonał punkty docelowe.

Niestety nie udało się osiągnąć dużej dokładności przemierzanej trasy. Spowodowane jest to błędem pomiarowym występującym w module GPS oraz zbyt wolnym odświeżaniem bieżącej lokalizacji, która wynosi w przybliżeniu 200ms. Kolejną przeszkodą jest działanie silnika spalinowego, który generuje zbyt duże drgania mechaniczne, prowadzące do zakłóceń akcelerometru. Jeszcze inną przyczyną jest zainstalowany serwonapęd o niedostatecznym momencie obrotowym, który odpowiedzialny jest za skręt kół kierowanych modelu. Pomimo zadania skrętu kół, serwonapęd nie jest w stanie w pełni zrealizować ich przemieszczenia podczas postoju lub wolnej jazdy.

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Supervisor: Hanna TOVCANETS[2], Vitaliy GERASIMOV[3]

PERSPEKTYWY ROZSZERZENIA ZASTOSOWAŃ URZĄDZEŃ LASEROWYCH W PRODUKCJI ODZIEŻY

Streszczenie: Niniejsza praca dotyczy możliwości rozszerzenia zastosowań technologii laserowych w produkcji odzieży. W szczególności opisano perspektywy zastosowania urządzeń technicznych, w których używa się wiązki promieni laserowych do optycznej identyfikacji konturów ubrań na powierzchni stołu uniwersalnej maszyny do szycia (stosujące ścieg łańcuszkowy). Celem użycia lasera jest rozszerzenia ich funkcjonalności oraz redukcja zakresu pracy ręcznej w rozplanowaniu położenia małych detali.

Słowa kluczowe: produkcja odzieży, uniwersalna maszyna do szycia, ścieg łańcuszkowy (stębnówka), urządzenie laserowe

THE PERSPECTIVES OF EXTENDING THE APPLICATION OF LASER EQUIPMENT IN CLOTHING PRODUCTION

Summary: the article deals with the possibilities of expanding the use of laser technology in clothing production. Specifically it substatiated the perspectives of using technical devices with laser beams for optical identification of contours of details of garments on the surface of the industrial table of universal sewing machine of lockstitch with the aim to expand its functionality and reducing the share of manual work on plaining location of small details.

Keywords: clothing production, universal sewing machine of lockstitch, laser machinery

1. Introduction

The priority tasks of any industrial production, including sewing, can include reducing the complexity of manufacturing production, energy and technology optimization. One of the most effective ways of solving thementioned problems is the maximum mechanization and automation of the production process.

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However, implementation of common concept of integrated mechanization and automation of the production process, which requires standardization and unification of the installalion production, is in conflict with the realities of modern clothing production. It is characterized by following features: reducing of ordering quantity magnitude in the wide-scale sizes; the need for constant change models produced; using a wide range of materials with different technical characteristics for a certain type of clothing; diversity of the technologies.Under such circumstances it is not economically to complete the equipment park of clothing company with expensive semiautomatic, which will be not used at full capacity because of its limited functionality. More rational will be expending technical and functional posibilities of major groups of universal sewing machines and special purpose (including universal sewing machine shuttle stick), with the most widely used technology.

2. Results and discussion

Implementation of laser systems in the design of sewing equipment, according to the author, can have positive significant results in reducing the proportion of non-manual types of work in the manufacturing of garments.
As it is known, laser technology is quite young (it is more than 50 years), but today there is no such field, where it has not been used. Laser beams are widely used in industry for cutting, welding and soldering as well as for non-contact measurement [1]. The use of lasers in the garment industry currently following - Figure 1.

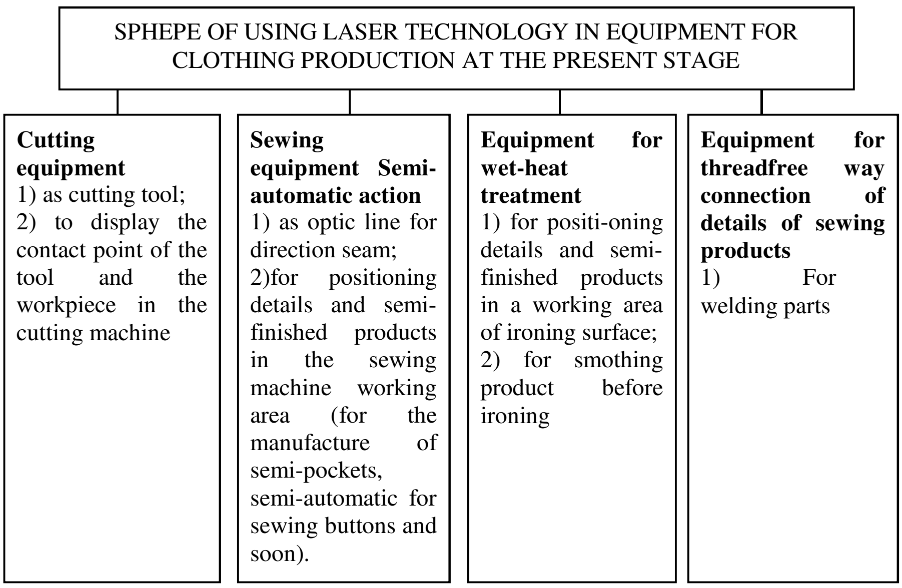

Figure 1. Sphere of application of laser beams in the technological equipment in the garment production

At the same time project laser systems can be used by sewing machine operator as optical identifiers details of clothing manufactured products on working surface. Given with the help of the successful technical solution to implement laser technology can significantly extend the functionality of the universal destination of sewing machine lockstitch [2]. Their use can provide:
- reduction of low performing manual work for planning location for small details;
- reducing time for making garments;
- optimization the production process operations by focusing on one area of one employee;
- increasing productivity of equipment by expanding its functionality.

To ensure a quality use of laser beams as optical identifiers of parts of garments laser systems must be responsible for several requirements - Figure 2:

REQUIREMENTS LASER SYSTEMS AS OPTICAL IDENTIFICATOR FOR DETAILS OF SEWING PRODUCTS

- High and constant brightness of laser beam
- Convenience in fixing to frame
- Protection from wrong diametrically opposed
- Compact and small sizes
- Economical construction and energy seving device
- Surety and unfailing in operating
- Low position of erection

Figure 2. Requirements for laser systems for sewing machines

Laser beams can be solved in three variants - Figure 3:

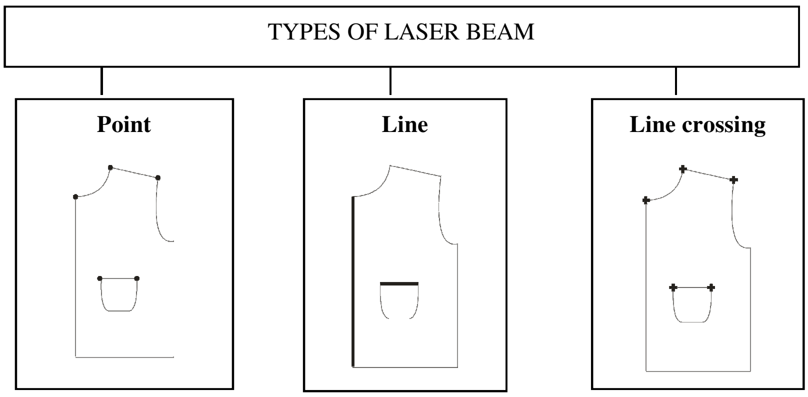

Figure 3. Options for solving project laser beams

For optical identification of contour details of garments more appropriate will be the usage of laser technologies, which are generated by semiconductor laser of red range irradiation band (λ = 0,63 mkm) as a line or crossing lines. But it should be noted, that the laser beams of red spectrum is not suitable for identifying details of textile material which is red. In such case it is reasonable to use laser beams of blue spectrum (λ = 0,44 mkm).

Technical decision of the functioning of such a laser system provides minimal required set of devices: laser radiation source; laser beam modulator for positioning in space and time on the surface, which is identified; bracket; adapter to the laser [3]. The work of laser devices as a means of identification of contour of details of garments by the operator sewing machine can be successfully realized on the basis of computer-aided design (CAD), including subsystems "CAD-designer" and "CAD - technologist", which today are widely used in technologies of clothing production. In this case flexible connection and transmission of information from the workplace "CAD-designer" and "CAD-technologist" to the operator's workplace of sewing machine which use a laser system can perform for the sake of wireless technologies on noisy signals.

3. Conclusions

In given article author analyzes the possibilities of using the laser technologies in sewing equipment. Established the sphere of using lasers in modern clothing production. Defined major requirements to laser devices, which can be used for optical identification of contour of details of garments by operator of sewing machine. Defined the types of laser beams and lists of technical devices, necessary for work of laser system. Established possibilities of operation of laser systems through system of automatic design and transmission information using wireless technologies.

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Opiekun naukowy: Jacek RYSIŃSKI[2]

STANOWISKO DO POMIARU PRĘDKOŚCI TRANSMISJI DANYCH

Streszczenie: W praktyce niewielu inżynierów stosując rozwiązania komunikacyjne zastanawia się nad czasami transmisji danych czy wydajnością i efektywnością pracy zastosowanego rozwiązania komunikacyjnego. W pracy omówiono projekt stanowiska do badania pracy oraz szybkości komunikacji pomiędzy platformami Arduino. Praca składa się z projektu wykonania stanowiska laboratoryjnego oraz opracowania jego oprogramowania.

Słowa kluczowe: transmisja danych, platforma Arduino, XBee, komunikacja szeregowa

TEST STAND FOR SPEED MEASURING OF DATA TRANSMISSION

Summary: In practice, very few engineers wonder about the features of the communication system. In many cases it is sufficient that the system confirms the execution of the exchange transaction data. The paper presents the laboratory equipment (rigs) for testing velocity of message exchange between Arduino platforms.

Keywords: data transmission, Arduino, XBee, serial communication

1. Wstęp

Wykonanie stanowiska laboratoryjnego, szczególnie przy urządzeniach służących do testowania i badania systemów komunikacyjnych przysparza wiele problemów związanych z kompatybilnością elektryczną, wpływem różnych zakłóceń czy też problemami we współdziałaniu układów na linii komunikacyjnej. Patrząc na różne problemy, gdzie maszyna posiada różne podzespoły, które muszą się wzajemnie komunikować i wzajemnie kontaktować przy dodatkowo ruchomych elementach warte jest rozważenie zastosowań różnego rodzaju systemów czy to przewodowych czy też bezprzewodowych. Stanowisko to ma za zadanie zaprezentowanie różnych

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sposobów komunikacji a dzięki odrębnej konstrukcji także do przetestowania jej w różnych warunkach w celu dobrania odpowiedniej komunikacji dla danej sytuacji. Dzięki niej można także zbadać różnicę prędkości przesyłu danych dla różnych systemów oraz porównać je między sobą.
Stanowisko zostało zaprojektowane tak, aby nie było potrzeby ciągłego przepinania się pomiędzy różnymi elementami składowymi, lecz wszystkie te systemy są wbudowane w jeden spójny układ, mając do dyspozycji moduły platformy Arduino:

- płytka Mega 2560,
- płytka X-Bee,
- moduł RS 485,
- wyświetlacz dotykowy Adafruit 2.8" TFT.

Rozwiązaniem problemu jest zaprojektowanie i wykonanie płytki PCB uwzględniając połączenia pomiędzy poszczególnymi elementami systemu tak, aby można było korzystać z różnych modułów komunikacyjnych jednocześnie, oraz wykonanie oprogramowania testującego szybkości przesyłu dla każdego modułu komunikacyjnego.

2. Moduły komunikacyjne

2.1. Arduino

Arduino jest mikrokontrolerem mającym postać płytki wyposażonej w złącze uniwersalnej magistrali szeregowej (USB) służące do komunikacji z komputerem, a także inne złącza służące so podłączania zewnętrznych elementów elektronicznych takich jak silniki, przekaźniki, głośniki, diody laserowe, mikrofony itp.. Urządzenia podłączone do Arduino mogą być zasilane prądem pobieranym ze złącza USB, ogniwa 9 V lub zewnętrznego zasilania (zasilacz). Urządzenia te mogą być sterowane za pośrednictwem komputera lub – po uprzednim zaprogramowaniu i odłączeniu od komputera- przez samo Arduino. Oprogramowanie służące do programowania Arduino jest łatwe w użyciu i jest dostępne za darmo na platformy Windows, Mac i Linux. Sercem Arduino jest mikrokontroler. Wszystkie pozostałe elementy na płytce układu zajmują się zasilaniem układu lub pozwalają na komunikację układu z komputerem.

2.2. Moduł sieciowy X-BEE

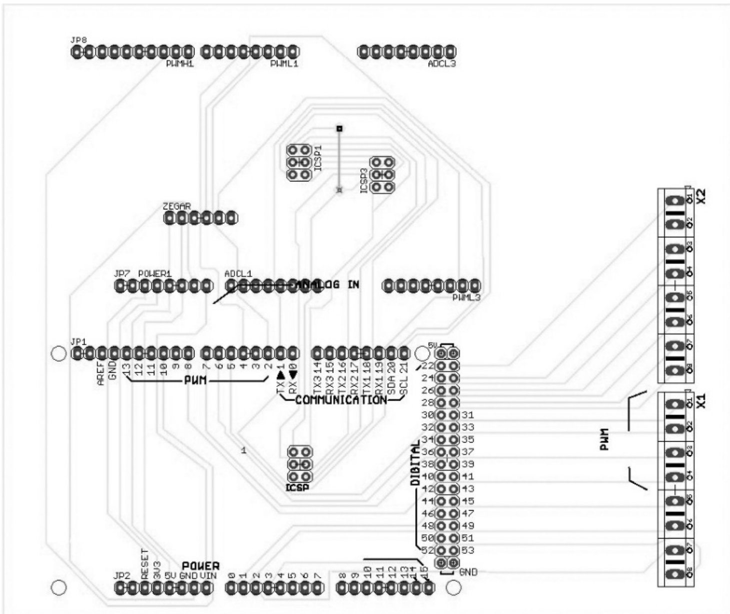
Xbee jest systemem bezprzewodowego wysyłania danych na większe odległości oraz z większą szybkością niż w przypadku podstawowych modułów komunikacji radiowej, warto rozważyć zastosowanie modułów danych XBee. Moduły odbierają i wysyłają dane szeregowe bezpośrednio do co najmniej jednego układu XBee i dalej do komputera lub komputerów. Moduły XBee nie wymagają stosowania dodatkowych bibliotek — działają jak proste mosty danych szeregowych wysyłających i odbierających dane za pośrednictwem linii szeregowej systemu Arduino. Na płytce Xbee umieszczony jest przełącznik danych, który określa, czy dane ze złącza USB na płytce Arduino lub nadajnika XBee mają być wysyłane do mikrokontrolera. Gdy chcemy odbierać dane za pośrednictwem komputera musimy skonfigurować komputer tak, aby mógł odbierać dane. Do jednego komputera można podłączyć wiele nadajników XBee, z których każdy może wysyłać własne dane w celu monitorowania wielu urządzeń. W ten sposób można w komfortowych warunkach, nie wstając od biurka, monitorować różne czujniki (na przykład czujniki temperatury) rozmieszczone na dużym obszarze. W podobny sposób można nawet sterować wieloma systemami Arduino z modułami XBee

2.3. Wyświetlacz Adafruit 2.8 TFT

Wyświetlacz TFT wykonano jako nakładkę na układ Arduino. Wykonano go z możliwością obsługi poprzez dotyk, o przekątnej 2,8”. Ekran posiada podświetlenie LED, rozdzielczość wynosi 240x320 p indywidualnej kontroli . Na płytce znajduje się także gniazdo karty microSD. Płytka komunikuje się poprzez magistrale SPI. Jest kompatybilna z Arduino Uno, Leonardo oraz Mega.

3. Projekt i wykonanie płytki PCB

Zaprojektowano i wykonano płytkę drukowaną w programie CadSoft EAGLE na której są umieszczono elementy platformy Arduino oraz wyświetlacz Adafruit.



Rysunek 1. Zaprojektowana płytka drukowana

Połączone zostały wspólnie zasilania wszystkich modułów. Komunikację ICSP oraz PWM dla wszystkich modułów, zostały także połączone wspólnie. Dodatkowo wyprowadzono po cztery sygnały analogowe, cztery piny PWM oraz osiem sygnałów cyfrowych z płytki Arduino MEGA na złącza śrubowe typu ARK. W razie późniejszej potrzeby rozbudowy doprowadzono także wyprowadzenia do modułu Ethernet Shield oraz zegara RTC.

Tak zaprojektowany układ został następnie wykonany za pośrednictwem frezarki CNC w postaci wyfrezowanych ścieżek na jednostronnej płytce PCB. W celu podłączenia elementów referencyjnych oraz ewentualnej zmiany zastosowano połączenia w postaci listew typu goldpin oraz gniazd o przedłużonych wyprowadzeniach. Daje to możliwość podłączenia podzespołów Arduino po obu stronach płytki PCB oraz w razie awarii bądź potrzeby zamiany któregoś z podzespołów dedykowanych łatwą możliwość wyjęcia bądź podmiany. Dzięki wyprowadzeniom na złącza typu ARK, możemy podłączać i wykorzystywać dodatkowe wyjścia/wejścia analogowe, cyfrowe bądź PWM na zewnątrz płytki i w łatwy i przejrzysty sposób podłączyć do płytki Arduino nowe podzespoły. Na zewnątrz płytki PCB zostały wyprowadzone wszystkie piny, w które został wyposażony Arduino MEGA 2560, przez co możemy także wykorzystać je do podłączeń dodatkowych podzespołów takich jak np. złącza RS232 bądź RS485 i wielu innych. Na tak powstałej płytce można wykonywać podstawowe ćwiczenia z komunikacji poprzez interfejsy XBEE, RS232, RS485, zwykły UART a także w przyszłości ETHERNET, a dzięki zastosowaniu dotykowego wyświetlacza LCD, dokonywać także uprzednio zaprogramowanych nastaw oraz zmian z poziomu samego układu. Dodatkowo dzięki wyprowadzeniom można do niego podłączyć różne inne moduły komunikacyjne i rozbudować system o nowe możliwości.

Rysunek 2. Stanowisko laboratoryjne - widok z góry

4. Opracowanie oprogramowania diagnostycznego

Głównymi założeniami stanowiska jest testowanie pracy różnych modułów komunikacyjnych, zapoznanie się ze sposobami ich programowania dla platformy Arduino oraz wykonanie prób przesyłania różnych przykładowych ciągów znaków i pomiar czasu przesyłu dla różnych modułów komunikacyjnych oraz w różnych warunkach pracy.
Aby spełnić te zadanie potrzebne jest zapoznanie się z budową, zasadą działania modułu komunikacyjnego, budową dedykowanym im bibliotek oraz sposobami ich

obsługi programowej dla każdego z modułów komunikacyjnych oraz stworzenie spójnego oprogramowania dla dwóch stanowisk, tak aby wzajemnie ze sobą się komunikowały. Jako, iż stanowisko posiada różne moduły komunikacyjne potrzeba stworzyć system gdzie bez potrzeby przepinania się pomiędzy modułami komunikacyjnymi, można było szybko przełączyć się pomiędzy modułami komunikacyjnymi i dokonać dalszych prób. Stanowisko posiada także wyświetlacz dotykowy na którym warto umieścić cały system sterowania oraz diagnostyki dla pomiarów, tak aby nie było konieczności ciągłej zmiany programu do konkretnego modułu. Z racji poznania przez późniejszych operatorów sposobów oprogramowania i obsługi, kod został napisany prosto i modułowo. Każdy moduł odpowiedzialny za daną część programu jest umieszczony w odrębnym podprogramie, co daje nam wgląd do zasady i sposobu ich obsługi.

Do obsługi modułów komunikacyjnych oraz wyświetlacza skorzystano z następujących bibliotek:

- Adafruit_ILI9341.h – do obsługi wyświetlacza,
- Adafruit_STMPE610.h – do obsługi dotyku,
- Wire.h – do obsługi komunikacji UART,
- SPI.h – do komunikacji z modułami zewnętrznymi.

Program przy uruchomieniu urządzenia wyświetla okno główne aplikacji oraz nadaje wartości początkowe w postaci pierwszego możliwego ciągu znaków („A”), transmisji za pomocą protokołu UART oraz zeruje wszystkie zmienne dla protokołu pomiarowego. Na ekranie głównym przedstawiono wszystkie parametry, które są aktualnie nastawione na urządzeniu oraz przyciski za pośrednictwem których można zmienić ciąg znaków do przesłania oraz przycisk do wyboru modułu komunikacyjnego za pośrednictwem którego chcemy dokonać pomiarów. W celu dokładniejszego sprawdzenia różnic w każdej z transmisji, dodano możliwość wyboru liczby powtórzeń pomiarów dla wybranej komunikacji. Stanowisko daje możliwość pomiarów dla jednego, dziesięciu, pięćdziesięciu oraz stu powtórzeń. Pomiar jest wykonywany poprzez transmisję danych do drugiego stanowiska, gdzie po odczytaniu dane zostają przesłane powrotnie. Na tej podstawie zostaje obliczony czas całej transmisji i dzielony na pół co daje nam czas transmisji w jedną stronę. Czas ten jest obarczony błędem w postaci czasu przetwarzania w stanowisku odbiorczym, lecz wartość jest pomijalnie mała (nie wpływa na wynik końcowy). Dla kilku powtórzeń wskazywany jest czas minimalny, maksymalny oraz średni.

Rysunek 3. Przykładowe okna na wyświetlaczu dotykowym, w kolejności wstawiana: a) Okno główne, b) Okno wyboru tekstu, c) Okno wyboru komunikacji, d) Wyniki pomiaru

Przykładowy fragment programu:

```
#include <SPI.h>
#include <Wire.h>
String odebrane = "";
String wyslane = "ALA";
unsigned long CzasPoczatkowy;
unsigned long CzasKoncowy;
unsigned long Czas;
unsigned int dane;

void pomiarUART()
{
  CzasPoczatkowy = micros();
  Serial.println(wyslane);

while(Serial.available() > 0) {
odebrane = Serial.readStringUntil('\n');
}
  CzasKoncowy = micros();
  Czas = (CzasKoncowy - CzasPoczatkowy);
dane=sizeof(wyslane);
Serial.writeln(Czas);
Serial.writeln(dane);
}

void setup(void)
{
  Serial.begin(9600);
  CzasPoczatkowy = 0; CzasKoncowy = 0;
  Czas = 0; Dane = 0;
  pomiarUART();
}
```

5. Podsumowanie

Zaprojektowane stanowisko laboratoryjne zbudowane w oparciu o platformę programistyczną Arduino zapewnia szybką, prostą i bezproblemową pracę przy uruchomieniu, testowaniu i badaniu zastosowanych metod komunikacji. Zastosowanie wyświetlacza dotykowego daje możliwość samodzielnej pracy w każdych warunkach bez potrzeby komputera, a dzięki przygotowanym wyprowadzeniom można poszerzyć jego funkcjonalność o dodatkowe moduły bądź czujniki i testować je na gotowym systemie, bądź maszynie oraz rozbudować je w układy zdalnego sterowania, a także dołożyć inne moduły komunikacyjne.

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DIAGNOSTICS BASED ON POSITIONING PERFORMANCE DURING CIRCULAR MOTION

Abstract: The article discus selected methods of technical diagnostics focused to analysis of circular motion that can be performed on machine tools, industrial robots and manipulators. Such methods are relatively easy to implement and some of them are commonly used in industry as it offers information about overall condition of examined device that is easy to interpret.

Keywords: technical diagnostics

DIAGNOSTYKA TECHNICZNA W OPARCIU O DOKŁADNOŚĆ POZYCJONOWANIA RUCHU KOŁOWEGO

Streszczenie: W artykule omówiono wybrane metody diagnostyki technicznej związanej z analizą ruchu kołowego, które mogą być stosowane na obrabiarkach, robotach przemysłowych oraz manipulatorach. Omówione metody są łatwe w realizacji w warunkach warsztatowych i są powszechnie stosowane w przemyśle, a otrzymane wyniki dają informacje o ogólnym stanie badanego urządzenia i są łatwe do interpretacji.

Słowa kluczowe: diagnostyka techniczna, pomiar

1. Introduction

The quality of production and especially the quality of machined parts is directly connected to condition of machine tool that creates its individual surfaces. At first sight, the condition of most of production industrial devices such as machine tools, industrial robots, and manipulators can be relatively assumed by evaluating of various parameters of its characteristic function – the movement. If device condition is in adequate state then the precision of the movement should be in certain limits.

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However, the evaluation of positioning precision is complex task with plenty of methods and approaches with various requirements to measuring and evaluating tools and with different outputs. Therefor it can be difficult to choose diagnostic methods that are optimal for particular case [3, 6].

Some of diagnostic methods are using analysis of results of circular interpolation measured either on produced parts or on device itself. Methods that can be used for analyzing results of measurements to reveal potential problems on industrial machinery are very similar regardless of method used for measurement as far as some nature of captured data are of same kind [1, 4].

2. Diagnostic measurements of circular motion

In order to keep accuracy of machined parts in certain limits it is crucial to maintain precision of machine tools in reasonable limits. The same applies to positioning performance (precision and repeatability of positioning) of industrial robots and manipulators. Such maintenance requires access to reliable information about overall actual machine tool condition that can provide assumptions about past, current, and emerging problems with tool positioning precision, overall functionality and sustainability of production [7].

There are various diagnostic methods and approaches that are able to check machine tool ability to produce parts of required precision. People usually tend to think of electronically controlled machines as absolutely precise, yet the positioning precision is variates thru the lifecycle of device that normally decreases with time and can be restored thru proper maintenance[6].

Measurement of geometrical properties of machine tools, which includes also positioning precision, has been around as long as machines itself as measurements are essential part of its production and maintenance. Demand for keeping machine tool operating is constantly increasing, thus every downtime should be reasonable and legitimate and as short as possible, and that creates pressure to optimization and increasing effectivity of maintenance and diagnostic processes.

One of the most advanced groups of methods of evaluating of positioning performance of numerically controlled (NC) machines uses analysis of circular interpolation[7].

Standard interpretation of measurements that involves circular motion is polar diagraph that shows deviation from ideal shape, regardless it show path of action element of examined device or measurement of circular shapes machined on machine tools. Examples of such diagraphs is shown on Fig. 1. If examined machine would be in ideal condition, then the actual shape of diagraph would be a perfect circle with zero deviation from programmed radius. In real world, many factors such as wear, constructional inaccuracies and environmental factors can cause various deviations of shape of actual path and shape of polar diagraph in extension [2].

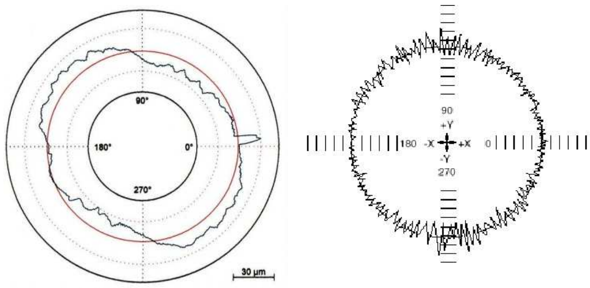

Figure 1. Sample polar diagram of circular interpolation accuracy

Experienced diagnosticians are able to reveal some types of machine tool faults and inaccuracies just by look on such diagram and by identification and localization of characteristic features that indicates specific condition or error occurrence. Measurement can be done simple in one plane (usually it is X-Y plane), when main evaluated parameter is circularity, or in multiple planes what is called volumetric test and evaluated parameter is sphericity.

This article deals with two basic methods to measure positioning accuracy during circular interpolation. One is direct measuring on examined device and second is indirect method that is based on analysis of circularity of machined element. Direct measuring of positioning accuracy during circular interpolation is performed on unloaded machine. Such measurement on machine tools is not affected by inaccuracies arising from forces generated by cutting process, since the measurement is performed on an unloaded machine. By contrast the measurement of machined components (indirect measurement) must take into account other factors, such as type of tool, cutting conditions, the impact of material, workpiece deformations due clamping forces etc. It is clear that measurement of machined features is not suitable for evaluating of precision of robots, manipulators, and other non-machining NC devices. There are also various measurement method for analyzing circular interpolation that uses various reference objects such as precisely grinded cylinders or spheres with known diameters.

2.1. Direct measurements

Each of methods mentioned above requires different approach and different type of measuring device. The direct measurement can be performed with device such as Renishaw Ballbar (Fig. 2) Renishaw Ballbar consists of precise linear sensor with precise steel ball on the ends. The balls exactly fits into magnetic mounts, one to the mount held as tool in spindle; second one on pivot that is usually mounted on worktable. Unlocked mount of pivot have three degrees of freedom what allows simple aligning of mounts with setting ball in order to precisely set center of measuring circle.

Essentially, the Renishaw Ballbar is a linear displacement sensor designed to perform a simple, rapid check of a machine tool's positioning performance according to recognized internationals standards based on measuring deviations in the radius of circular movement measured by a transducer in the ballbar and captured by the computer software. Software provided with this device is able to detect and measure wide range of inaccuracies faults that and reveal some machine faults which are the source of such inaccuracies. The data from measurement are stored in *.b5r file that is formatted similarly to XML standard what allows reading, processing, and further analysis of measured values with custom software. For machine tools or devices with perpendicular feeds it is possible to identify following errors and faults: backlash, cyclic error, lateral play, master-slave changeover, offset change, plot rotation, positional tolerance, radius change, reversal spikes, scaling error, servo mismatch, spiral error, squareness, slick slip, tri-lobe (straightness), vibration, of machine.

Figure 2. Renishaw Ballbar QC20-W and its mounting on effector of delta robot Fanuc M-1iA [8]

Measurements of characteristics of motions on industrial robots and manipulators with serial or parallel kinematics (excluding devices with Cartesian construction) is difficult as commonly real displacement of effector from programmed coordinates is too big and thus absolute positioning precision of such devices is not sufficient for Renishaw Ballbar and its software recognize measurement record as unusable. This does not mean that it is not possible to measure such devices with Ballbar at all, but the measurement have to be treated differently. Ballbar type device are not designed specifically to measure serial kinematics and thus such measurements on such devices does not offer as many benefits as on machine tools or devices with Cartesian construction. Also international standards does not include such measurements for robots and manipulators.

However, the Ballbar type devices are more and more common in industry as it offer fast way to check positioning performance and conditions of machine tools and therefor there is demand for implementing such tests on other type of devices. Already there are some commercial applications that are designed specifically for measurements of robot positioning performance by Ballbar device. Such software are usually does not inherit ability to point out specific fault together with possible causes and its percentage share of overall positioning error what is normally available for machine tools. Still, such software offers easy way to monitor and record robot degradation, to compare accuracy before and after calibration and usually also to generate program for measurement and its main purpose is to offer cheaper, easier, and faster alternative to standard robot performance tests (for example ISO 9283).

At Department of Automation and Production Systems, Faculty of Mechanical Engineering, University of Zilina, in order to analyze data measured with Renishaw Ballbar, the software for reading converting and exporting data with code name FormAnalyzer (Fig. 3) was created. It is capable of reading, filtering and exporting data from *.b5r files to specified format. In order to check consistency of measurements it is capable of displaying basic polar diagraph, performing basic tasks such as harmonic analysis using fast Fourier transformation, and calculating roundness. This software purpose is not only to export data necessary for further analysis in other software but also to verify consistency of data in files that Ballbar software evaluated as unusable because of excessive deviations during measurement as it is common with industrial robots and manipulators.

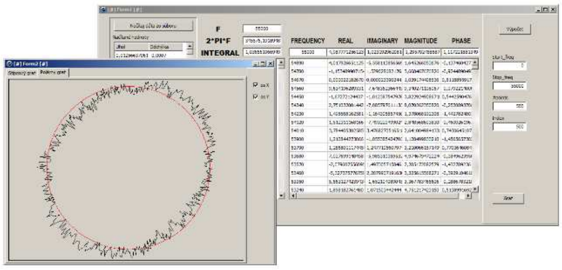

Figure 3. FormAnalyzer software with loaded measurement record and displayed polar graph

2.2. Indirect measurements

Indirect measurement methods, that are based on circular interpolation analysis, requires machining special so called master workpiece with features of defined shape and size. Geometrical shape of such workpiece can be measured by common methods, in this case the shape is cylindrical hole and its roundnes was measured by Talyrond 73 (Fig. 4). This measurement device specifically designed to measure roundness of cylindrical shapes using ROFORM software. Measuring of described workpiece is shown on Figure at the right side. ROFORM software is capable of performing evaluation of measurement by spectral analysis and filtering. Data vaptured by Talyrond are in encoded file *.frm. File stores encoded results of fast Fourier transform, real and imaginary part separely. In order to obtain actual measured profile is necesary to perform reverse fast Fourier transformation.

Figure 4. Measuring device Talyrond 73

Actual measuring of described workpiece is displayed at Figure . ROFORM software are capable of performing evaluation of shape deviations of circular feature in polar diagraph using spectral analysis and various filters. Measured data are saved in proprietary file with *.frm extension. The binary file contains encoded results of fast Fourier transform where real and imaginary part are saved separately to two different streams. In order to obtain actual measured profile, in form of list of deviations from ideal shape that can be interpreted as poplar diagraph, it is necessary to perform reverse fast Fourier transformation.

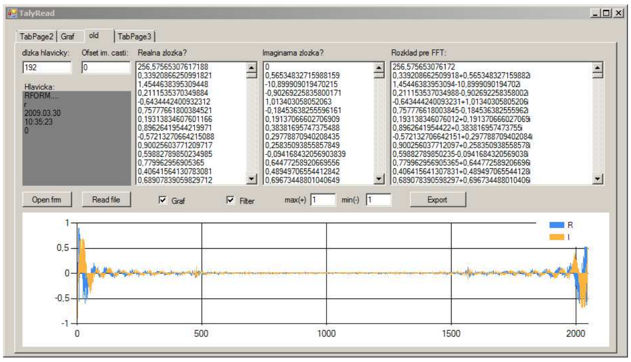

Figure 5. Measurement record from ROFORM application opened in TalyRead softwar read for exort

At Department of Automation and Production Systems, Faculty of Mechanical Engineering, University of Zilina, was developed custom application TalyRead (Fig. 5) capable of reading such files and exporting data in format required for further analysis.

3. Analyzing of measurement data

The analysis of results of measurements mentioned above can be done with proprietary software offered by producers of measurement devices but in order to have ability to compare data from multiple measurement methods it is necessary to have one tool capable of analyzing data from multiple sources. Main characteristic in measurement positioning performance during circular motion is roundness that can be analyzed with SigmaRound, what is a highly interactive software package allowing use of various filters and reference circles as applied to software-generated or user-imported data files. This software allows also harmonic (chatter) analysis, outlier detection and removal, partial arc analysis, and more.
Some partial analysis can be done with tools described in chapters above (TalyRead and FormAnalyzer) that were originally created in order to test and confirm algorithms before implementation into expert system that is currently under development at our department. Currently we are also working on methodology and software tools designed specifically to measure positioning performance of industrial robots, manipulators, and other devices, with serial or parallel non-Cartesian kinematics.
For machine tools with common kinematics it is relatively easy to interpret polar diagraph, its specific deformation and to assign its possible source (fault or error). Example of such fault is metering error, which causes the oval shape of the polar diagraph oriented along the axis in position 0 ° or 90 °. The direction graph

deformation does not depend on the measuring direction and its size is usually not affected by the machine feed rate. Metering error is defined as the difference in the measured paths in axes during the test. For example the measurement in the XY plane, should the dimensions X and Y move be exactly the same, so measured shape should be symmetrical around any line placed through center of coordinate system (assuming that eccentricity was removed by filtering of harmonic components). Metering error is then as the difference between the metering values of the individual axes (see the values a, b Fig. 6). Value of metering error is measured from the polar diagram reconstructed after filtering out higher harmonics. In the Ballbar software the value of metering error depends on calibration of the device. If the Ballbar was calibrated, then the metering error is shown in the form of precise length tracks of axes and if the system has not been calibrated, then the metering error is shown just as difference between the axes X and Y. Detecting this error is based on harmonic analysis of measured profile. This error is characteristic by significant value of second harmonic and by orientation of deformation along one of the axis. Measuring this error using indirect methods requires careful clamping of workpiece in order to reduce it deformation.

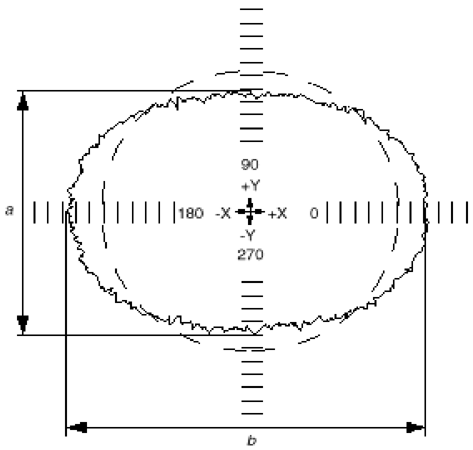

Figure 6. Polar diagraph with shape typical for metering error

4. Conclusion

The development of various methods for the measuring of numerically controlled devices such as machine tools, industrial robots and manipulators is still a hot topic. There are wide range of various methods deployed in practice, where individual devices and methods are constantly developed, improved and implemented. A significant development in field of measuring of geometric parameters of machine tool is replacement of multiple various measuring devices by more universal ones. Selection and application of optimal diagnostic methods is a complex task as each method have its own specifics.

The quality and reliability of production to some extends directly depends on positioning performance of machinery as it affects accuracy of produced parts,

reliability of processes, and even feasibility of production itself. Therefor it monitoring of such characteristic should be important part of regular maintenance and diagnostics. There are several methods with similar outputs but requiring slightly different inputs. One of such groups are methods based on analyzing parameters of positioning during circular motion. The measurements of positioning performance that uses circular motion is relatively common and reliable but it have some limitations, especially if it deals with non-Cartesian kinematics.
Data obtained by these methods are usually showed in form of polar diagram that experienced expert can easily interpret and directly diagnose several errors and failures simply just by look on such graph. Contrary computer program have to analyze such shape by mathematical methods that require several different tools. This article summarizes such tools, software, approaches, and methods currently used at Department of Automation and Production Systems, Faculty of Mechanical Engineering, University of Zilina.

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STANOWISKO POMIAROWE ZŁOŻONE Z ROBOTA PRZEMYSŁOWEGO I TRIANGULACYJNEJ GŁOWICY LASEROWEJ DO BADANIA CECH GEOMETRYCZNYCH WYROBÓW

Streszczenie: Artykuł prezentuje stanowisko doświadczalne złożone z sześcioosiowego robota przemysłowego współpracującego z laserową głowicą pomiarową, oraz zakres dotychczas zrealizowanych badań. Genezą dla zbudowania stanowiska jest oszacowanie zdolności pomiarowych robota wyposażonego w głowicę pomiarową. Stanowisko pomiarowe ma dokonywać pomiaru w cyklu automatycznym wielkości geometrycznych rzeczywistych wyrobów w warunkach przemysłowych. Dla opisanego stanowiska została opracowana dedykowana metoda kalibracji TCP narzędzia. Stanowisko zbudowano w laboratorium Katedry Technologii Maszyn i Automatyzacji ATH.

Słowa kluczowe: sześcioosiowy robot przemysłowy, triangulacyjna głowica laserowa, TCP narzędzia, detektor promienia lasera

TEST STAND INCLUDING INDUSTRIAL ROBOT AND LASER DISPLACEMENT SENSOR TO MEASURE GEOMETRICAL FEATURES OF PRODUCTS

Summary: The paper presents test stand including six axis industrial robot cooperate with laser displacement sensor and the range of research was done. The idea to create the test stand is to evaluate measurement capability of laser displacement sensor installed on industrial robot. Test stand is developed to measure geometrical feature of parts in real industrial environment. The dedicated method was developed to properly calibrate tool's TCP. Test stand, laser detector and calibration method were developed on Department of Production Engineering and Automation of ATH.

Keywords: six axis industrial robot, laser displacement sensor, tool TCP, laser detector

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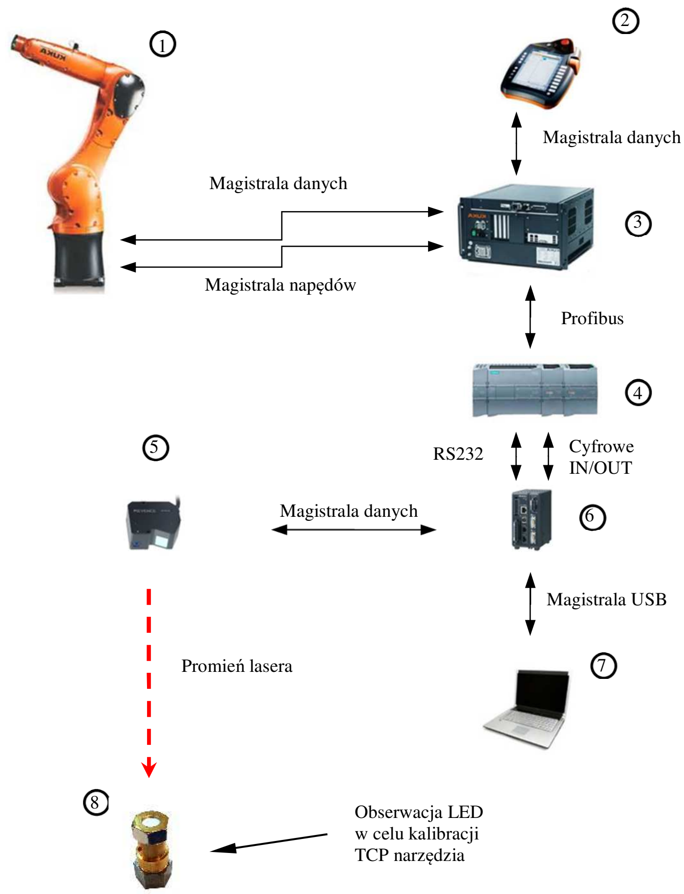
1. Wstęp

Nowoczesną produkcję cechuje znaczne zróżnicowanie oraz krótkie okresy produkcji komponentów. Współczesne przedsiębiorstwa, w celu zachowania konkurencyjności, muszą ciągle wprowadzać na rynek nowe produkty i stosować innowacyjne procesy wytwórcze. Istotne jest maksymalne ograniczenie kosztów produkcji przy zachowaniu wysokiej jakości wytwarzanych wyrobów.
Mierzenie wyrobów za pomocą czujnika laserowego nie jest już tylko specyfiką dobrze wyposażonych działów badawczych, lecz zaczyna odgrywać coraz większą rolę w realiach przemysłowych. Konieczność kontroli produkowanych wyrobów jest jednym z kluczowych obszarów działalności współczesnych fabryk. Również każdego roku rośnie tendencja wykorzystywania robotów przemysłowych [8].
Wykorzystane w celach inspekcji narzędzia pomiarowe powinny zapewniać wysoką dokładność, odporność na warunki pracy oraz szybkość zbierania punktów pomiarowych. Cechujące się wysoką dokładnością realizowanych pomiarów Współrzędnościowe Maszyny Pomiarowe z uwagi na surowe normy dotyczące warunków środowiska pracy (klimatyzowane pomieszczenia z atmosferą wolną od zapyleń) oraz długie czasy pomiaru przedmiotów praktycznie nie spełniają kryteriów bezpośredniego pomiaru wprost na linii produkcyjnej [3].
Aby spełnić wymagające warunki pracy cechujące produkcję wyrobów w warunkach przemysłowych, zbudowano stanowisko doświadczalne złożone z robota przemysłowego z zainstalowaną laserową głowicą pomiarową. Za wyborem wiązki laserowej, jako medium zbierającym informacje o mierzonym przedmiocie zdecydowały w głównej mierze czynniki jak brak kontaktu z przedmiotem mierzonym (możliwość uniknięcia przypadkowej kolizji), oraz szybkość zbierania informacji. Istnieje wiele metod optycznych za pomocą, których można badać odległości pomiędzy czujnikiem a przedmiotem, jednak metoda triangulacji laserowej należy do najdokładniejszych. Co więcej, badania prowadzone na zbudowanym stanowisku wykazały [1], że wiarygodne pomiary można przeprowadzać już dla czasu relaksacji stanowiska wynoszącym ok. 1s po wykonaniu ruchu do punktu pomiarowego.

2. Budowa stanowiska pomiarowego

Stanowisko badawcze zostało zbudowane w Katedrze Technologii Maszyn i Automatyzacji ATH. Stanowisko (Rys. 1) oparto na sześcioosiowym manipulatorze przemysłowym KR 6 R900 AGILUS (1) z kompaktowym kontrolerem KR C4 (3) oraz dotykowym smartPAD-em (2), umożliwiającym obsługę robota oraz programowanie ruchów. Urządzeniem mierzącym jest optyczny, czujnik laserowy LK-H152 (5) sterowany przez kontroler LK-G5001P (6) . Dostęp do parametrycznej konfiguracji odczytów lasera oraz wizualizację i zarządzanie wynikami pomiarów umożliwia pakiet LK-Navigator 2, zainstalowany na PC (7). Sercem całego stanowiska badawczego jest kompaktowy sterownik PLC SIMATIC S7-1200 (4), wyposażony dodatkowo w opcjonalne moduły komunikacyjne PROFIBUS i RS 232. Program zapisany w sterowniku PLC zapewnia synchronizację pomiędzy programem pozycjonującym robota a zapisem danych pochodzących z kontrolera LK-G5001P. Dodatkowy element stanowiska to detektor promienia lasera (8), umożliwiający przeprowadzenie kalibracji TCP (ang. Tool Center Point) narzędzia, konieczne dla prowadzenia dalszych pomiarów.



Rysunek 1. Architektura stanowiska badawczego

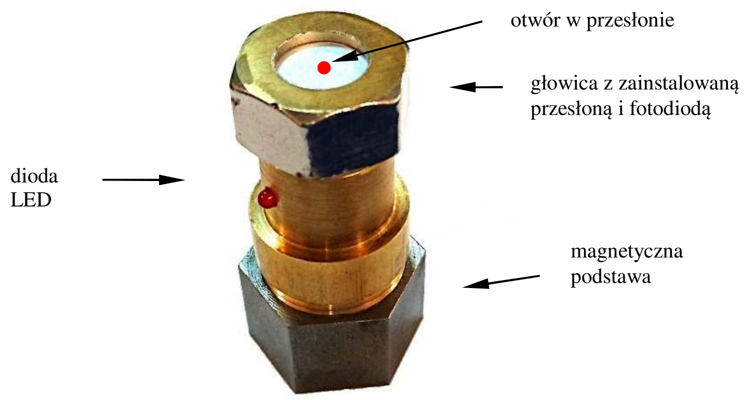
3. Kalibracja TCP narzędzia

Procedura wyznaczania TCP narzędzia różni się w zależności od zastosowanego narzędzia zainstalowanego na robocie. W opisywanym zastosowaniu, umieszczenie triangulacyjnej głowicy pomiarowej na robocie ma na celu automatyzację pomiaru cech geometrycznych mierzonego przedmiotu dla programowo ustalonych punktów. W celu dokonania kalibracji TCP głowicy pomiarowej zaprojektowano i przetestowano dedykowany do tego zadania detektor promienia laserowego. Prezentowana metoda, detektor oraz stanowisko badawcze zostało opracowane w Katedrze Technologii Maszyn i Automatyzacji ATH, dla celów estymacji niepewności pomiarów realizowanych czujnikiem laserowym zainstalowanym na robocie przemysłowym.

Pomiar narzędzia współpracującego z robotem jest niezbędny, aby układ sterowania robota znał kierunek najazdu narzędzia oraz jego przestrzenną orientację.
Dla kalibracji narzędzia można użyć podstawowej metody polegającej na wkręceniu ostro zakończonego pręta w odpowiednie miejsce w narzędziu robota. Następnie ostrym końcem tego pręta dokonuje się najazdu na inny ostro zakończony pręt znajdujący się w zasięgu pracy robota. Najazd odbywa się do momentu, aż oba ostro zakończone punkty zbliżą się na najmniejszą odległość. Przez kilkukrotne wykonanie tej operacji z różnych pozycji najazdowych możliwe jest określenie współrzędnych TCP narzędzia.
W pracy [4] podano przegląd różnych technik kalibracji TCP w zależności od typu zastosowanego narzędzia współpracującego z robotem.
Jedną z implementacji jest metoda o nazwie Laser LAB [4], która oparta jest na wykorzystaniu technologii laserowej. W tym przypadku wiązki laserowe są emitowane przez każdy z pięciu czujników rozmieszczonych w obudowie w kształcie pentagonu. W środku obudowy znajduje się wydrążenie, w którym wiązki pięciu laserowych promieni mogą przecinać się w jednym miejscu. Na flanszy robota zamocowana jest metalowa sfera o znanym promieniu *r*, która jest pozycjonowana w wydrążeniu w pentagonie.
Jeszcze innym sposobem wyznaczenia TCP jest użycie czujnika siły, jak ma to miejsce dla robotów firmy ABB wyposażonych w funkcjonalny dodatek umożliwiający rejestrację tego parametru [4]. Ramię robota wraz z zainstalowanym narzędziem wyposażonym w czujnik jest zbliżane do trzech nieruchomych trzpieni, rejestrując siłę nacisku i za pomocą interfejsu zwraca wartość siły do układu sterowania robota. Oprogramowanie wyznacza położenie punktu TCP. Ten sposób jest dogodny ponieważ w dalszej pracy robota otrzymujemy znane położenie TCP oraz wartość nacisku, jaki w tym punkcie posiada narzędzie na obrabianą powierzchnię, co ma znaczenie dla takich aplikacji jak np. polerowanie powierzchni przedmiotu obrabianego.

3.1. Detektor promienia lasera

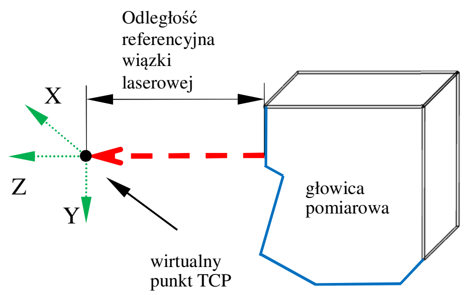
W celu wykonania pełnej kalibracji narzędzia, opracowano detektor promienia laserowego. Fotodioda lawinowa bpyp30 znajdująca się wewnątrz detektora, oświetlona promieniem lasera z głowicy pomiarowej generuje napięcie, które jest proporcjonalne do natężenia źródła światła. Światło lasera pada na fotodiodę poprzez otwór o stałej średnicy znajdujący się w nieprzezroczystej przesłonie. Poziom generowanego napięcia rejestrowany był na oscyloskopie cyfrowym (OWON XDS3102A). Badania prowadzone dla różnych średnic otworu w przesłonie wykazały, że wraz ze zmniejszającą się średnicą wydatnie zwiększa się dokładność ustalenia TCP narzędzia.
Zaświecenie diody LED znajdującej się w obudowie detektora jest dla obserwatora informacją, że wiązka lasera pada dokładnie na fotodiodę. W podstawie detektora zainstalowano magnes neodymowy, pozwalający na wygodne zamontowanie detektora na stalowym podłożu i gwarantującym jego niezmienną pozycję podczas całego procesu kalibracji. Całość zamontowana jest w niewielkiej i wytrzymałej mechanicznie obudowie (Rys. 2).



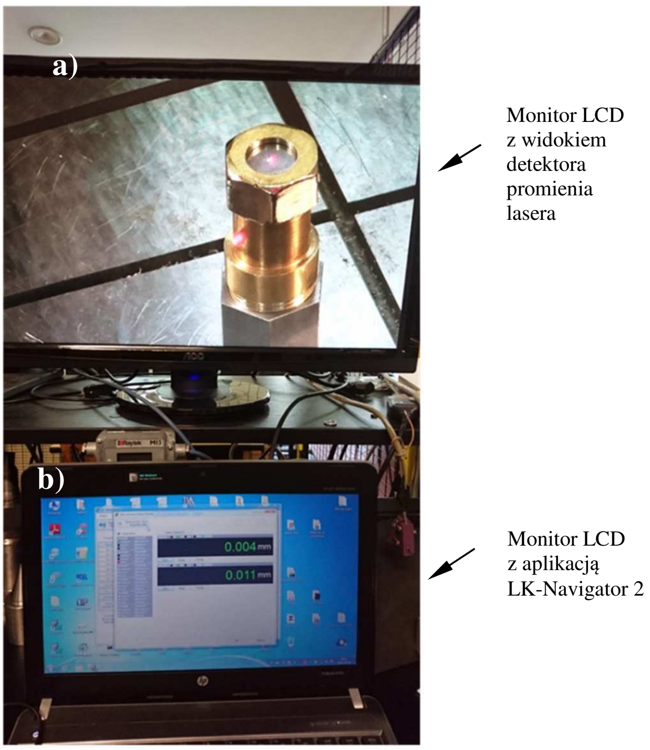
Rysunek 2. Skonstruowany detektor promienia lasera

3.2. Cel i metoda kalibracji

Metoda kalibracji wykorzystująca opisany detektor promienia lasera zastała opisana w pracy [2]. Kalibrację przeprowadzono stosując metodę XYZ czteropunktową. Wybrana metoda czteropunktowa wymaga najazdu wybranym punktem narzędzia (zawsze ten sam) z czterech możliwie różnych kierunków, na jeden punkt referencyjny znajdujący się w zasięgu robota.
Aby wykonać zadanie inspekcji za pomocą robota przemysłowego z zainstalowanym czujnikiem laserowym, konieczne jest dokonanie ustalenia punktu TCP narzędzia pomiarowego, oraz ustalenie układu współrzędnych związanego z przedmiotem poddawanym inspekcji. Praktyka pokazuje, iż narzędzia współpracujące z robotem powinny być dogodnie zdefiniowane w układzie przestrzennym robota. Mając powyższe na uwadze, laserową głowicę pomiarową można potraktować jako narzędzie, którego częścią roboczą jest emitowana wiązka lasera z punktem odniesienia umiejscowionym w środku zakresu pomiarowego (ok. 150 mm od czoła głowicy laserowej dla modelu LK-H152). Z praktycznego punktu widzenia to właśnie ten punkt powinien zostać zdefiniowany jako TCP narzędzia (Rys. 3). Poprawne i przemyślanie wykonanie kalibracji narzędzia (wybranie punktu TCP i orientacji układu współrzędnych) jest kluczowe do dalszej, efektywnej pracy przy określaniu układów współrzędnych dla mierzonych części maszyn.



Rysunek 3. Głowica pomiarowa wraz z układem współrzędnych i wirtualnym punktem TCP

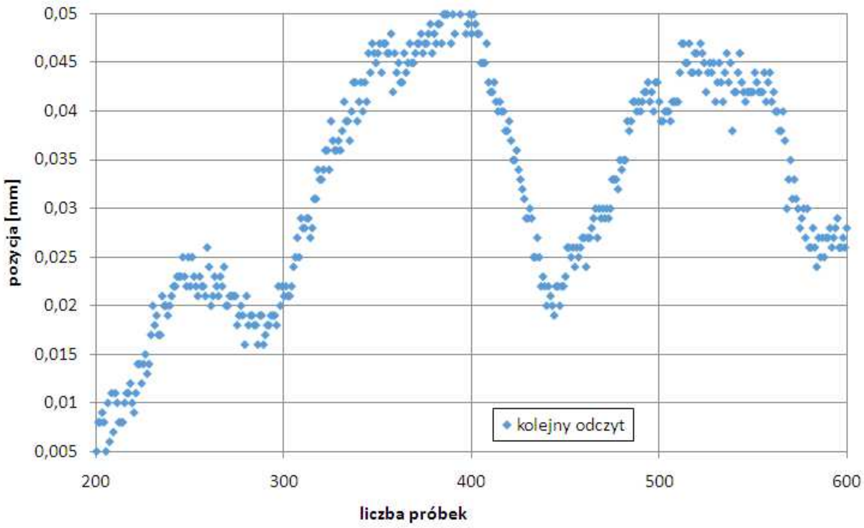


Rysunek 4. Sposób przeprowadzenia kalibracji: a) widok detektora promienia na monitorze LCD i b) wartości odległości zmierzonej przez laser w oprogramowaniu LK – Navigator 2 na zewnętrznym PC podłączonym przez port USB do kontrolera głowicy pomiarowej

Pozycjonowanie promienia lasera ponad fotodiodą umieszczoną w detektorze dostarcza równoważnych informacji, jak obserwacja wybranej, fizycznej krawędzi narzędzia i ustalanie względem przyjętego punktu referencyjnego znajdującego się na pręcie kalibracyjnym. Uzyskanie żądanej odległości od detektora promienia lasera było możliwe dzięki obserwacji podawanej przez głowicę pomiarową wartości dystansu w oprogramowania LK-Navigator 2, zainstalowanym na PC (Rys. 4).

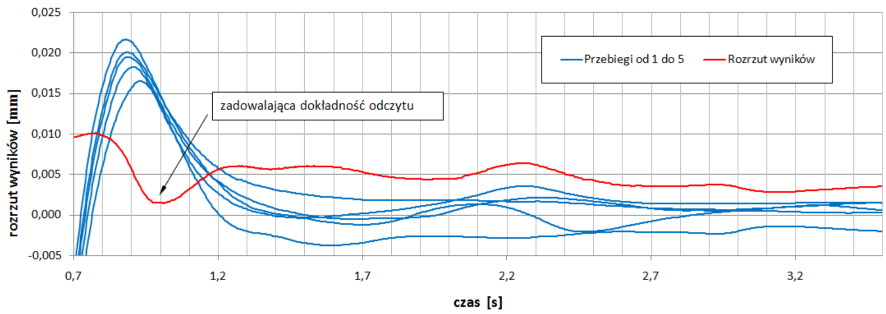
4. Badania prowadzone na stanowisku doświadczalnym

Dane otrzymane z głowicy pomiarowej (Rys. 5) prezentują się w postaci chmury punktów, których gęstość rozkładu zależy od częstotliwości zapisywanych wyników. Jak wykazały badania [1], powodem takiego rozrzutu wyników są przede wszystkim drgania manipulatora po zatrzymaniu w pozycji pomiarowej. Jak widać, pojedynczy pomiar po wykonaniu ruchu robota byłby obarczony dużym błędem, a odczekanie pełnego czasu relaksacji trwającego dla stanowiska ok. 5 sek. byłoby niecelowe.



Rysunek 5. Przykładowa seria w postaci chmury punktów

Dane uzyskane z badań na prezentowanym stanowisku posłużyły do wykonania analizy zakłóceń w otrzymywanych wynikach [1]. Wykorzystano analizę danych metodą FFT (ang. Fast Fourier Transform) dostępną w pakiecie *MS Excel* w celu wyekstrahowania składowych częstotliwości w widmie sygnału otrzymywanego z lasera pomiarowego.



Rysunek 6. Rozrzut wyników dla pięciu kolejnych prób pozycjonowania robota

Prezentowane przebiegi (Rys. 6) obrazują zagadnienie powtarzalności dla uśrednionych przebiegów. Widocznych jest kolejno pięć prób pozycjonowania, przy zachowaniu identycznych parametrów ruchu. Rozrzut wyników zaznaczony jest na ilustracji kolorem czerwonym. Wyniki te wskazują, że już po czasie 0.99s powtarzalność odczytu wynosi 0.0015 mm.

W efekcie możliwe stało się określenie czasu relaksacji dla badanego stanowiska, po którym poziom zakłóceń wydatnie się zmniejsza w analizowanym sygnale. Kryterium jest kompromis pomiędzy czasem odczytu dla pojedynczego punktu a dokładnością pomiaru.

Prezentowana metoda, detektor oraz stanowisko badawcze zostało opracowane w Katedrze Technologii Maszyn i Automatyzacji ATH.

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Hamid FABLER[1]

ZMINIATURYZOWANE STANOWISKO BADAWCZE DO TESTÓW ROZCIĄGANIA

Streszczenie: Własności materiałowe w odniesieniu do rozciągania – takie jak graniczna wytrzymałość na rozciąganie, wytrzymałość na rozciąganie, wydłużenie oraz współczynnik elastyczność są bardzo ważnymi czynnikami w projektowaniu inżynierskim obiektów technicznych. Jednakże, dla studentów nie jest łatwym do zrozumienia oraz oszacowania własności materiałowe w odniesieniu do rozciągania. W niniejsze pracy, opisujemy małą oraz łatwą w obsłudze maszynę/stanowisko do testów na rozciąganie. Została ona zaprojektowana, aby pomoc studentom przeprowadzić testy na rozciąganie w pomieszczeniach uczelni, posługując się miniaturową próbką. Maszyna testowa do testowania rozciągania składa się z silnika krokowego używanego jako źródła obciążenia, czujnika obciążania, wzmacniacza sygnału z czujnika obciążenia, systemu akwizycji danych oraz ramy maszyny testującej. Zmierzony sygnał obciążenia jest wzmacniany przez wzmacniacz i przesyłany do systemu akwizycji danych (DAQ). System DAQ współpracując z oprogramowaniem LabVIEW otrzymuje sygnały z czujników obciążenia oraz czujnika przemieszczenia. Stosując tą maszynę testującą, można przeprowadzać testy rozciągania na miniaturowych próbkach dla prędkości zmian przemieszczenia w zakresie 0.001~1.0 mm/s.

Słowa kluczowe: przenośne stanowisko do testów na rozciąganie, miniaturowa próbka, obróbka cieplna, wykres ‘naprężenie-odkształcenie’

DESIGN MINIATURIZED TENSILE TESTING MACHINE

Summary: The tensile properties of materials, such as the ultimate tensile strength, yield strength, elongation and elastic modulus, are very important factors for engineering designs. However, it is not easy for students to understand and evaluate the tensile properties of materials. In this study, a small and handy tensile testing machine was designed to help students conduct tensile tests in class using a miniature tensile specimen. The tensile testing machine consists of a stepping motor as an actuator, a load-cell, a load-cell amplifier, a data acquisition system and the testing machine frame. The detected load signal is amplified by the amplifier and is sent to the data acquisition (DAQ) system. The DAQ system with LabVIEW software receives the signals from the load-cell and displacement gauge. Using this testing machine, it is possible to conduct tensile tests on miniature tensile specimens at speeds of 0.001~1.0 mm/s..

Keywords: portable tensile testing machine, miniature specimen, heat treatment, stress-strain curve

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1. Introduction

In engineering design and analysis, tensile stress-strain relationships are frequently needed. From the relationships of the material, various mechanical properties, such as the ultimate tensile and yield strengths, Young's modulus, Poisson's ratio, the elongation, and reductions in area can be obtained. Also, the true stress-strain properties, strain hardening and tensile toughness can be calculated by means of conversion using special equations from the stress-strain curve.

To conduct a tensile test, it is first necessary to consider the tensile testing equipment and specimens. The most widely used tensile testing machines are screw-driven testing machines with a moving crosshead and a closed-loop servo- hydraulic testing machine with a hydraulic actuator. However, testing machines are relatively heavy and are typically installed in a laboratory. Conventional test methods for evaluating mechanical properties require a massive testing machine and relatively large material samples.

Miniature tensile testing techniques to obtain the mechanical properties of materials have been an interest of many researchers [1-5]. Partheepan et al proposed a simple miniature disc-type tensile specimen and fixtures to hold specimens with the help of a rigid pin to predict the mechanical properties of materials [1]. They verified the feasibility of the sample geometry using finite element method (FEM) analysis.

A miniforce tester driven by a DC-servomotor with a ball-screw guide-way was newly developed for a solder ball joint shear test by Chao and Liu [2]. The full-scale displacement and maximum applied load were 100 mm and 100 kgf, respectively. The displacement resolution of the stage was maintained at 1 micron using a precision digital displacement gage closed-loop control module. LaVan developed a tensile testing system to perform tensile tests on microsamples 3.1 mm long with a gauge cross-section of 0.2 mm2 [3]. They conducted a tensile test of samples cut from weld metal to investigate the local mechanical properties of the weld joint.

A novel tensile device compatible with a scanning electron microscope (SEM) was designed and built by Ma et al [4]. They integrated a servo-motor and a three-stage reducer for a quasistatic loading mode with a loading speed of 10 nm/s. They adopted a small lead precise ball screw with left- and right-hand threads to keep the center of the specimen stationary during the tensile test.

Hou and Chen developed a new uniaxial tensile testing system, consisting of a closed-loop piezo-electric (PZT) actuator, a load cell, and two grippers to hold the specimen in order to investigate the mechanical behavior of thin films [5]. However, these systems are complicated and/or much more expensive than conventional tensile testing methods.

Acquiring new instructional laboratory apparatuses and preparing samples are a challenge due to typical budgetary limitations. In addition, sophisticated skills are required to operate the testing machine, especially the servo-hydraulic testing machine. Therefore, a new approach for an easy-to-handle and inexpensive tensile testing system is necessary for undergraduate students in mechanical, civil and materials engineering, so that they may conduct tension tests easily by themselves.

In this article, a miniaturised tensile testing system involving the use of a specially designed miniature tensile specimen is proposed. The system developed was designed to convert the rotation motion of a ball screw into the linear motion of specimen grips that apply a tensile load to the specimen. The frame contains an aligned linear motion guide for the movement of the specimen grips, ensuring the co-linearity of the travel axes. One side of the specimen is connected to a ball-screw block and the other side is connected to a load-cell to detect the load magnitude. It was concluded that such an apparatus can be designed, developed and constructed in house within a manageable budget. This can be accomplished by taking advantage of the capstone senior design project.

2. Design of the tensile testing machine specifications

The performance requirements of the machine were established for breaking using a 6061 aluminium alloy plate specimen with a thickness of 1 mm. In terms of the loading capacity of the testing machine, the specimen preparation and handling processes, thin miniaturized specimens are suitable. The functional requirements of the machine are as follows:

- Sample size: 1 mm thick, gauge cross-section area of 4 mm2, and gauge length of 8 mm.
- Maximum stroke: 20 mm.
- Maximum tensile force: 2.0 kN.

3. Design concept

The machine is designed to pull one end of the sample, while the other end of the sample is attached to the load cell to monitor the applied load. The maximum tensile load to break the aluminium 6061 sample with a cross section area of 4 mm2 and an ultimate tensile strength of at most 300 MPa was determined to be 1.2 kN. Thus, the maximum tensile force requirement of the machine was set to 2.0 kN. The load is measured with load cells with 0.5% of the maximum rated load.

In order to pull the sample without torsion, a ball screw converts the stepping motor rotation into linear motion. A ball screw with a diameter of 10 mm and pitch of 2 mm positioned in line with the specimen provides the tensile force. A chain is used to couple the stepping motor to the ball screw because a collinear arrangement would have made the system too long. A stepping motor with a capacity of 40 N-cm generates a full rotation in 200 steps and can be driven by the control system in 1/5 steps. A linear motion guide is adopted for precise alignment of the specimen without any distortion during gripping and tensile loading. Figure 1 shows the overall structure of the miniaturized tensile testing machine.

Figure 1. Photo of the miniature tensile testing machine with a size of 330 x 280 x 155 mm: 1) stepping motor; 2) ball screw block; 3) specimen holders; 4) miniature tensile specimen; 5) load-cell; 6) displacement gage; 7) chain; 8) bearing holder; 9) linear motion guide; and 10) control box.

A special specimen holder was designed to carry out the tensile test. The specimen holder consists of two fixtures made of die steel, as shown in Figure 2.

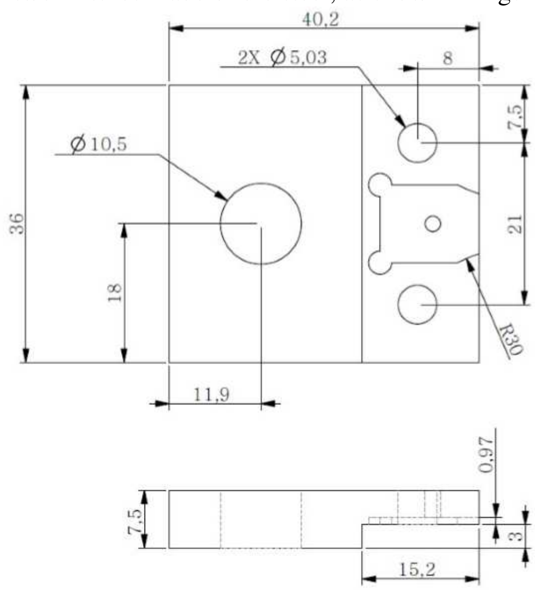

Figure 2. Dimensions of the specimen holder (all dimensions in mm)

The specimen fits into a cut-out in the specimen holder. The cut-out is machined into the same shape and dimension of the grip section of the specimen, 0.97 mm deep on the holder, for easy fixing of the specimen. The fixture is provided in the form of a hole that is 10.5 mm in diameter to hold the specimen with the help of a loading pin with a diameter of 10 mm. The test specimen experiences the tensile load through the loading pin. The specimen is attached at both ends by fixing the specimen holders. The prepared test specimen fixed in, then, gripped with the help of the loading pin. The test was carried out in the present case with a speed of 0.15 mm/min. A preload of 1 N is applied to nullify the effect of any initial nonlinearity in the output of the miniature test.

A National Instruments USB-6009 data acquisition card is used to create the square-wave signal that drives the stepper motor and to acquire the analogue signals from the load cell indicator as well as the displacement gage. The application software of the system is written in LabVIEW, a graphical programming language provided by National Instruments. The graphical user interface (GUI) provides the user with complete control over all aspects of the tensile testing machine, as shown in Figure 3. When first powered up, the GUI guides the user through all of the steps necessary to conduct the measurements. Geometrical details such as the length, width and thickness of the test specimen are supplied to the software. All data gathered throughout the experiments can be exported to a text file for further processing using a spreadsheet tool.

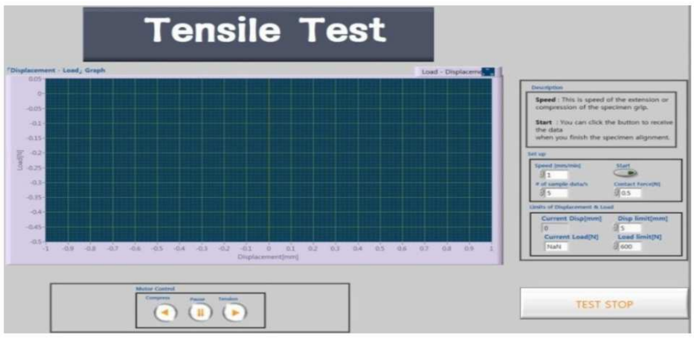

Figure 3. The user interface written in LabVIEW. The interface includes a real-time plot of the applied load against displacement. Also included are setup routines for the sample setup process.

4. Specimen testing

In this study, a miniature specimen is designed, as shown in Figure 4.

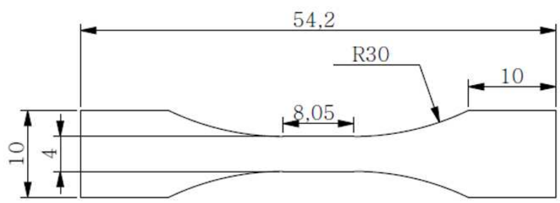

Figure 4. Dimensions of the miniature tensile specimen.

The size and dimensions of the specimen were miniaturised, based on a conventional standard tensile specimen. A finite element analysis of the miniature tensile test was

carried out using the commercially available OptiStruct code in order to verify the specimen geometry without stress concentration. An elastic analysis of this test was carried out with the specimen geometry using various radii (from 5 mm to 40 mm) of gauge section of the specimen.
Figure 5 shows the longitudinal stress distribution at an applied load of 500 N. The nominal stress of the gauge section with a cross-section area of 4 mm2 is 125 MPa, as expected. The stress distribution result verifies that there is no stress concentration on the gauge section of the specimen geometry with a radius of 30 mm, as shown in Figure 5.

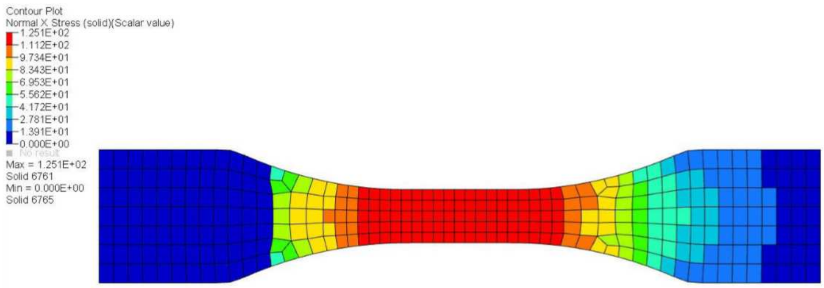

Figure 5. Finite element result of the miniature specimen to check the stress concentration

In order to make many specimens inexpensively for students, a punching process was adopted. The punch and die were made of SKD11 die steel. A die in the same shape as the specimen is punched on a thin plate with a thickness of 1 mm, as shown in Figure 6. The procedure for making this specimen is much easier compared with those of conventional tensile test specimens, which require a number of machining operations.

Figure 6. Photo of the specimen using a blanking process and a blanked-out plate.

5. Tensile testing and results

Different types of heat treatment are generally utilised to achieve a good combination of strength and ductility. Therefore, in order to help students understand the effects of heat treatments on mechanical properties, five specimens were provided to acquire the optimal heat treatment condition with respect to the ultimate tensile strength. The students were supposed to conduct tensile tests of specimens, which had been heat-treated under different conditions. In order to understand the influence of a heat treatment on the mechanical behaviour, heat-treatable aluminium 6061 alloy was adopted.

The students were supposed to find the optimal ageing time for the highest tensile strength of the 6061 alloy within an aging time range. The specimens were solid-solution-treated at 803 K for 1 hour, quenched in room-temperature water and, then, underwent aging treatments within an aging range of 0 to 300 minutes. The students had to choose an arbitrary aging time from between 0 and 300 minutes, because the maximum ultimate tensile strength was found near 120 minutes according to our previous experimental results. The students were asked to provide the stress-strain curve of the tested samples and determine the optimum aging time for the highest ultimate tensile strength in a laboratory class. They also had to summarise the test results, as shown in Table 1.

Table 1. Summarised tensile test results on various aging time

Ageing time (min.)	YS (MPa)	UTS (MPa)	Elongation (%)
0	81.1	169.5	42.3
10	150.8	258.7	27.3
30	254.2	298.5	17.5
60	276.1	302.3	12.8
120	287.8	309.9	13.3
180	274.2	297.6	13.5
210	275.2	303.7	13.7
240	245.1	282.4	15.2
300	243.2	283.8	13.9

Figure 7 presents the engineering stress-strain curves of the aluminium 6061 alloy at various aging times. Regarding the solid-solution treated sample, the ultimate tensile strength (UTS) and yield strength (YS) were 81.1 MPa and 169.5 MPa, respectively. The maximum UTS of the aged treatment of aluminium 6061 alloy was 309.9 MPa, which is close to that of aluminium 6061 T6 tempered alloy [6]. Therefore, from Figure 7, the optimal aging time for obtaining the highest UTS was found to be close to 120 minutes. Compared to the solid-solution-treated sample, the UTS and YS of the aged sample with an aging time of 120 minutes both increased dramatically by 83.9% and 254.9%, respectively. However, the degree of elongation decreased from 42.3% to 13.3%. The difference in the strength and ductility is attributed to the precipitation strengthening effect from the heat treatment. From these experiments, students could understand the effect of a heat treatment on mechanical properties and could learn how to acquire the UTS, YS and elongation of materials from tensile tests. Figure 8 shows the UTS and YS values against aging times for the solid-solution-treated aluminium 6061 alloy samples. According to this figure, the UTS and YS increased continuously up to 120 minutes and, then, decreased with increasing ageing time.

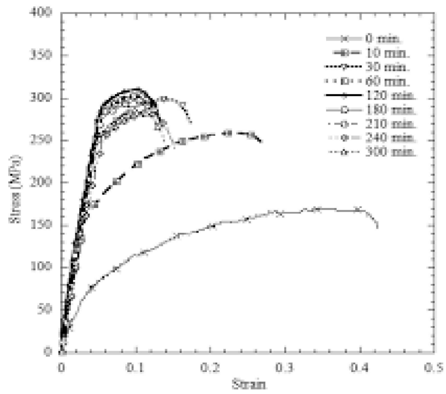

Figure 7. Example of a uniaxial tensile stress-strain curve for various aging-treated Al-6061 alloys

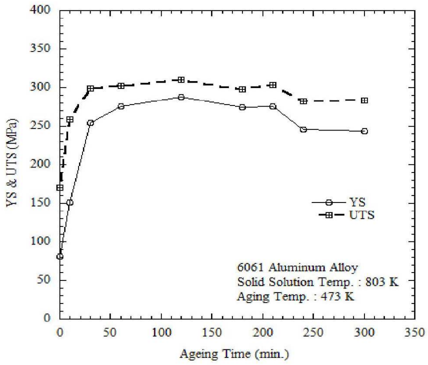

Figure 8. YS and UTS results for the 6061 aluminium alloys after the heat treatment

6. Conclusions

This article described a method to evaluate material properties using a miniature tensile testing machine with a miniature specimen through a simple experimental setup. A portable miniaturised tensile testing apparatus was designed and developed. The newly designed specimen is small in size and easy to prepare. Finally, the developed testing system can be used as an instructional experimental apparatus to assist students in their efforts to understand the basic mechanical properties of materials.

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MECHANIZM PRZESTRZENNY Z PARAMI KINEMATYCZNYMI Z UŻYCIEM WAŁKA ŚLIMAKOWEGO O ZMIENNYM SKOKU

Streszczenie: W niniejszej pracy opisano nowe rozwiązanie koncepcyjne mechanizmu przestrzennego. Mechanizm zbudowany jest z ogniw będących w podwójnym kontakcie m.in. ogniwami są przekładnie ślimakowe o zmiennym skoku. Proponowany mechanizm ma zdolność do pracy w ograniczonej przestrzeni współrzędnych kartezjańskich ze względu na nałożone więzy.

Słowa kluczowe: Mechanizm, stopień swobody, para kinematyczna

DEVELOPMENT OF THE SPATIAL MECHANISM WITH VARIABLE PITCH IN SCREW KINEMATIC PAIR

Summary: The present study focuses on the development of new spatial mechanism with variable pitch in screw kinematic pair which have been made double contact by connection of two-DoF cylindrical and five-DoF dotted pairs. The proposed mechanism has the ability to work in the limited Cartesian space of coordinates after imposition of two general contraints on the movement of its links.

Keywords: mechanism, degree-of-freedom, kinematic pair

1. Introduction

Spatial mechanisms are used more and more in modern engineering applying for various technological operations [1-4]. One of the families of spatial mechanisms includes mechanisms with two general imposed constarints or so-called "mechanisms of the second family" according to the classification Professor Artobolevsky I.I. [5].

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These mechanisms are spatial closed kinematic chains by the structure, the number of degrees of freedom for them is calculated by the formula [6]

$$W_2 = 4n - 3p_5 - 2p_4 - p_3 \quad (1)$$

where n – number of movable links, p_5, p_4 and p_3 – numbers of one-, two- and three-DoF kinematic pairs. The coefficient of n equalled to four means that the output link in such mechanisms can have four relative movement in three-dimensional Cartesian space of coordinates.

2. Synthesis of the kinematic scheme of five-bar mechanism with two general imposed constraints

From formula (1) when $W_2 = 1$ and if $p_4 = 0$ and $p_3 = 0$, the simplest structure of mechanism will be one with n=4, $p_5 = 5$ (we consider systems with number of mobile links n ≥ 3). All links in this mechanism will be the two-paired, i.e. adding two kinematic pairs by each [7].
Mechanism is constructed by these parameters is shown in Figure 1 [8]. It consists of four mobile links, interconnected itself and fixed link by five one-DoF kinematic pairs.

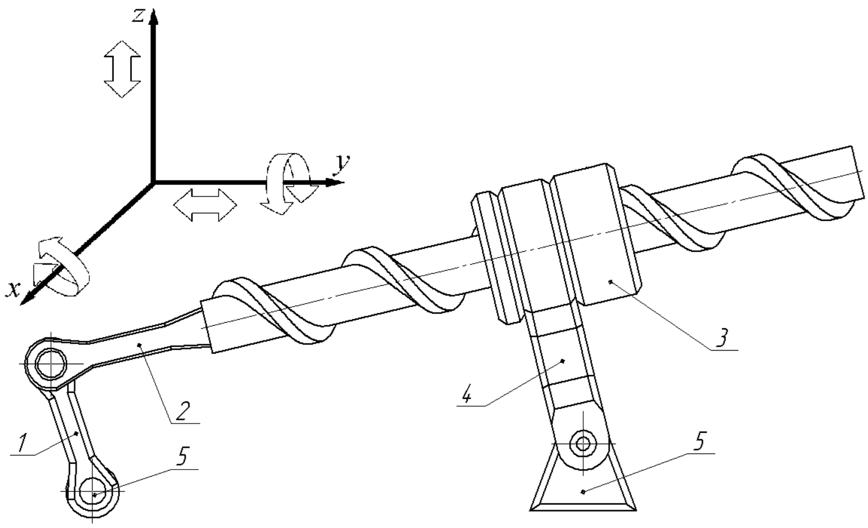


Figure 1. Five-bar mechanism with two imposed constraints

Under positions 1-5 there are designated in the Figure 1: crank, screw coupler, nut, rocker and fixed link. Two general constraints are imposed in this mechanism in a way that eliminates rotation around axis *z* and sliding motion along the axis *x*. The remaining four movements are possible, they are shown with respect to the coordinate axes in the Figure 1.

3. The application of double-contact screw kinematic pair in mechanism with two general imposed constraints

Screw kinematic pair as a connection of screw and nut (kinematic pair of links 2-3 in the Figure 1) can be used as a double contact [9] in the form of two-DoF cylindrical pair and five-DoF dotted pair (Figure 2). The connection of thes two pairs will result one-DoF screw pair, however with additional functional capabilities.

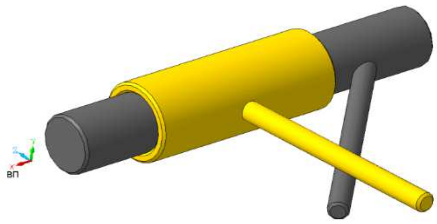


Figure 2. Double-contact screw kinematic pair

Contacts in this pair carried on the surface ("cylinder-chute") and at the point of contact between two fingers, one of which connected with cylinder, another one with gutter. To give a sliding motion for the cylinder along its axial axis, its additional rotation relatively gutter will be performed, i.e. screw motion will be reprodiced. Both movements are connected with the formula

$$\varphi = f(h) \tag{2}$$

where φ - angle of rotation of the cylinder around its axial axis, which depends on the angle between fingers forming additional constraint, h – sliding motion of the cylinder relativeli its axial axis.

The disadvantage of the above-mentioned pair, is that its links are not made as retained, because fingers have only point contact. This leads to the impossibility of practical application of this pair in mechanisms and machines. In this regard, it was proposed to perform this pair with retained links as it is shown in Figure 3.

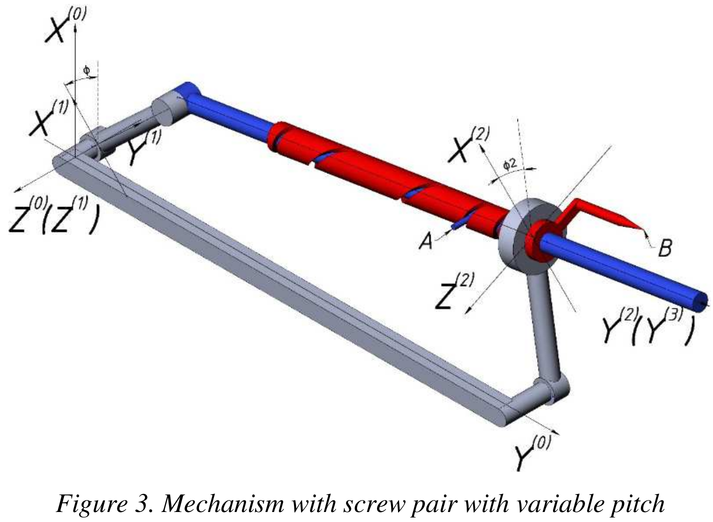


Figure 3. Mechanism with screw pair with variable pitch

The number of DoF of this mechanism, the types of links and DoF of kinematic pairs compared to the five-bar mechanism from the Figure 1 remain the same, but the output motion of the nut has big difference in view of the fact that the screw kinematic pair is formed with variable pitch. This transformation of the mechanism allows to vary the type of spatial curve which is reproducible by the output link, by changing the curvature of the slot in the double-contact screw pair.

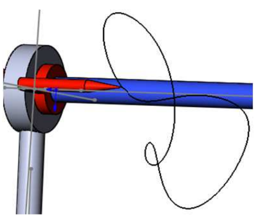
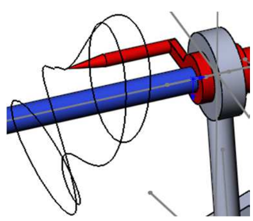
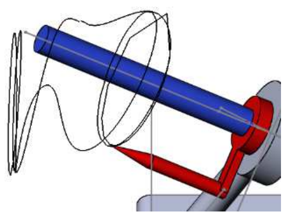
Discuss the operation principle of the mechanism with variable pitch. Given the rotation for the crank through an angle φ, then the coupler moving coplanar will transmit a movement to the nut in screw kinematic pair via a finger which is connected to the cylinder as a one link. Next nut, remaining coaxial with coupler, and rotating through an angle φ_2 relatively to the rocker 4, sets the movement of the working tool *B*, reproducing a spatial curve. The rocker 4, closing the kinematic chain, makes oscillating movement.

The practicability of using a variable pitch in screw pair, may be required due to different conditions. For example, if it is necessary to accelerate a working body or to have its smooth deceleration, reducing the overall resistance of mechanism, loads on the drive. Variable character of movement allows to apply it in equipments for mixing different mixtures.

4. Reproducing a path of motion by the output link

Refer to the determination of the path motion of the output link. The shape of the path depends on driving link speed and such geometric parameters of the mechanism, as the dimensions of the links, the orientation of slot on the gutter (angle of ascent of helix). The shapes of the curves reproduced by the working tool depending on the above-mentioned parameters are shown in the Table 1.

Table 1. Spatial curves at various ratios of turnover of nut and crank

1 turnover of nut / 1 turnover of crank	2 turnovers of nut / 1 turnover of crank	3 turnovers of nut / 1 turnover of crank
		

Thus, changing the parameters of the mechanism, we can get different types of spatial spiral curves with different pitches, curvature of the axis of helix and the angle of its ascent.

5. Conclusions

1. We have considered the novel scheme of spatial five-bar mechanism with the application of double-contact screw kinematic pair with variable pitch.
2. It was substantiated an operation principle of the mechanism and presented its three-dimensional model.
3. Using the computational calculation we have simulated space curves reproducible by output link, a nut, when ratios of turnover of nuts and crank are 1:1, 1:2 and 1:3.
4. Developed mechanism can be realized for reproduction of spatial spiral curves with different parameters, for mixing of building materials due to the complex helical movement of the output link.

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STATYKA I KINEMATYKA PRZEKŁADNI BIPLANETARNEJ

Streszczenie: W referacie przedstawiono metodykę wyznaczania przełożenia kinematycznego i sił obwodowych i promieniowych w zazębieniach kół przekładni biplanetarnej. Te obliczenia można uznać za podstawowe i ważne, gdyż poprzedzają one obliczenia projektowe poszczególnych kół zębatych, wałów i łożysk przekładni biplanetarnej.

Słowa kluczowe: statyka, kinematyka, przekładnia biplanetarna, wzór Willisa

STATICS AND KINEMATICS OF BIPLANETARY GEARS

Summary: The paper presents a methodology of determining the kinematical ratio of biplanetary gear and forces (circumferential and radial) in meshing of gear wheels. These calculations are the basic and very important calculations, since they precede the designing calculation of wheels, shafts and bearings of biplanetary gear.

Keywords:statics, kinematics, biplanetary gear, Willis formula

1. Wprowadzenie

Przykład przekładni biplanetarnej, obiegowej podwójnej przedstawiono na rysunku 1. Składa się ona z głównej przekładni obiegowej złożonej z koła słonecznego 1 zazębionego z pierwszym wieńcem satelity 2, jarzma h oraz pary kół, tj. satelity 6 zazębionego z unieruchomionym kołem centralnym 7. Przekładnia obiegowa wewnętrzna zwana satelitarnym mechanizmem obiegowym złożona jest z koła słonecznego 3, satelitów 4, koła wewnętrznego 5 oraz jarzma H. Jarzmo H napędza koło obiegowe 6 należące już do przekładni głównej. Koło centralne 5 wchodzące w skład satelitarnego mechanizmu obiegowego jest jednocześnie jarzmem h głównej przekładni obiegowej.

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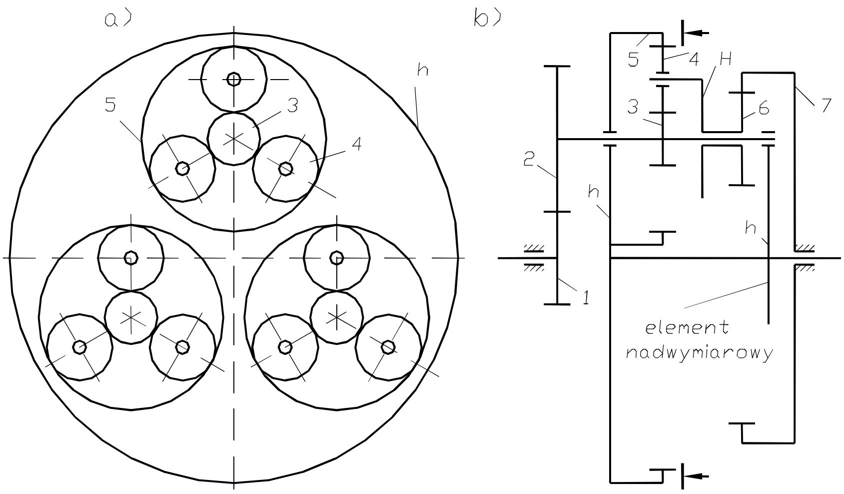
Charakterystyczną cechą tej przekładni jest to, że satelity obiegowego mechanizmu satelitarnego wykonują ruch złożony obracając się wokół trzech osi – własnej, centralnej mechanizmu planetarnego i centralnej głównej przekładni obiegowej. Ta właściwość przekładni wykorzystywana jest głównie w organach urabiających kombajnów górniczych oraz maszyn rolniczych.
Stopień ruchliwości tej przekładni wynosi:

$$W = 3 \cdot n + 2 \cdot p_5 - p_4 = 15 - 10 - 4 = 1, \tag{1}$$

gdzie:
$n = 5$ - liczba elementów ruchomych,
$p_5 = 5$ - liczba par 5. klasy,
$p_5 = 4$ - liczba par 4. klasy (zazębień, liczonych tylko raz).



Rysunek 1. Schemat kinematyczny przekładni biplanetarnej

Stopień ruchliwości $W = 1$, tak więc do wyznaczenia prędkości każdego z elementów przekładni wystarczy tylko jedna dana wartość prędkości wyjściowej bądź wejściowej.

2. Przełożenie kinematyczne przekładni

Zgodnie z definicją przełożenia kinematycznego przełożenie $i^7_{1,h}$ (od zębnika 1 do jarzma h przy kole 7 nieruchomym) tej przekładni wynosi:

$$i^7_{1,h} = \left(\frac{n_1}{n_h}\right)_{n_7=0}, \tag{2}$$

gdzie $n_1 = n_N = n_{wej}$ jest prędkością zębnika 1, czyli wejściową przekładni, a $n_h = n_{wyj}$ prędkością jarzma h, czyli prędkością wyjściową przekładni (Rys. 1).

W celu wyznaczenia tego przełożenia kinematycznego $i_{1,h}^{7}$ należy najpierw wyznaczyć przełożenie bazowe przekładni wewnętrznej przy nadaniu całej przekładni obiegowej prędkości obrotowej równej $-n_h$ (czyli rozpatrywać jej kinematykę względem jarzma h) [2, 3]. Wtedy względne prędkości obrotowe poszczególnych kół przekładni są równe $n_j^h = n_j - n_h$ dla $j = 1, 2, \ldots, 7$, przy czym $n_5^h = n_5 - n_h = 0$ (bo $n_5 = n_h$) oraz $n_7^h = n_7 - n_h = -n_h$ (bo $n_7 = 0$).

Podobnie względna prędkość obrotowa jarzma wewnętrznego H względem jarzma h wynosi $n_H^h = n_H - n_h$.

Przełożenie bazowe planetarnej przekładni wewnętrznej złożonej z kół 3, 4, 5 oraz jarzma H o danych prędkościach względnych n_3^h, n_4^h, n_5^h i n_H^h można wyznaczyć ze wzoru Willisa:

$$i_{3,5}^{H} = \frac{n_3^h - n_H^h}{n_5^h - n_H^h} \tag{3}$$

oraz ze wzoru na przełożenie kół 3, 4 i 5 względem jarzma H w funkcji liczby zębów (jak dla przekładni o osiach stałych):

$$i_{3,5}^{H} = \left(\frac{n_3^h - n_H^h}{n_4^h - n_H^h}\right)\cdot\left(\frac{n_4^h - n_H^h}{n_5^h - n_H^h}\right) = \left(\frac{n_3^h - n_H^h}{n_5^h - n_H^h}\right) = \left(-\frac{z_4}{z_3}\right)\cdot\left(-\frac{z_5}{z_4}\right) = \left(\frac{z_5}{z_3}\right), \tag{4}$$

czyli

$$i_{3,5}^{H} = \left(\frac{z_5}{z_3}\right) = \frac{n_3^h - n_H^h}{-n_H^h}, \tag{5}$$

bo $n_5^h = n_5 - n_h = 0$.

Aby wyznaczyć poszukiwane przełożenie przekładni biplanetarnej należy niewiadome prędkości względne n_3^h oraz n_H^h w powyższym wzorze (5) wyznaczyć w funkcji n_h i/lub n_1 z dwóch warunków na przełożenia $i_{H,7}$ (przełożenie od jarzma H do koła 7) oraz $i_{3,1}$ (przełożenie od koła 3 do koła 1):

$$i_{H,7} = \frac{n_H^h}{n_7^h} = \frac{n_6^h}{n_7^h} = -\frac{z_7}{z_6}, \tag{6}$$

skąd

$$n_H^h = n_7^h \cdot \left(-\frac{z_7}{z_6}\right) = n_h \cdot \frac{z_7}{z_6}, \tag{7}$$

bo $n_7^h = n_7 - n_h = -n_h$.

Podobnie

$$i_3^1 = \frac{n_3^h}{n_1^h} = \frac{n_2^h}{n_1^h} = -\frac{z_1}{z_2} \tag{8}$$

skąd

$$n_3^h = n_1^h \cdot \left(-\frac{z_1}{z_2}\right) = (n_1 - n_h) \cdot \left(-\frac{z_1}{z_2}\right), \tag{9}$$

bo $n_3 = n_2$, czyli także $n_{3,h} = n_{2,h}$.

Tak więc iloraz liczby zębów z_5/z_3 ze wzoru (7) po kolejnych przekształceniach przyjmuje postać (12):

$$\left(\frac{z_5}{z_3}\right) = \frac{\left(\frac{n_1}{n_h} - 1\right) \cdot \left(-\frac{z_1}{z_2}\right) - \frac{z_7}{z_6}}{-\frac{z_7}{z_6}}. \tag{10}$$

Stąd wzór na przełożenie przekładni biplanetarnej (2) przedstawia się następująco:

$$i_{1,h}^{7} = \left(\frac{n_1}{n_h}\right)_{n_7=0} = 1 - \frac{z_7}{z_6} \cdot \frac{z_2}{z_1} \cdot \left(1 - \frac{z_5}{z_3}\right). \tag{11}$$

Przykładowo wartość przełożenia dla przyjętych liczb zębów przekładni biplanetarnej $z_1 = 21$, $z_2 = 81$, $z_3 = 21$, $z_4 = 24$, $z_5 = -69$, $z_6 = 21$, $z_7 = -72$ wynosi:

$$i_{1,h}^{7} = 1 - \frac{z_7}{z_6} \cdot \frac{z_2}{z_1} \cdot \left(1 - \frac{z_5}{z_3}\right) = 1 - \frac{-72}{21} \cdot \frac{81}{21} \cdot \left(1 - \frac{-69}{21}\right) = 57{,}676. \tag{12}$$

3. Siły w zazębieniach kół zębatych

Rozkład sił obwodowych w zazębieniach wyznaczono metodą wykreślno-analityczną. Na rysunku 2 przedstawiono siły obwodowe działające na koło słoneczne 1 (czynne) oraz na trzy satelity 2. Założono prawy kierunek prędkości kątowej (obrotowej) koła 1, czyli także prawy kierunek wejściowego momentu obrotowego T_1. Do wyznaczenia sił w zazębieniach konieczne są wartości średnic kół, które wyznaczono zakładając wstępnie wartości modułów $m_I = 2$ oraz $m_{II} = 4$.

Z warunku równowagi obrotowej zębnika 1 wyznaczono wartość siły obwodowej $F_{o1,2}$ działającej na ząb zębnika 1 a pochodzącej od oddziaływania zęba koła 2:

$$T_1 - s_I \cdot F_{o1,2} \cdot \frac{d_1}{2} = 0, \tag{13}$$

skąd

$$F_{o1,2} = \frac{2 \cdot T_1}{s_I \cdot d_1} = \frac{T_1}{s_I \cdot r_1} = \frac{2 \cdot T_1}{s_I \cdot m_I \cdot z_1} = \frac{2 \cdot 120{,}2 \cdot 10^3}{3 \cdot 2 \cdot 21} = 1907{,}937 \text{ N}, \tag{14}$$

gdzie $s_I = 3$ jest liczbą kół 2 (satelitów) odbierających napęd od zębnika 1.

Zgodnie z zasadą akcji i reakcji zachodzi równość sił:

$$\vec{F}_{o2,1} = -\vec{F}_{o1,2},$$

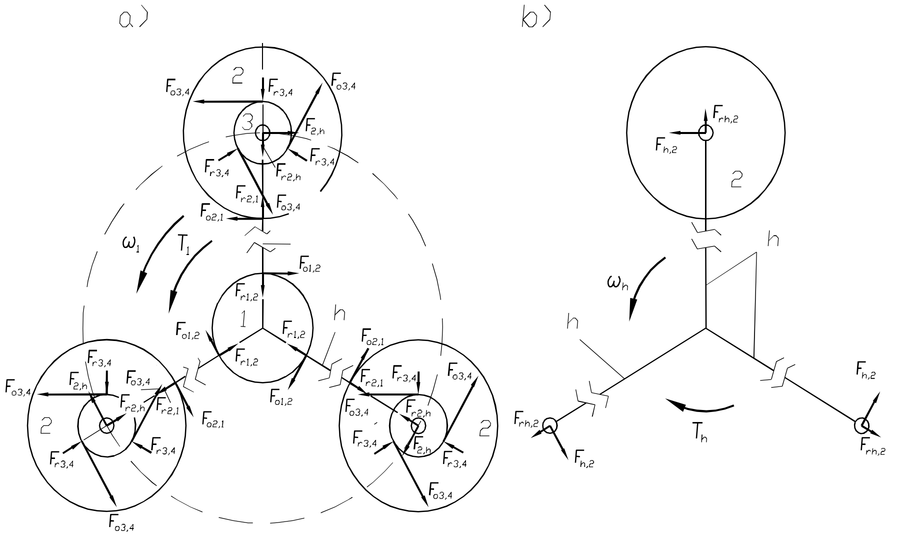
czyli wartość siły $F_{o2,1}$ wynosi:

$$F_{o2,1} = F_{o1,2} = 1907{,}937\ \mathrm{N}\,, \tag{15}$$

gdzie $F_{o2,1}$ jest siłą obwodową działającą na ząb koła 2 pochodzącą od oddziaływania zęba zębnika 1.

Z warunku równowagi momentów obrotowych działających na koła 2 i 3 można wyznaczyć wartości trzech sił obwodowych $F_{o3,4}$ działających na zęby koła słonecznego 3 a pochodzących od oddziaływania zębów trzech satelitów 4 (Rys. 2):

$$F_{o2,1} \cdot \frac{d_2}{2} - s_{II} \cdot F_{o3,4} \cdot \frac{d_3}{2} = 0\,. \tag{16}$$



Rysunek 2. Siły w zazębieniu kół 1, 2 i 3

Tak więc siła obwodowa $F_{o3,4}$ działająca na ząb koła słonecznego 3 wynosi:

$$F_{o3,4} = F_{o2,1} \cdot \frac{d_2}{s_{II} \cdot d_3} = F_{o1,2} \cdot \frac{r_2}{s_{II} \cdot r_3} = \frac{T_1}{s_I \cdot r_1} \cdot \frac{r_2}{s_{II} \cdot r_3} = \frac{2 \cdot T_1}{3 \cdot m_I \cdot z_1} \cdot \frac{m_I \cdot z_2}{3 \cdot m_{II} \cdot z_3}\,, \tag{17}$$

gdzie $s_{II} = 3$ jest liczbą satelitów 4 zazębionych z kołem 3 i kołem wieńcowym 5, r_2 i r_3 są promieniami kół podziałowych 2 i 3 ($r_2 = d_2/2$; $r_3 = d_3/2$), czyli:

$$F_{o3,4} = 1907{,}937 \cdot \frac{162}{3 \cdot 42} = 2453{,}062\ \mathrm{N}\,. \tag{18}$$

Siła promieniowa:

$$F_{r3,4} = F_{o3,4} \cdot \mathrm{tg}\,\alpha = 2861{,}906 \cdot \mathrm{tg}\,20^\circ = 892{,}842\ \mathrm{N}\,. \tag{19}$$

Koło obiegowe 2 zazębione jest jedynie z kołem słonecznym 1, tak więc działa na niego moment obrotowy T_2 wyznaczony z równania równowagi obrotowej koła 2:

$$T_2 - F_{o2,1} \cdot \frac{d_2}{2} = 0\,, \tag{20}$$

czyli

$$T_2 = F_{o2,1} \cdot \frac{d_2}{2} = 1907{,}937 \cdot \frac{2 \cdot 81 \cdot 10^{-3}}{2} = 154{,}543\ N \cdot m\,. \qquad (21)$$

Dla zapewnienia równowagi obrotowej wału kół 2 i 3 ułożyskowanego w jarzmie h wartość momentu T_2 jest równa wartości momentu T_3 działającego na satelitę 3:

$$T_3 = s_{II} \cdot F_{o3,4} \cdot \frac{d_3}{2} = 3 \cdot 2453{,}062 \cdot 21 \cdot 10^{-3} = 154{,}543\ N \cdot m = T_2\,. \qquad (22)$$

Wartość siły poziomej $F_{2,h}$ działającej na oś kół 2 i 3 od oddziaływania wału jarzma h wyznacza się z równania rzutu sił działających na koła 2 i 3 na oś poziomą:

$$F_{2,h} - F_{2,1} + F_{3,4} \cdot (2 \cdot \cos\varphi - 1) + F_{r3,4} \cdot (\sin\varphi - \sin\varphi) = 0\,. \qquad (23)$$

Tak więc:

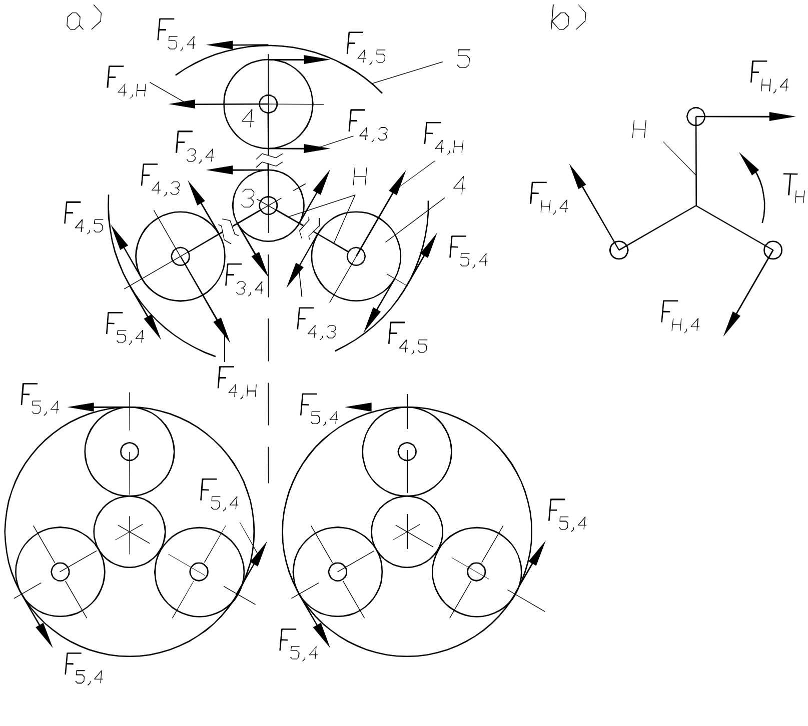
$$F_{2,h} = F_{2,1} = 1907{,}937\ N\,. \qquad (24)$$

Z równania rzutów sił działających na koła 2 i 3 wynika:

$$F_{r2,h} - F_{r2,1} + F_{3,4} \cdot (\sin\varphi - \sin\varphi) + F_{r3,4} \cdot (2 \cdot \cos\varphi - 1) = 0\,, \qquad (25)$$

czyli

$$F_{r2,1} = F_{2,1} \cdot \mathrm{tg}\,\alpha = 1907{,}937 \cdot \mathrm{tg}\,20^\circ = 694{,}432 N\,. \qquad (26)$$



Rysunek 3. Siły w zazębieniu kół 3, 4 i 5 (pominięto siły promieniowe)

Z zasady akcji i reakcji wyznaczyć można siły $F_{h,2}$ i $F_{r\,h,2}$ działające na wał od koła 2:

$$\vec{F}_{h,2} = -\vec{F}_{2,h} \text{ czyli } F_{h,2} = F_{2,h} = 1907{,}937\,N \qquad (27)$$

oraz

$$\vec{F}_{rh,2} = -\vec{F}_{r2,h} \quad \text{czyli} \quad F_{rh,2} = F_{r2,h} = 694,432\,\mathrm{N}. \qquad (28)$$

Mając wyznaczone siły działające na koło 3 - obwodową $F_{o3,4}$ i promieniową $F_{r3,4}$ - można wyznaczyć siły działające na satelitę 4 i koło wieńcowe 5 o uzębieniu wewnętrznym (wykorzystując zasadę akcji i reakcji).

Mianowicie spełnione są zależności wektorowe na siły obwodowe i promieniowe działającą na koła 4 i 5:

$$\vec{F}_{o4,3} = -\vec{F}_{o3,4}, \qquad \vec{F}_{r4,3} = -\vec{F}_{r3,4}, \ \vec{F}_{o5,4} = -\vec{F}_{o4,5}, \qquad \vec{F}_{r5,4} = -\vec{F}_{r4,5},$$

gdzie

$$F_{o4,5} = F_{o4,3} = F_{o3,4} = 2453,062\,\mathrm{N}, \qquad (29)$$

gdyż spełnione jest równanie równowagi:

$$F_{o4,3} \cdot \frac{d_4}{2} - F_{o4,5} \cdot \frac{d_4}{2} = 0. \qquad (30)$$

Tak więc siła obwodowa działająca na ząb koła wieńcowego 5 pochodząca od oddziaływania zęba satelity 4 wynosi:

$$F_{o5,4} = F_{o4,5} = 2453,062\,\mathrm{N}. \qquad (31)$$

Siłę działającą na wał koła 4 pochodzącą od oddziaływania jarzma H wyznacza się z równania równowagi na oś poziomą:

$$F_{4,H} = F_{o4,3} + F_{o4,5} = 2 \cdot F_{o4,3} = 2 \cdot \frac{T_1}{s_I \cdot r_1} \cdot \frac{r_2}{s_{II} \cdot r_3} = 4906,124\,\mathrm{N}. \qquad (32)$$

Korzystając z zasady akcji i reakcji wyznacza się siłę poziomą $F_{H,4}$ działającą na jarzmo H od oddziaływania satelity 4:

$$\vec{F}_{H,4} = -\vec{F}_{4,H}, \quad \text{czyli} \quad F_{H,4} = F_{4,H} = 4906,124\,\mathrm{N}. \qquad (33)$$

Ponieważ $F_{r4,3} - F_{r4,5} = 0$ (bo $F_{r4,3} = F_{r3,4} = F_{r4,5} = F_{r5,4}$), więc składowa pionowa $F_{rH,4}$ siły działającej na jarzmo H wynosi:

$$F_{rH,4} = 0. \qquad (34)$$

Moment obrotowy działający na jarzmo H a pochodzący od oddziaływania $s_{II} = 3$ satelitów 4 wynosi:

$$T_H = s_{II} \cdot F_{H,4} \cdot r_H = s_{II} \cdot 2 \cdot \frac{T_1}{s_I \cdot r_1} \cdot \frac{r_2}{s_{II} \cdot r_3} \cdot (r_3 + r_4), \qquad (35)$$

$$T_H = s_{II} \cdot F_{H,4} \cdot r_H = 3 \cdot 4906,124 \cdot 45 \cdot 10^{-3} = 662,327\,\mathrm{N \cdot m},$$

gdzie promień jarzma H wynosi

$$r_H = \frac{d_3 + d_4}{2} = r_3 + r_4 = \frac{r_3 + |r_5|}{2} = 45. \qquad (36)$$

Moment ten napędza jedno koło 6, gdyż $T_6 = T_H$, gdzie

$$T_6 = F_{o6,7} \cdot r_6. \qquad (37)$$

Tak więc siła obwodowa $F_{o6,7}$ działająca na ząb koła 6 od oddziaływania zęba koła 7 wynosi (Rys. 4):

$$F_{o6,7} = F_{H,4} \cdot s_{II} \cdot \frac{r_3 + r_4}{r_6} = 2 \cdot \frac{T_1}{s_I} \cdot \frac{r_2}{s_{II} \cdot r_1 \cdot r_3} \cdot s_{II} \cdot \frac{r_3 + r_4}{r_6} = 15769{,}684\ \mathrm{N}. \qquad (38)$$

Koło 6 działa na jarzmo h siłą poziomą

$$F_{h,6} = F_{6,h} = F_{o6,7} = 15769{,}684\ \mathrm{N} \qquad (39)$$

oraz pionową

$$F_{rh,6} = F_{r6,h} = F_{r6,7} = F_{o6,7} \cdot \mathrm{tg}\,20^\circ = 5739{,}696\ \mathrm{N}, \qquad (40)$$

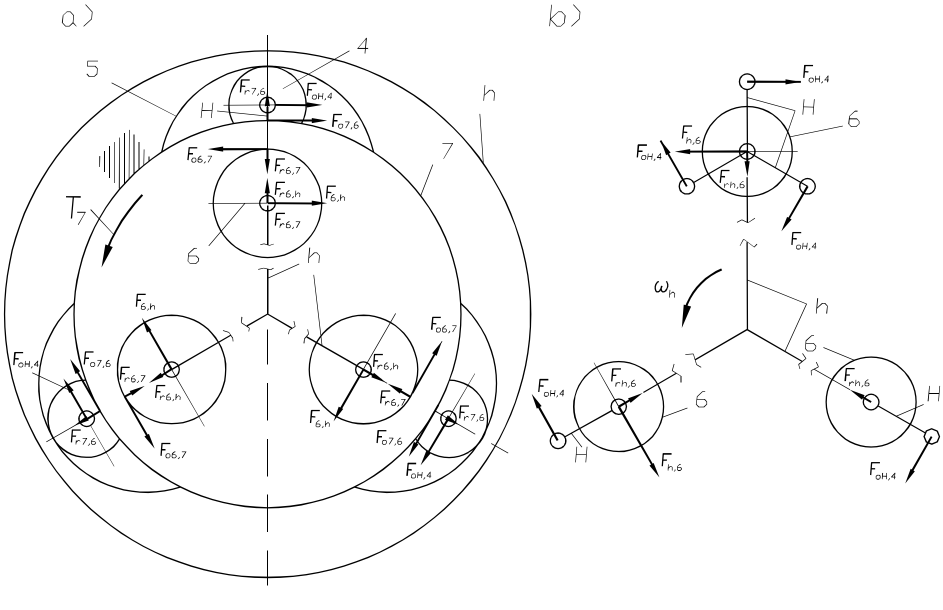
przy czym $\vec{F}_{o6,7} = -\vec{F}_{6,h} = \vec{F}_{h,6}$ oraz $\vec{F}_{r6,7} = -\vec{F}_{r6,h} = \vec{F}_{rh,6}$.

Ponieważ siła działająca na ząb koła wieńcowego 7 pochodząca od oddziaływania zęba koła 6 jest równa $\vec{F}_{o7,6} = -\vec{F}_{o6,7}$, czyli

$$F_{o7,6} = F_{o6,7} = 15769{,}684\ \mathrm{N}, \qquad (41)$$

więc moment hamowania koła 7 (potrzebny do utrzymania koła wieńcowego 7) wyznacza się z równania równowagi momentów obrotowych:

$$T_7 - s_{III} \cdot F_{o7,6} \cdot \frac{|d_7|}{2} = 0. \qquad (42)$$



Rysunek 4. Siły w zazębieniu kół 6 i 7

Po podstawieniu wzoru na siłę $F_{o7,6} = F_{o6,7}$ otrzyma się zależność na moment hamowania koła 7:

$$T_7 = s_{III} \cdot F_{o7,6} \cdot |r_7| = 2 \cdot T_1 \cdot s_{III} \cdot \frac{r_2 \cdot (r_3 + r_4)}{s_I \cdot r_1 \cdot r_3} \cdot \frac{|r_7|}{r_6} = 6528{,}649\ \mathrm{N \cdot m}, \qquad (43)$$

gdzie promień koła 7 wynosi $r_7 = \frac{d_7}{2} = 0{,}5 \cdot m_{II} \cdot z_7 = 0{,}5 \cdot 4 \cdot (-69) = -138$

Wartość momentu wyjściowego T_h wyznaczyć można z równania równowagi jarzma h:

$$s_I \cdot F_{h,2} \cdot r_h + s_{III} \cdot F_{h,6} \cdot r_h + s_{III} \cdot T_5 - T_h = 0 \,, \tag{44}$$

gdzie promień r_h jarzma h oraz siła obwodowa $F_{o5,4}$ działająca na ząb koła 5 wynoszą:

$$r_h = \frac{d_1 + d_2}{2} = r_1 + r_2 = \frac{42 + 162}{2} = 102 \,, \tag{45}$$

$$F_{o5,4} = F_{o4,5} = 2453{,}062\,\mathrm{N} \,. \tag{46}$$

Ponadto moment obrotowy działający na jarzmo 5 pochodzący od oddziaływania trzech kół wieńcowych 5 wynosi:

$$T_5 = s_{II} \cdot s_{III} \cdot F_{o5,4} \cdot \frac{|d_5|}{2} = s_{II} \cdot s_{III} \cdot \frac{T_1}{s_I} \cdot \frac{r_2}{s_{II} \cdot r_1 \cdot r_3} \cdot |r_5| = 1523{,}351\,\mathrm{N \cdot m} \,. \tag{47}$$

Tak więc wzór na moment wyjściowy przyjmuje postać:

$$\begin{aligned} T_h = {} & s_I \cdot \frac{T_1}{s_I \cdot r_1} \cdot (r_1 + r_2) + s_{II} \cdot 2 \cdot \frac{T_1}{s_I} \cdot \frac{r_2}{s_{II} \cdot r_1 \cdot r_3} \cdot s_{III} \cdot \frac{r_3 + r_4}{r_6} \cdot r_H + \\ & + s_{III} \cdot s_{II} \cdot \frac{T_1}{s_I} \cdot \frac{r_2}{s_{II} \cdot r_1 \cdot r_3} \cdot |r_5| \,, \end{aligned} \tag{48}$$

gdzie $r_1 + r_2 = |r_7| - r_6$ oraz $r_3 + r_4 = \dfrac{|r_5| + r_3}{2}$.

Po kolejnych przekształceniach otrzymuje się ostateczną postać wzoru na moment wyjściowy T_h:

$$T_h = T_1 \cdot \left\{ 1 + \frac{r_2}{r_1} \cdot \left[1 + \left(\frac{|r_7|}{r_6} + \frac{|r_5|}{r_3} \cdot \frac{|r_7|}{r_6} - 1 \right) \cdot \frac{s_{III}}{s_I} \right] \right\} . \tag{49}$$

Tak więc wartość momentu wyjściowego T_h wynosi:

$$T_h = 120{,}2 \cdot \left\{ 1 + \frac{81}{21} \cdot \left[\frac{|72|}{21} + \frac{|69|}{21} \cdot \frac{|72|}{21} \right] \right\} = 6932{,}701\,\mathrm{N \cdot m} \,. \tag{50}$$

Ze wzoru (49) można także wyznaczyć wzór na przełożenie kinematyczne:

$$i_{wej,wyj} = 1 + \frac{z_2}{z_1} \cdot \left[1 + \left(\frac{|z_7|}{z_6} + \frac{|z_5|}{z_3} \cdot \frac{|z_7|}{z_6} - 1 \right) \right] . \tag{51}$$

W ten sposób można potwierdzić wartość przełożenia wyznaczoną z wykorzystaniem wzoru Willisa (12):

$$i_{wej,wyj} = 1 + \frac{z_2}{z_1} \cdot \left[\frac{|z_7|}{z_6} \left(1 + \frac{|z_5|}{z_3} \right) \right] = 57{,}676 \,. \tag{52}$$

4. Podsumowanie

W artykule przedstawiono sposoby obliczania kinematyki przekładni biplanetarnej z wykorzystaniem wzoru Willisa oraz sił w zazębieniach kół zębatych metodą „free body diagram”, czyli metody uwalniania kół zębatych od więzów. Stosując metodę Willisa wyznaczono przełożenie kinematyczne przekładni. Drugą metodą nie tylko wyznaczono wszystkie siły działające w zazębieniach kół zębatych oraz wartość momentu wyjściowego, ale także po kilku dodatkowych przekształceniach matematycznych wyprowadzono inny wzór na przełożenie kinematyczne. Dzięki temu możliwe było sprawdzenie poprawności wzoru wyprowadzonego na podstawie zależności Willisa.

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MODELOWANIE NUMERYCZNE PROCESÓW MIESZANIA W BIOGAZOWNIACH

Streszczenie: W pracy przybliżono zagadnienie modelowania przepływu biomasy w fermentorach biogazowni. Omówiono skrótowo podstawy teoretyczne i metodologię modelowania. Przedstawiono przykładowe wyniki modelowania pola prędkości, mocy mieszania, sił osiowych pochodzących od wirników mieszadeł dla zbiorników procesowych istniejących biogazowni. Symulacje przeprowadzono dla stanu ustalonego z uwzględnieniem nienewtonowskich właściwości mieszanego medium. Zastosowano model lepkości Herschel-Bulkley'a.

Słowa kluczowe: numeryczna mechanika płynów, biogazownie, model Herschel-Bulkley

NUMERICAL MODELING OF MIXING PROCESSES IN BIOGAS PLANTS

Summary: The issue of biomass flow in fermenters of biogas plants by means of Computational Fluid Dynamic is briefly highlighted in the paper. The theoretical basics and modelling methodology has been shortly discussed. The results of CFD simulations of velocity field, mixing power, axial forces generated by mixer impellers, for real scale process tanks of biogas plants are presented. The steady state simulations are carried out taking into account non-Newtonian rheological properties of the fluid. The Herschel-Bulkley viscosity model have been applied.

Keywords: Computational Fluid Dynamics, biogas plants, Herschel-Bulkley model

1. Wstęp

Intensywność mieszania i charakter pola prędkości w zbiornikach fermentacyjnych mają kluczowe znaczenie dla prawidłowego przebiegu procesów w wydzielonych komorach fermentacyjnych biologicznych oczyszczalni ścieków jak i w fermentatorach biogazowni rolniczych, a co za tym idzie sprawność energetyczną instalacji. Zadaniem mieszadła (mieszadeł) jest równomierne rozprowadzenie substancji odżywczych, zapobieganie sedymentacji cząstek stałych i ujednorodnienie temperatury. Prawidłowy dobór mieszadeł ze względu na moc zainstalowaną oraz

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usytuowanie w komorze fermentacyjnej jest trudny przede wszystkim ze względu na złożone właściwości reologiczne mieszanego medium. Medium poddawane fermentacji posiada cechy płynu nienewtonowskiego tzn. jego lepkość pozorna zależy od szybkości ścinania. Obliczanie na drodze analitycznej mocy mieszania, sił działających na mieszadło i elementy konstrukcji czy też określenie pola prędkości w zbiorniku fermentacyjnym jest zagadnieniem trudnym i często wymagającym przeprowadzenia eksperymentów w skali półtechnicznej. Istotnym wsparciem projektowania systemów mieszania w komorach fermentacyjnych są metody numerycznej mechaniki płynów. Metody te pozwalają poprzez numeryczne rozwiązanie równań różniczkowych transportu dla masy pędu i energii określić pola prędkości, ciśnienia, temperatury i innych wielkości opisujących warunki fizyczne panujące w komorze fermentacyjnej. W pracy przedstawiono wyniki modelowania pola prędkości w wydzielonej komorze fermentacyjnej oczyszczalni ścieków oraz w komorze fermentacyjnej biogazowni rolniczej. Zawartości komór fermentacyjnych należą do grupy płynów nienewtonowskich rozrzedzanych ścinaniem

2. Model matematyczny przepływu

Model matematyczny opisujący mieszanie mechaniczne płynu nienewtonowskiego podczas fermentacji beztlenowej oparto na o następujące założenia:

- zawartość komory fermentacyjnej stanowi medium jednofazowe, w którym oddziaływania międzyfazowe pomiędzy pęcherzykami biogazu , a cieczą są pomijalne,
- medium posiada stałą temperaturę i jest nieściśliwe,
- medium przejawia cechy nienewtonowskiego płynu pseudo-plastycznego.

Przepływ jednofazowego płynu opisują równania transportu masy pędu i energii. W modelowanych zbiornikach występują zarówno obszary o przepływie turbulentnym jak i laminarnym. Do opisu turbulencji zastosowano półempiryczny dwurównaniowy model k - ε oparty o uśrednione równania Naviera-Stokesa. W/w równania dla układu jednofazowego przyjmują postać:
- Równanie zachowania masy (równanie ciągłości):

$$\frac{\partial}{\partial t}\rho + \nabla \cdot (\rho \vec{v}) = S_m, \tag{1}$$

- Równanie pędu

$$\frac{\partial}{\partial t}(\rho \vec{v}) + \nabla \cdot (\rho \vec{v} \vec{v}_q) = -\nabla p + \nabla \cdot \vec{\vec{\tau}} + \rho \vec{g} + \vec{F}, \tag{2}$$

gdzie:

$\vec{v}$ – prędkość [m/s],
ρ – gęstość [kg/m^3],
S_m – dodatkowe źródło masy, zmienne lub stałe [kg/s]
p – ciśnienie [Pa],
$\vec{\vec{\tau}}$ – tensor naprężeń [Pa],

$\vec{g}$ – przyspieszenie grawitacyjne [m/s^2],
$\vec{F}$ - wektor sił zewnętrznych [N].

W modelu k-ε domknięcie równań jest realizowane poprzez wprowadzenie dwóch dodatkowych równań różniczkowych transportu: dla energii kinetycznej turbulencji k i szybkości dyssypacji energii kinetycznej turbulencji ε. Dla przepływu jednofazowego równania te przyjmują postać:

$$\frac{\partial}{\partial t}\rho k + \nabla \cdot (\rho \vec{v} k) = \nabla \cdot \left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\nabla k\right] + G_k + \rho\varepsilon \tag{3}$$

$$\frac{\partial}{\partial t}\rho \varepsilon + \nabla \cdot (\rho \vec{v} \varepsilon) = \nabla \cdot \left[\left(\mu + \frac{\mu_t}{\sigma_\varepsilon}\right)\nabla \varepsilon\right] + \frac{\varepsilon}{k}\left(C_{1\varepsilon} G_k + C_{2\varepsilon}\rho\varepsilon\right) \tag{4}$$

gdzie:

k - energia kinetycznej turbulencji [m^2/s^2]
ε - szybkość dyssypacji energii kinetycznej turbulencji [m^2/s^3]
m_t - współczynnik lepkości burzliwej
G_k - współczynnik produkcji k
$C_{1\varepsilon}$ = 1,44
$C_{2\varepsilon}$ = 1,92

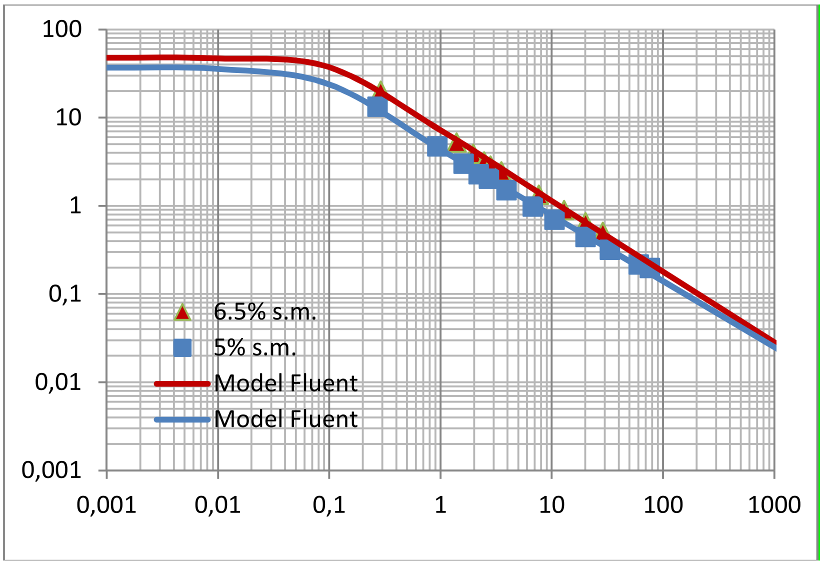
Wielkości $C_{1\varepsilon}$=1.44 i $C_{2\varepsilon}$=1.92 są stałymi eksperymentalnymi. Wartości turbulentnej liczby Prandtla również zostały określone eksperymentalnie wynoszą σ_k=1 i σ_ε=1.3 odpowiednio dla k i ε [1].
Do modelowania nienewtonowskich właściwości mieszanego medium zastosowano model Herschly-Bulckly zaimplementowany w programie Ansys Fluent [1]. W modelu tym dynamiczny współczynnik lepkości pozornej η jest opisany za pomocą równania 5 [1

$$\begin{cases} \text{dla } \dot{\gamma} \geq \dot{\gamma}_c \quad \eta = \dfrac{\tau_0}{\dot{\gamma}} + k\left(\dfrac{\dot{\gamma}}{\dot{\gamma}_c}\right)^{n-1} \\ dla \ \dot{\gamma} \leq \dot{\gamma}_c \quad \eta = \dfrac{\tau_0}{\dot{\gamma}_c}\left(2 - \dfrac{\dot{\gamma}}{\dot{\lambda}_c}\right) + k\left[(2-n) + (n-1)\dfrac{\dot{\gamma}}{\dot{\gamma}_c}\right] \end{cases} \tag{5}$$

gdzie:
K - współczynnik konsystencji
n - wskaźnik płynięcia
τ_0 - granica płynięcia
γ_0 - graniczna prędkość ścinania

Dla osadu o zawartości 5% s.m. parametry te wynoszą odpowiednio: k=24.3, n=0.25, τ_0 =0,1 Pa, γ_0=0,1 1/s, a dla 6.5% k=31,4, n=0.21, τ_0 =0,2 Pa, γ_0=0,15 1/s.

Na rys. 1 przedstawiono eksperymentalne wartości dynamicznego współczynnika lepkości pozornej wg danych zawartych w pracy [2] oraz krzywe wg równania 5.



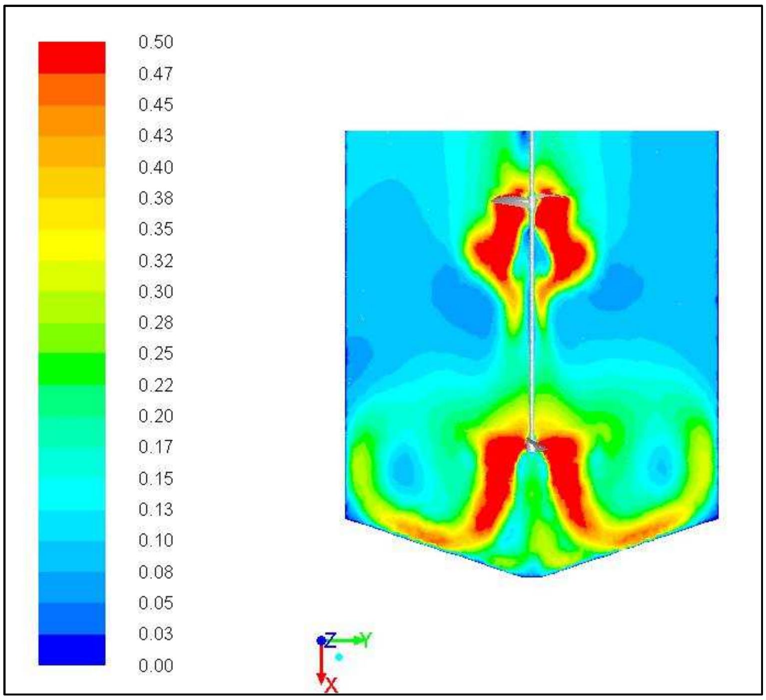
Rysunek 1. Zależność współczynnika lepkości pozornej osadu wtórnego o zawartości suchej masy 5% i 6,5% na podstawie danych literaturowych (2) i krzywa na podstawie modelu zaimplementowanego w programie Fluent

4. Wyniki obliczeń dla wydzielonej komory fermentacyjnej

Symulację przeprowadzono dla wydzielonej komory fermentacyjnej o pojemności roboczej około 2800m3. Komory tego typu pracują w Centralnej Oczyszczalni Ścieków PWiK Gliwice. W komorze zainstalowano mieszadło pionowe z silnikiem o mocy 7.5kW z dwoma wirnikami stalowymi dwułopatowymi o geometrii śrubowej o średnicach 4.2 i 3.2m. Obliczenia przeprowadzono dla stanu ustalonego przy zastosowaniu modelu turbulencji Reynolds k-ε, na wielościennej siatce objętości skończonych złożonych z 158000 elementów. Obliczenia przeprowadzono dla prędkości mieszadła n=15,2 obr/min w dwóch kierunkach. Przyjęto właściwości reologiczne medium jak dla mieszaniny osadu wstępnego i wtórnego o zawartości 5% s.m. wg (2). Uzyskane wyniki obliczeń pola prędkości przedstawiono w formie wykresów konturowych – rys. 2 i 3. W tabeli 1 zebrano wartości obciążeń wału mieszadła oraz wartość średniej prędkości przepływu w komorze.

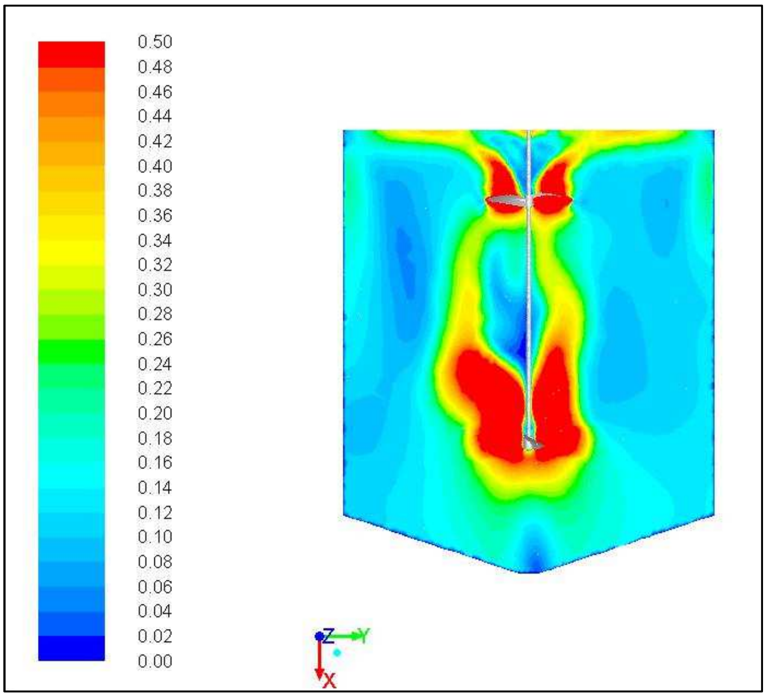
Tabela 1. Wyniki parametrów przepływu dla wydzielonej komory fermentacyjnej.

Parametr	Wartość	Jednostka
Siła osiowa wirnika dolnego	3728	N
Siła osiowa wirnika górnego	1253	N
Moment skręcający wirnika górnego	731	Nm
Moment skręcający wirnika dolnego	2102	Nm
Prędkość średnia w zbiorniku	0.16	m/s
Moc mieszania	4.5	kW
Siła osiowa od obu wirników	4981	Nm



Rysunek 2. Wykres konturowy prędkości przepływu w płaszczyźnie xy. Zawartość suchej masy 5%, n=15.2 obr/min (pompowanie w dół). Symulacja dla stanu ustalonego. Skala barwna prędkości przepływu w [m/s]

Z wykresów konturowych prędkości (rys. 2 i 3) wynika, że mieszadło zapewnia wystarczające wymieszanie zawartości komory fermentacyjnej (praktycznie brak stref martwych). Podczas rewersyjnej pracy z jednej strony mieszadło skutecznie przeciwdziała sedymentacji osadu (pompowanie w dół), a po zmianie kierunku obrotów na przeciwny (pompowanie w górę) zapewnia usuwanie kożucha z powierzchni.



Rysunek 3. Wykres konturowy prędkości przepływu w płaszczyźnie xy. Zawartość suchej masy 5%, n=-15.2 obr/min (pompowanie w górę). Symulacja dla stanu ustalonego.

5. Wyniki obliczeń dla fermentora biogazowni rolniczej

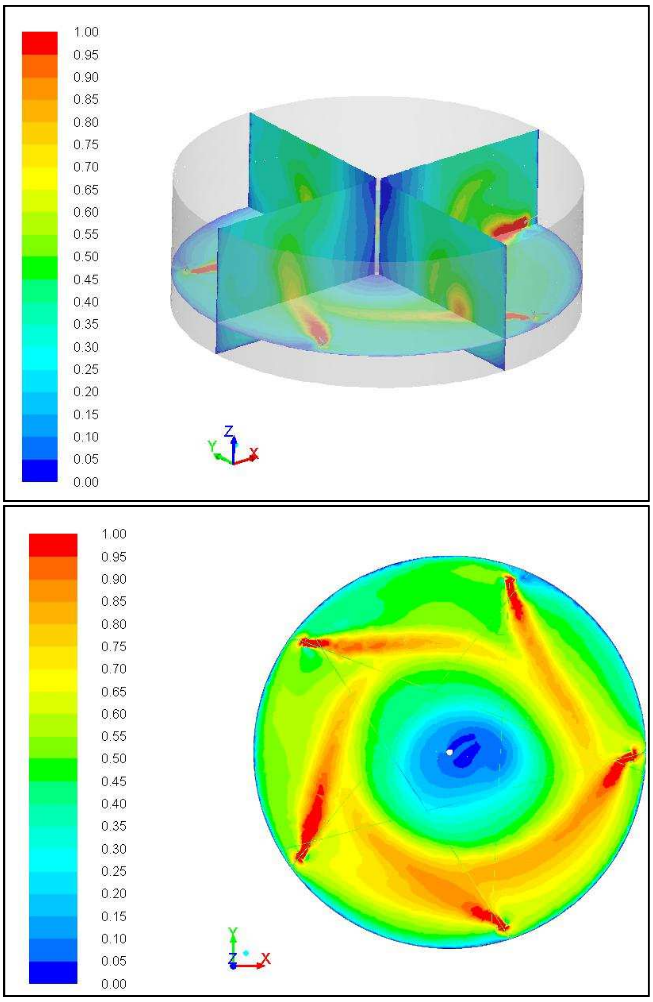
Symulacje przeprowadzono dla fermentora o średnicy 24m i poziomie wypełnienia 8m. Fermentor posiada konstrukcję betonową zamkniętą, od góry zamkniętą membraną elastyczną wspartą na słupie centralnym. Zbiornik wyposażono w pięć mieszadeł średnioobrotowych poziomych z trójłopatkowymi wirnikami stalowymi o średnicy 650mm o mocy 5.5kW. Mieszadła rozmieszczono na obwodzie zbiornika. Obliczenia przeprowadzono dla stanu ustalonego przy zastosowaniu modelu turbulencji Reynolds k-ε, na wielościennej siatce objętości skończonych złożonych z 615854 elementów. Obliczenia przeprowadzono dla prędkości mieszadła n=286 obr/min. Przyjęto właściwości reologiczne medium jak dla osadu wtórnego o zawartości 6,5% s.m. wg [2]. Uzyskane wyniki obliczeń pola prędkości przedstawiono w formie wykresów konturowych – rys.4. W tabeli 2 zebrano przykładowe wyniki obliczeń obciążeń wału jednego z mieszadeł oraz wartość prędkości średniej w zbiorniku. Wartości obciążeń pozostałych mieszadeł kształtowały się na podobnym poziomie. Z wykresów konturowego prędkości-rys.4 wynika, że przy takim ustawieniu mieszadeł niewielka strefa martwa tworzy się wokół słupa centralnego podpierającego membranę fermentora. Problem ten można częściowo wyeliminować przez zmianę kąta ustawienia jednego z mieszadeł.

Tabela 2. Wyniki parametrów przepływu dla fermentora biogazowni

Parametr	**Wartość**	**Jednostka**
Siła osiowa wirnika dolnego	1285	N
Moment skręcający wirnika górnego	134	Nm
Prędkość średnia w zbiorniku	0.16	m/s
Moc mieszania	4.0	kW

a)

b)



Rysunek 4. Wykresy konturowe prędkości przepływu w fermentorze biogazowni rolniczej w wybranych płaszczyznach przekroju: a) widok izometryczny, b) w płaszczyźnie przechodzącej przez oś wału mieszadeł. Zawartość suchej masy 6.7%, n=286 obr/min. Symulacja dla stanu ustalonego. Skala prędkości przepływu w [m/s]

6. Podsumowanie

Przedstawione przykładowe wyniki symulacji dotyczą rzeczywistych obiektów, na których zainstalowano mieszadła dobrane zgodnie z wynikami obliczeń CFD. W trakcie rozruchu mieszadeł w wydzielonych komorach fermentacyjnych COŚ PWiK Gliwice przeprowadzono pomiary mocy mieszania. Pomiary wykazały zgodność obliczeń numerycznych z błędem nie większym niż 10%.
Poza czynnikami wynikającymi z metodologii obliczeń numerycznych dokładność wyników symulacji zależy w decydującym stopniu od dokładności określenia właściwości reologicznych (krzywych ścinania) mieszanego medium.
W przyszłości, przy wdrożeniu tego typu urządzeń wystąpią problemy wykonawcze, które będą kierunkiem do dalszych badań i prac, związanych z:

- - zastosowaniem nowych wariantów materiałowych dla konstrukcji śmigła mieszadła (stali typu duplex/superduplex) oraz poprzez nową technologię łączenia tych stali, które pozwolą na szersze wykorzystanie urządzeń uwzględniające wielkość, gęstość i agresywność mediów roboczych,
- - zmianą rozwiązania konstrukcji przekładni walcowej oraz konstrukcji nośnej umożliwiającej wprowadzenie modułowych konstrukcji składających się z zunifikowanych elementów co umożliwi zwiększenie seryjności produkcji oraz obniżenie kosztów wykonania konstrukcji, zracjonalizowanie konstrukcji nośnej,
- - wykonaniem typoszeregu mieszadeł, różnej wielkości i mocy, dostosowanej do wielkości i rodzaju mieszanych mediów, co będzie miało przełożenie na uniwersalność zastosowania mieszadła i szybsze zaprojektowanie wyrobu adekwatnie do potrzeb klienta, obniżki kosztów wykonania (unifikacja niektórych elementów) i efektywny serwis.

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METODY REALIZACJI OPERACJI LOGICZNYCH JĘZYKA LD W URZĄDZENIACH STERUJĄCYCH OPARTYCH O ARCHITEKTURĘ 8051

Streszczenie: W niniejszym artykule przedstawiono problem realizacji operacji logicznych na danych wymienianych pomiędzy urządzeniami w sieci przemysłowej. Pokazano metody dostępu do danych jednobitowych, sposoby wykonania operacji na nich oraz cechy architektury systemu które wspomagają oraz utrudniają te operacje. Omawiane urządzenia zbudowane są jako systemy mikroprocesorowe o 8-bitowej architekturze 8051.

Słowa kluczowe: Operacje logiczne, mikroprocesory, 8051

THE METHODS OF THE LOGICAL OPERATIONS IN CONTROL DEVICES BASED ON 8051 ARCHITECTURE

Summary: This paper presents problem of implementation of logical operations, that are the basic element of LD language. It shows methods of access to a single-bit data, ways of executing operations on the data and features of system architecture that support or complicate this operation. The described control devices that were built as microprocessor systems with 8-bit 8051 architecture.

Keywords: Logical operations, microprocessors, 8051

1. Wprowadzenie

Nowoczesne systemy sterowania maszyn i urządzeń coraz rzadziej budowane są w oparciu o logikę przekaźnikowo-stycznikową. Rolę elementów wykonawczych i sterujących przejmują urządzenia mikroprocesorowe takie jak sterowniki PLC. Realizują one algorytm sterowania, przedstawiony w formie programu dla mikroprocesora, pobierają dane z podłączonych cyfrowych i analogowych czujników oraz sterują dyskretnymi i wielostanowymi wyjściami. Elementy czujnikowe,

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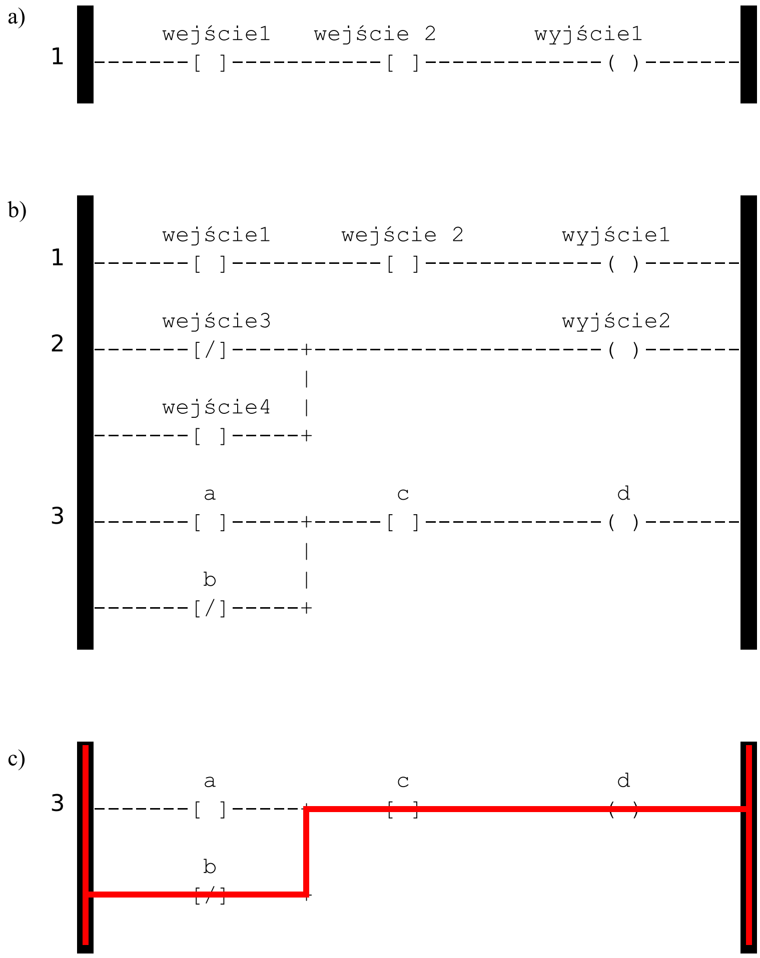
wykonawcze oraz sterujące mogą zostać rozproszone po całym obiekcie, którym sterują, ale dzięki sieciom przemysłowym mogą w deterministycznym czasie wymieniać między sobą potrzebne im dane.
Podstawowym czujnikiem podłączonym do sieci przemysłowej jest wejście dwustanowe dostarczające dane o wielkości jednego bitu. Wyłączniki krańcowe, przełączniki, kurtyny bezpieczeństwa itp. udostępniają do urządzenia akwizycji wejść tylko informację o zadziałaniu lub nie. Dzięki rozmiarowi takiej informacji stan wielu czujników może być przechowywany w jednym słowie i przekazany przez sieć jednocześnie.
Z drugiej strony, najprostsze urządzenia wyjściowe z systemu także realizują tylko dwa stany pracy: otwarcie lub zamknięcie zaworu hydraulicznego, załączenie sygnalizatora akustycznego lub wysterowanie stycznika i załączenie silnika.
Przedstawiony w artykule język drabinkowy LD (ang. Ladder Diagram) posiada pulę specjalnych rozkazów operujących na pojedynczych bitach, reprezentujących stan czujników binarnych, a także pozwala na sterowanie dwustanowymi wyjściami elementów wykonawczych.
W artykule przedstawiono metodę realizacji operacji logicznych w systemie mikroprocesorowym o architekturze 8051. Dane, będące argumentami operacji pobierane są poprzez sieć polową, np. Modbus z urządzenia akwizycji wejść dyskretnych – dwustanowych.

2. Język drabinkowy

Wzorowany na schematach elektrycznych stykowo-przekaźnikowych systemów sterowania język drabinkowy LD (ang. Ladder Diagram) został ujęty w normie IEC 61131-3 opisującej tekstowe i graficzne języki programowania sterowników PLC [1]. W normie [2] zdefiniowano także elementarne typy danych, z których dla tego artykułu ważny jest jedynie typ BOOL. Zmienna tego typu ma wielkość jednego bitu i przyjmować może dwa stany FALSE (fałsz) oraz TRUE (prawda) odpowiadające wartościom liczbowym 0 oraz 1.
Programy w języku LD zbudowane ze zbiorów połączonych ze sobą elementów graficznych grupowanych w obwody (rys. 1a). Następnie, aby wskazać sekwencyjne wykonanie operacji, obwody umieszczane względem siebie pionowo tworząc szczeble (rys. 1b) . W ramach jednego obwodu, algorytm sterowania realizowany jest zgodnie z przepływem prądu (ang. power flow) od lewej szyny zasilania, sprawdzając wszystkie warunki aż do prawej strony (rys. 1c).



Rysunek 1. a) Jeden obwód. b) Trzy szczeble. c) Sterowanie przepływem prądu w warunkach: a=0, b=0, c=1

Podstawowymi elementami języka LD są styki oraz cewki. Reprezentują one dwustanowe wejścia oraz wyjścia. W tabeli 1 przedstawiono rodzaje cewek i styków które zostaną omówione w tym artykule.
Zestaw symboli dodatkowo można zredukować zauważając, że cewki zatrzaskiwane to odpowiednie połączenie pozostałych symboli co przedstawiono na rys. 2. W pierwszym i drugim obwodzie bit wyjściowy jest ustawiany i kasowany w zależności od warunków. Trzeci obwód realizuje to samo zadanie za pomocą zwykłej cewki i logiki ze sprzężeniem zwrotnym.

Tabela 1. Podstawowe symbole graficzne języka LD omawiane w artykule

Rodzaj	Symbol	Funkcja
Styk statyczny normalnie otwarty	`wejście` `-[ ]-`	Stan po lewej stronie symbolu przenoszony jest na prawą stronę, jeżeli wejście jest w stanie logicznym 1. W przeciwnym przypadku po prawej stronie pojawia się stan 0.
Styk statyczny normalnie zamknięty	`wejście` `-[/]-`	Stan po lewej stronie symbolu przenoszony jest na prawą stronę, jeżeli wejście jest w stanie logicznym 0. W przeciwnym przypadku po prawej stronie pojawia się stan 1.
Cewka zwykła	`wyjście` `-( )-`	Stan po lewej stronie symbolu przepisywany jest do zmiennej wyjście.
Cewka negująca	`wyjście` `-(/)-`	Stan przeciwny do stanu po lewej stronie symbolu przepisywany jest do zmiennej wyjście.
Cewka zatrzaskiwana ustawiająca	`wyjście` `-(S)-`	Jeżeli stan po lewej stronie symbolu ma wartość logiczną 1 to zmienna wyjściowa ustawiana jest w stan 1.
Cewka zatrzaskiwana kasująca	`wyjście` `-(R)-`	Jeżeli stan po lewej stronie symbolu ma wartość logiczną 1 to zmienna wyjściowa ustawiana jest w stan 0.

```
        warunek                        wyjście
1  -------[ ]--------------------------(S)-------

        warunek2                       wyjście
2  -------[ ]--------------------------(R)-------

        warunek        warunek2        wyjście
3  -------[ ]-----+-----[/]-------------( )-------
                  |
        wyjście   |
   -------[/]-----+
```

Rysunek 2. Realizacja cewek zatrzaskiwanych. 1) Ustawianie. 2) Kasowanie. 3) Jednoczesna realizacja gałęzi 1 i 2

3. Architektura 8051

Seria 8051 to rodzina mikrokontrolerów 8-bitowych opracowana przez firmę Intel w 1980 roku, a rozwijana do dziś w postaci układów scalonych (np. firma Atmel) oraz opisów sprzętu do zastosowania w logikach programowalnych (np. polska firma Digital Core Design). Mikrokontrolery tej serii zbudowane zostały w zmodyfikowanej architekturze harwardzkiej, co oznacza, że obszary pamięci przechowujące dane i program zostały rozdzielone, jednak współdzielą magistrale

danych i adresową. Lista rozkazów zaprojektowana została zgodnie z architekturą CISC (ang. Complex Instruction Set Computing) co oznacza, że zawiera specjalizowane, złożone rozkazy oraz wiele trybów adresacji. Kosztem zastosowania architektury CISC jest zwiększenie liczby cykli zegara potrzebnych na wykonanie rozkazu, w stosunku do prostszych architektur.
Do rdzenia mikroprocesora podłączono cztery banki zawierające po 8 rejestrów roboczych. Dodatkowo zastosowano wewnętrzną pamięć RAM o wielkości 128B (z czego 128 bitów ma możliwość adresacji bitowej) oraz jednobitowy procesor funkcji logicznych [3]. Charakterystyczną cechą mikroprocesorów o architekturze CISC jest występowanie akumulatora – rejestru używanego w większości operacji arytmetycznych i logicznych. Pomimo możliwości wykonania operacji na rejestrach roboczych oraz danych w pamięci, to operacje z wykorzystaniem akumulatora wykonywane są w najmniejszej liczbie cykli zegarowych.

4. Sposoby realizacji rozkazów bitowych

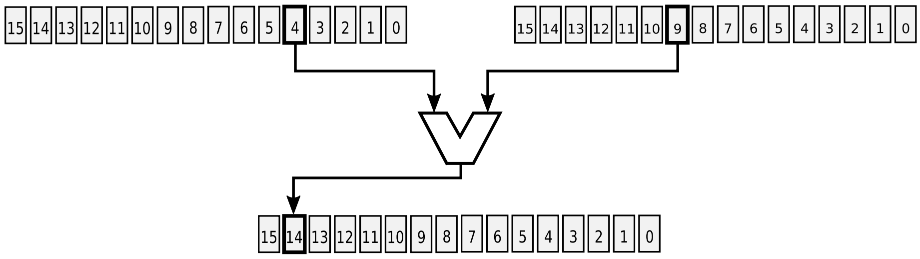
Podstawowym typem danych w języku drabinkowym, opisanym w akapicie 2, jest BOOL, czyli zmienna logiczna – bitowa. Za pomocą odpowiedniego łączenia styków i cewek realizować można operacje logicznej sumy (połączenie równoległe) i iloczynu (połączenie szeregowe) których tablice prawdy przedstawiono poniżej (tab. 2).
Ponieważ omawiane mikroprocesory należą do rodziny 8-bitowej, najmniejszą jednostką organizacji danych, na której mogą przeprowadzać operacje jest bajt zawierający osiem bitów. W kolejnych paragrafach przedstawione zostaną algorytmy realizacji operacji bitowych w architekturach większych niż jednobitowe.

Tabela 2. Tablice prawdy dla operacji sumy i iloczynu bitowego

Wartość pierwszego argumentu	**Wartość drugiego argumentu**	**Wartość iloczynu**	**Wartość sumy**
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	1

4.1. Algorytm używający operacji logicznych

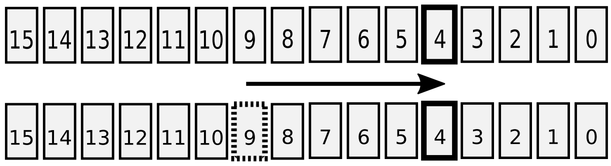
Dostępne w mikroprocesorach instrukcje logiczne najczęściej operują na wszystkich bitach słowa jednocześnie. W ogólnym przypadku, należy wykonać operację na dwóch bitach znajdujących się w różnych bajtach pamięci, na różnych pozycjach a wynik zapisać w innym bajcie na jeszcze innej pozycji (rys. 3). W tym celu zaproponowano poniższe algorytmy.



Rysunek 3. Schemat operacji bitowej w systemie 16-bitowym

Metoda operująca na dwóch słowach:

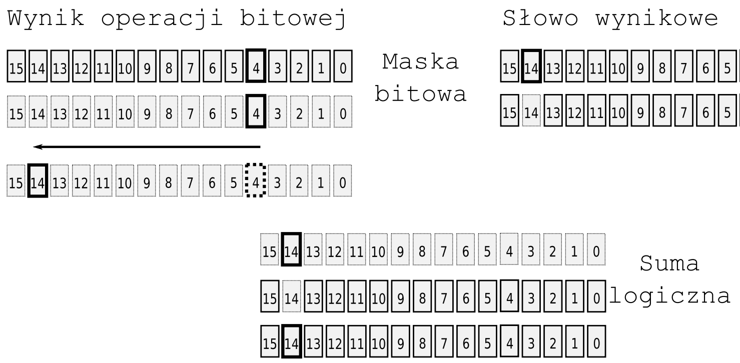
1. Pobranie z pamięci bajtu zawierającego bit pierwszego argumentu.
2. Przesunięcie bitowe w lewo lub w prawo, aby umieścić bit argumentu na założonej pozycji (rys. 4).
3. Pobranie z pamięci drugiego bajtu zawierającego bit drugiego argumentu.
4. Przesunięcie bitowe rejestru z drugim argumentem tak, aby znalazł się na tej samej pozycji co pierwszy argument.
5. Wykonanie operacji logicznej na obu bajtach.



Rysunek 4. Wyrównanie bitowych pozycji argumentów

Zakładając, że używana jest architektura CISC wynik otrzymywany jest w akumulatorze. Aby zapisać go w odpowiednim miejscu bajtu wynikowego zaproponowano następujący algorytm (rys. 5.):

1. Pobranie bajtu do którego należy zapisać bit wyniku operacji.
2. Operacja logicznego iloczynu w celu wyzerowania bitu wyniku w bajcie docelowym.
3. Przesunięcie bitowe wyniku operacji logicznej (jeżeli jest jeszcze konieczne) aby wyrównać pozycję wyniku z bajtem docelowym.
4. Operacja logicznego iloczynu w celu wyzerowania nieznaczących bitów w bajcie zawierającym wynik operacji logicznej.
5. Operacja sumy logicznej, zapisująca wynik operacji na odpowiedni bit bajtu docelowego.
6. Zapisanie bajtu z wynikiem do pamięci.



Rysunek 5. Wyrównanie bitowych pozycji argumentów

4.2. Algorytm używający operacji arytmetycznych

Operacje logiczne zrealizować można także za pomocą elementów arytmetycznych, jakimi jest np. sumator jednobitowy [5]. W systemach mikroprocesorowych, realizacje logicznego iloczynu i sumy można przedstawić jako operacje arytmetyczne na liczbach w zakresie od 0 do 1 z nasyceniem. Ponieważ w wielu architekturach mikroprocesorowych operacje mnożenia i dodawania są dostępne, przedstawiono propozycję algorytmu realizacji zagadnienia w ten sposób.
Suma i iloczyn logiczny:

```
1. Pobranie z pamięci bajtu zawierającego bit pierwszego argumentu.
2. Operacja logicznego iloczynu w celu wyzerowania nieznaczących bitów w bajcie zawierającym pierwszy argument.
3. Pobranie z pamięci bajtu zawierającego bit drugiego argumentu.
4. Operacja logicznego iloczynu w celu wyzerowania nieznaczących bitów w bajcie zawierającym drugi argument.
5. Operacja arytmetycznej sumy lub arytmetycznego iloczynu obu bajtów.
6. Wynik przechowywany jako stan zero akumulatora.
```

Wynik operacji przeprowadzonej według powyższego algorytmu nie jest już pojedynczym bitem w akumulatorze, ale jest reprezentowany, w zależności od architektury, jako flaga operacji arytmetycznej której wynikiem było zero lub jako wartość 0 w akumulatorze.

5. Realizacja operacji logicznych w architekturze 8051

Ze względu na organizację rdzenia mikroprocesora o architekturze 8051 wyróżniono warte uwagi elementy przedstawionych algorytmów:

1. Metoda wyrównywania pozycji bitów w operandach.
2. Operacje na argumentach w akumulatorze i pamięci.
3. Dostęp bitowy do pamięci wewnętrznej.
4. Użycie logicznej jednostki jednobitowej.

Dla każdej z realizacji algorytmu przedstawiono liczbę cykli procesora potrzebną do jego wykonania.

5.1. Realizacja za pomocą operacji logicznych

Algorytm przedstawiony w punkcie 4.1. można wprost zrealizować tak jak pokazano to w tabeli 3. Tylko pierwszy argument musi zostać pobrany z pamięci, pobranie do akumulatora przyspiesza obliczenia. Po pobraniu danych wykonywane jest wyrównanie pozycji bitów, do pozycji drugiego operandu. Następnie wykonywana jest właściwa operacja bitowa na pierwszym argumencie w akumulatorze oraz drugim w pamięci RAM, wynik zostaje zapamiętany w akumulatorze.

Tabela 3. Realizacja algorytmu 4.1 w 8051

Rozkaz	Argumenty	Liczba cykli	Znaczenie
MOV	A, direct1	1	Pobranie pierwszego argumentu z pamięci (z adresu bezpośredniego direct1) do akumulatora.
SWAP	*A*	*1*	*Zamiana tetrad (nieobowiązkowa).*
RL/RR	A	1	Przesunięcie bitowe rejestru A o jeden bit w lewo.
…	…	…	*Powtórzenie operacji przesunięcia.*
ANL	A, direct2	1	Właściwa operacja logiczna. Wynik na bicie w akumulatorze takim jak drugi argument.
		Od 2 do 4	

Liczba cykli potrzebnych na realizację algorytmu zależy od początkowej i docelowej pozycji bitu pierwszego argumentu. W tabeli 4 przedstawiono liczbę cykli potrzebną na przemieszczenie bitu z użyciem rozkazu zamiany tetrad oraz obrotu bitowego akumulatora w lewo i w prawo. Średnio potrzeba 1,375 cykli dla realizacji przesunięcia na dowolną pozycję.

Tabela 4. Liczba cykli potrzebnych do przesunięcia bitu z pozycji r na pozycję d

r\d	0	1	2	3	4	5	6	7
0	0	1	2	2	1	2	2	1
1	1	0	1	2	2	1	2	2
2	2	1	0	1	2	2	1	2
3	2	2	1	0	1	2	2	1
4	1	2	2	1	0	1	2	2
5	2	1	2	2	1	0	1	2
6	2	2	1	2	2	1	0	1
7	1	2	2	1	2	2	1	0

5.2. Realizacja za pomocą operacji arytmetycznych

Na liście rozkazów mikroprocesorów 8051 [4] znajdują się operacje arytmetyczne dodawania i mnożenia pozwalające zrealizować algorytm 4.2.

Tabela 5. Realizacja algorytmu 4.2 w 8051

Rozkaz	Argumenty	Liczba cykli	Znaczenie
MOV	A, direct1	1	Pobranie pierwszego argumentu z pamięci (z adresu bezpośredniego direct1) do akumulatora.
ANL	A,#data1	1	Iloczyn z maską bitową #data1.
MOV	B, A	1	Skopiowanie zawartości rejestru A do B.
MOV	A, direct2	1	Pobranie drugiego argumentu z pamięci (z adresu bezpośredniego direct2) do akumulatora.
ANL	A,#data2	1	Iloczyn z maską bitową #data2.
MUL/ADD	A, B	4/1	Mnożenie/dodawanie. Wynik w A.
JZ	Et1	2	Sprawdzenie stanu logicznego i skok.
		=11/8	

Operacje arytmetyczne przeprowadzane są na dedykowanych rejestrach: A (akumulator) oraz B. Wynik, w zależności od największego spodziewanego rezultatu, należy sprawdzić rozkazem skoku przy zerze w akumulatorze, sprawdzając flagę przeniesienia lub flagę przekroczenia zakresu.

5.3. Realizacja z wykorzystaniem cech architektury 8051

Obecna w mikroprocesorach 8051 jednobitowa jednostka logiczna oraz możliwość bitowej adresacji pamięci wewnętrznej pozwalają na realizację omawianych funkcji logicznych w sposób inny niż przedstawione w podrozdziałach 4.1 i 4.2 uniwersalne algorytmy.

Tabela 6. Realizacja funkcji logicznych za pomocą jednobitowej jednostki logicznej

Rozkaz	Argumenty	Liczba cykli	Znaczenie
MOV	C, bit1	1	Pobranie pierwszego argumentu z pamięci (z adresu bezpośredniego bitu bit1) do flagi przeniesienia C.
ANL/ORL	C, bit2	2	Właściwa operacja logiczna na bicie C oraz bicie z pamięci bit2. Wynik w C.
RLC	A	1	Zapis wyniku do akumulatora (operacja nie jest konieczna).
		= 4	

W metodzie przedstawionej w tabeli 5 pierwszy operand pobrano z pamięci bezpośrednio do flagi przeniesienia C. Właściwa funkcja logiczna realizowana jest na argumencie przechowywanym we fladze C oraz bezpośrednio adresowanym bicie w pamięci wewnętrznej. Wynik otrzymywany jest we fladze C, a następnie kopiowany do najmłodszego bitu akumulatora. Jeżeli w dalszych krokach nastąpią znów operacje z dostępem bitowym, przenoszenie wyniku do akumulatora nie jest konieczne.

Podobne operacje wykonać można używając wyłącznie dostępu bitowego i skoków warunkowych, co przedstawiono w tabeli 6 na przykładzie logicznego iloczynu. Tymczasowy wynik operacji przechowywany jest na najmłodszym bicie akumulatora a operacje jego modyfikacji pomijane są za pomocą skoków warunkowych sprawdzających stan bitów w pamięci. Liczba cykli potrzebnych na realizację tej metody jest jednak zależna od wartości operandów.

Tabela 7. Realizacja funkcji logicznych za pomocą adresacji bitowej i skoków

Rozkaz	**Argumenty**	**Liczba cykli**	**Znaczenie**
MOV	A,0	1	Początkowe 0 do akumulatora.
JNB	bit1, et1	2	Skok do et1 gdy pierwszy operand jest zerem.
JNB	bit2, et1	2	Skok do et1 gdy drugi operand jest zerem.
MOV	A, 1	1	Zapis wyniku 1.
Et1:	---	0	Koniec operacji. Wynik na najmłodszym bicie A.
		Od 2 do 4	

5.4. Zapis wyniku

Przedstawione wcześniej realizacje algorytmów dla procesorów o architekturze 8051 swoje wyniki zwracają na trzy sposoby:

1. Na konkretnym bicie akumulatora.
2. Poprzez stan zera w akumulatorze.
3. Poprzez flagę przeniesienia C.

Tabela 8. Zapis do pamięci wyniku z bitu w akumulatorze

Rozkaz	**Argumenty**	**Liczba cykli**	**Znaczenie**
ANDI	R0,K1	1	Logiczny iloczyn w celu wyzerowania nieznaczących bitów.
SWAP	*R0*	*1*	*Zamiana tetrad (nieobowiązkowa).*
LSL/LSR	R0	1	Przesunięcie bitowe rejestru R0 o jeden bit w lewo/prawo.
…	…	…	*Powtórzenie operacji przesunięcia.*
LD	R1,k1	2	Pobranie z pamięci docelowej komórki dla wyniku (z adresu k1 do rejestru R1).
ANDI	R1,K2	1	Logiczny iloczyn w celu wyzerowania bitu do zapisania.
OR	R1,R0	1	Logiczna suma. Wpisanie wyniku operacji.
ST	K1,R1	2	Zapis wyniku do pamięci.
		Od 7 do 9	

W tabeli 7 przedstawiono ogólną metodę zapisu bitu z rejestru lub akumulatora do pamięci. W zależności od numerów bitów wyniku operacji logicznej oraz docelowego bitu w pamięci czas wykonania jest różny.

Tabela 9. Zapis do pamięci wyniku z zastosowanie adresacji bitowej

Rozkaz	Argumenty	Liczba cykli	Znaczenie
MOV	C,A.bit1	1	Zapis bitu wyniku do flagi przeniesienia C.
MOV	Bit2,C	2	Zapis bitu do pamięci.
		= 3	

Stosując dostęp bitowy zapis wyniku jest o wiele szybszy. Gdy wynik operacji znajduje się na bicie w akumulatorze należy zrealizować oba rozkazy przedstawione w tabeli 8, gdy używano jednostki logicznej wystarczy drugi rozkaz.
Jeżeli wynik operacji otrzymano przez sprawdzenie czy w akumulatorze jest zero należy zapisać go w sposób zbliżony do przedstawionego w tabeli 5 ustawiając ręcznie odpowiednie bity a następnie realizując algorytm z tabeli 8 w celu zapisu do pamięci.

6. Podsumowanie

Przedstawione w artykule sposoby realizacji operacji bitowych w systemach mikroprocesorowych pokazują, że architektury operujące na wielu bitach jednocześnie wymagają dużego narzutu obliczeniowego na pobranie ze słowa stanu pojedynczego bitu. Czas wykonania właściwej operacji logicznej na dwóch operandach jest pomijalnie mały w zestawieniu z koniecznością wyłuskania bitu oraz jego zapisu w słowie wynikowym. W tabeli 9 przedstawiono podsumowanie liczby cykli potrzebnych na realizację opisanych wcześniej algorytmów. Pominięto metodę stosującą operacje arytmetyczne, ponieważ wymagała znacznie większej liczby cykli niż inne. Dla metod stosujących przesunięcia bitowe wyznaczono średnią liczbę cykli potrzebną na przemieszczenie operandu.
Zastosowanie charakterystycznej cechy architektury 8051 jaką jest adresacja bitowa pamięci wewnętrznej pozwala wyraźnie skrócić czas potrzebny na zapis wyniku. Należy jednak pamiętać, że obszar adresowany bitowo ograniczony jest do 128 bitów czyli 16 bajtów. Metoda ta będzie skuteczna, jeżeli wszystkie zmienne logiczne zmieszczą się w 128 bitach lub koprocesor sieciowy umożliwi transfer użytecznych zmiennych do tego obszaru niezależnie od algorytmu sterowania.
Pomimo dobrego wyniku w przypadku stosowania metody ze skokami warunkowymi, liczba cykli nie jest zależna od pozycji bitów w słowie pobieranym z pamięci, jak ma to miejsce w innych metodach, ale od wartości operandów. Zmienia się zatem podczas wykonywania algorytmu sterowania i nie jest znana w momencie kompilacji, a to uniemożliwia przewidzenie czasu trwania cyklu.
Zastosowanie jednobitowej jednostki logicznej nie przyśpiesza znacząco obliczeń w porównaniu ze stosowaniem rozkazów logicznych. Średni czas potrzebny na wykonanie obliczeń używając całych rejestrów jest zbliżony. Zysk pojawia się jednak

podczas zapisu, ponieważ wynik operacji jednostki logicznej otrzymywany jest we fladze C, natomiast w innych przypadkach trzeba go dopiero pobrać z akumulatora.

Tabela 10. Podsumowanie liczby cykli potrzebnych na realizację algorytmów

Metoda	**Liczba cykli obliczeń**	**Liczba cykli zapisu wyniku**	**Suma**
Operacje logiczne + zapis z maską bitową	2 – 4 (3.375)	7 – 9 (8.375)	9 – 13 (10.375)
Operacje logiczne + zapis z adresacją bitową	2 – 4 (3.375)	3	5 – 7 (6.375)
Operacje w jednostce logicznej + zapis z adresacją bitową	3	2	5
Skoki warunkowe + zapis z adresacją bitową	2 - 4	3	5 - 7

W artykule zwrócono uwagę, że podstawowe operacje logiczne, których argumentem są dwa bity w pamięci wymagają zastosowania specjalnych algorytmów, gdy są wykonywane w architekturach wielobitowych. Co więcej, obecność w mikroprocesorze jednostki wspomagającej operacje bitowe nie musi przynieść dużego przyspieszenia.
Pomimo istnienia procesorów jednobitowych [6] takie układy nie są popularne a zastosowanie bardziej złożonych architektur pozwala na wykonanie przez jedno urządzenie wielu funkcji, nie tylko sterowania, ale i komunikacji oraz wizualizacji [7].

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ZASTOSOWANIE KONWENCJONALNEJ DRUKARKI 3D DO WYTWARZANIA PODŁOŻY DLA INŻYNIERII TKANKOWEJ - WSTĘPNE TESTY

Streszczenie: Przedstawiono wstępną analizę możliwości użycia konwencjonalnej drukarki 3D wykorzystującej technologię osadzania topionego materiału do wytwarzania podłoży przeznaczonych dla inżynierii tkankowej. Wykonane rusztowania z materiału polimerowego o różnej mikrostrukturze, a tym samym o różnej wielkości porów, poddano obserwacjom mikroskopowym. Przeprowadzona analiza potwierdziła możliwość wykorzystania techniki druku przestrzennego do wytwarzania trójwymiarowych, porowatych, przestrzennych podłoży polimerowych o odpowiednio zaprojektowanej geometrii.

Słowa kluczowe: druk 3D,inżynieria tkankowa, rusztowania

APPLICATION OF CONVENTIONAL 3D PRINTER FOR SCAFFOLD PRODUCTION FOR TISSUE ENGINEERING - PRELIMINARY TESTS

Summary: An initial analysis of the possibility of using the conventional 3D printer for the production of scaffolds for tissue engineering by fused deposition modelling technology was presented. Polymeric scaffold materials, with different microstructure and different pore size as well, were investigated with microscopes. The analysis confirmed the possibility of the use of 3D printing technology to produce 3D, porous scaffolds with designed geometry.

Keywords: 3D printing, tissue engineering, scaffolds

1. Wprowadzenie

Pod koniec lat '80 ubiegłego wieku powstała technologia tak zwanego szybkiego wykonywania prototypów (ang. Rapid Prototyping), która pozwala na precyzyjną

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i powtarzalną produkcję pełnowymiarowych modeli części lub ich zespołów. Związane to było głównie z rozwojem technologii produkcji addytywnej (np. z wykorzystaniem druku przestrzennego) opartej na modelowaniu CAD [6]. Obecnie jesteśmy świadkami popularyzacji druku trójwymiarowego, czego przyczyną jest dostęp do szerokiej gamy drukarek 3D wykorzystujących różne technologie produkcji w zależności od używanego materiału. Z uwagi na prostą budowę i tani, powszechnie dostępny materiał, najpopularniejsze są drukarki oparte na technologii FFF/FDM (ang. FusedFilamentFabrication), które stopione tworzywo sztuczne układają w postaci cienkich ścieżek warstwa po warstwie. Zaowocowało to szybkim postępem technicznym oraz szerokim zastosowaniem tej technologii. Druk 3D stał się narzędziem chętnie wykorzystywanym w dziedzinie inżynierii tkankowej do budowy rusztowań dla tkanek i organów [3].

1.1. Podłoża wykorzystywane w inżynierii tkankowej

Inżynieria tkankowa zajmuje się odbudową i przywróceniem funkcji uszkodzonych lub usuniętych tkanek i narządów [5]. Jej metody opierają się głównie na manipulacji komórkami własnymi pacjenta, czynnikami wzrostu oraz biomateriałami stanowiącymi podłoże - rusztowanie dla nowopowstającej tkanki [1]. Materiał pełniący rolę podłoża powinien posiadać przestrzenną, porowatą strukturę tworzącą sieć wzajemnie połączonych kanalików ułatwiających adhezje, wzrost i tworzenie własnej matrycy przez komórki, a także umożliwiających penetracje formującej się tkanki oraz doprowadzenie substancji odżywczych [2]. Rozmiar porów powinien być optymalny dla wzrostu i proliferacji określonego typu komórek. Istotne jest również połączenie oraz rozmieszczenie porów w materiale. Ponadto biomateriał stosowany jako rusztowanie musi posiadać odpowiednie do zastępowanych tkanek właściwości: fizyczne, chemiczne i mechaniczne, które nie ulegną zmianie do czasu wygojenia tkanki. Rusztowanie powinno wykazywać zdolność do biodegradacji po spełnieniu wyznaczonej funkcji, przy czym produkty degradacji nie mogą być szkodliwe i nie powinny inicjować procesu zapalnego. Liczba nietoksycznych, ulegających biodegradacji materiałów wykorzystywanych do druku przestrzennego jest stosunkowo niewielka i w licznych laboratoriach na świecie prowadzone są prace nad wytworzeniem odpowiednich biomateriałów [4,5].

W ramach niniejszej pracy, przeprowadzono wstępne badania wykorzystujące technikę druku przestrzennego do opracowania sposobu wytwarzania trójwymiarowych, porowatych, przestrzennych podłoży polimerowych o odpowiednio zaprojektowanej geometrii. W przyszłości opracowane modele podłoży posłużą do wytwarzania metodą druku 3D rusztowań z odpowiednio opracowanych materiałów przeznaczonych do regeneracji tkanki chrzęstnej.

2. Materiały i metody

W badaniach wykorzystano materiał Z-PCABS w postaci filamentów firmy Zortrax. Z-PCABS, jest materiałem, który stanowi mieszankę poliwęglanów i ABS-u (kopolimer akrylonitryl/butadien/styren), łączącą w sobie cechy obu składników. Próbki do badań wytwarzano wykorzystując drukarkę Zortrax M200. Zastosowana drukarka pozwala na ustawienie parametrów druku, takich jak grubość warstwy, gęstość wypełnienia, liczba warstw powierzchni górnej i dolnej [7]. Mając na uwadze, że jednym z opisywanych w literaturze sposobów konstruowania podłoży jest naprzemienne układanie warstw obróconych względem siebie o 90°, zamodelowano i wykonano takie rusztowania. W pierwszym etapie pracy wydrukowano cztery próbki, różniące się między sobą architekturą tj. porowatością, wielkością porów, geometrią, grubością ścianek oraz rozmieszczeniem porów w materiale. Minimalna wielkość drukowanego punktu oraz minimalna grubość ścianki wynosiła 400 μm, grubość ścianek bocznych wynosiła 800 μm. Wykonane próbki (PCABS-1-4) posiadały warstwy ułożone naprzemiennie pod kątem 90°, otoczone ścianką o grubości 800 μm. Różnice w mikrostrukturze osiągnięto poprzez zmiany odległości pomiędzy drukowanymi liniami. Drukowanie odbywało się w pomieszczeniu o temperaturze 20°C,a grubość nanoszonej warstwy wynosiła 140 μm. Dodatkowo wykonano podłoże o większej grubości (PCABS-5), składające się z sześciu naprzemiennie ułożonych warstw. Podłoże składało się z prętów o przekroju kwadratowym o boku 1 mm, oddalonych od siebie o 1 mm. Grubość nanoszonej warstwy wynosiła 90 mikronów.

Wytworzone próbki zostały poddane ocenie mikrostruktury. Badania wykonano na mikroskopie optycznym do światła przechodzącego MB200 firmy OPTA-TECH oraz mikroskopie stereoskopowym SN firmy OPTA-TECH, wyposażonych w mikroskopową kamerę cyfrową CMOS 3 oraz oprogramowanie OptaViewIS do rejestracji i analizy zdjęć mikroskopowych. Badania przeprowadzono przy całkowitym powiększeniu 40x (mikroskop MB200) oraz 8x (mikroskop SN).

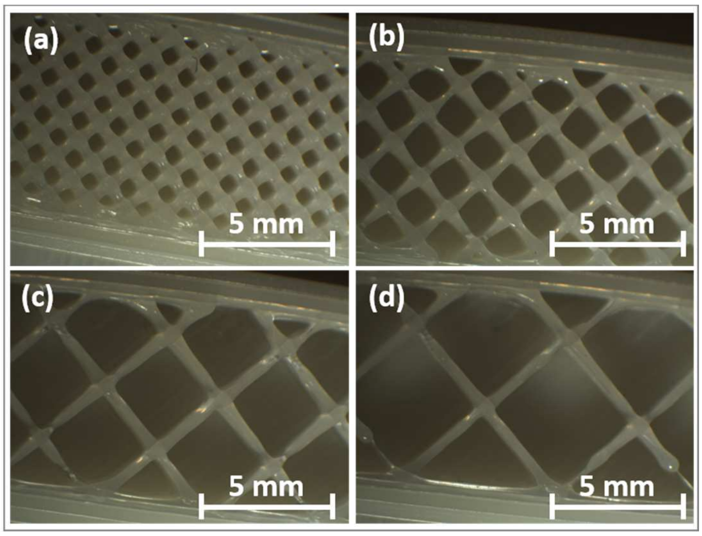
3. Wyniki i dyskusja

Duża porowatość otwarta w przypadku podłoży tkankowych pozwala na zasiedlenie oraz dostarczenie komórek do miejsca regeneracji. Dobór wielkości porów powinien być dostosowany do wielkości komórek danej tkanki. Dodatkowo porowata mikrostruktura rusztowania umożliwia transport składników odżywczych i produktów przemiany materii, a także sprzyja unaczynieniu nowopowstającej tkanki. Na rysunku 1 i 2 przedstawiono obrazy mikroskopowe czterech otrzymanych w wyniku druku 3D próbek. Z przedstawionych zdjęć wynika, że wytworzone próbki znacznie różnią się między sobą mikrostrukturą. Zagęszczenie mikrostruktury ma bezpośredni wpływ na wielkość porów oraz jednorodność materiału. Zestawienie tych parametrów dla badanych próbek (PCABS-1-4) przedstawiono w tabeli 1.

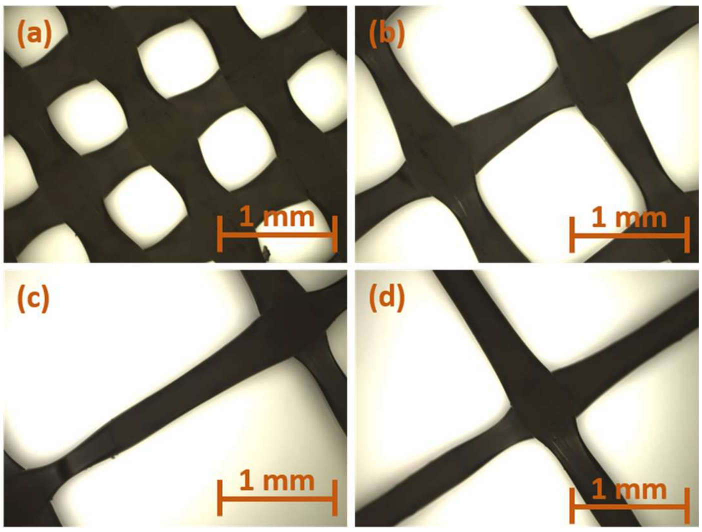
Tabela 1. Zagęszczenie mikrostruktury, przekrój porów i jednorodność materiału badanych próbek

Próbka	Zagęszczenie mikrostruktury	Przekrój porów, mm^2	Jednorodność materiału
PCABS-1	bardzo duże	0,3	bardzo duża
PCABS-2	duże	1,4	duża
PCABS-3	średnie	7,0	średnia
PCABS-4	małe	14,6	średnia

W przypadku próbek PCABS-3 i PCABS-4 zaobserwowano, że są one wykonane ze znacznie mniejszą dokładnością (Rys. 2c-d). Na zdjęciach mikroskopowych pojawiły się nieciągłości ścianek wypełnienia, zaburzające jednorodność wydruku.



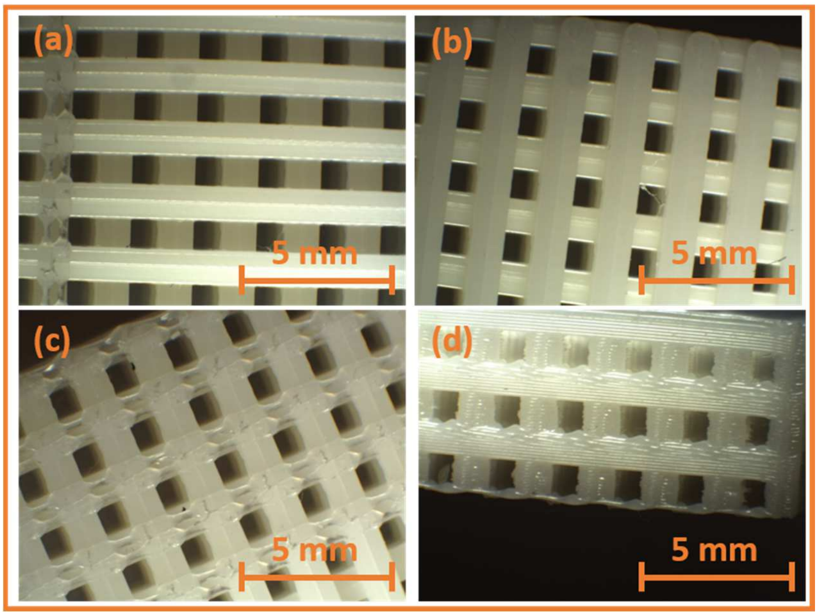
Rysunek 1. Obraz mikroskopowy podłoży wytworzonych metodą druku 3D a) PCABS-1, b) PCABS-2, c) PCABS-3, d)PCABS-4 (SN, pow. 8x).



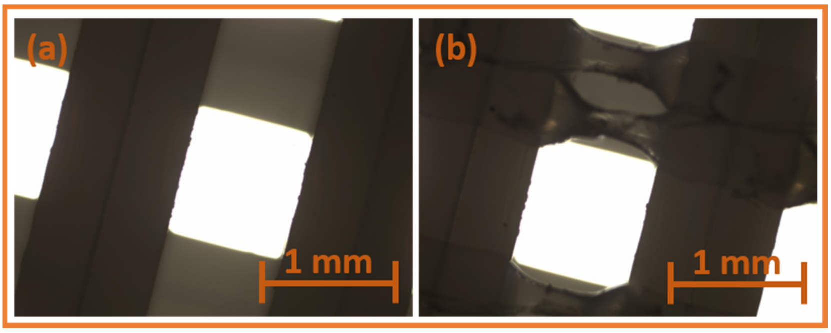
Rysunek 2. Obraz mikroskopowy podłoży wytworzonych metodą druku 3D a) PCABS-1, b) PCABS-2, c) PCABS-3, d)PCABS-4, (MB200, pow. 40x).

W ramach pierwszego etapu badań przeanalizowano zdjęcia próbek w celu określenia odpowiedniej wielkości porów i grubości ścianek między nimi jak również oceny jednorodności próbek po wydruku. Najbardziej jednorodną okazała się próbka o najmniejszym rozmiarze porów.

W drugim etapie badań przeprowadzono obserwacje mikrostruktury próbki PCABS-5. Zdjęcia mikroskopowe próbki z nadrukowanymi kolejnymi warstwami obróconymi względem siebie o 90° przedstawiono na rysunku 3. Każda warstwa złożona jest z szeregu równoległych prętów, tworzących strukturę porowatą. Widoczne są składowe pręty o przekroju kwadratowym i boku długości 1 mm. Analiza zdjęć wykazała homogeniczność struktury również w miejscach połączenia warstw (Rys. 4). Nie zaobserwowano pęknięć ani innych defektów powierzchni. Uzyskane pory charakteryzują się bardzo dużą powtarzalnością. Na zdjęciach (Rys. 3a–c; Rys 4b) widoczne są dwie ścieżki z których zostały wykonane pręty.



Rysunek 3. Powierzchnia próbki z nadrukowanymi kolejnymi warstwami obróconymi względem siebie o 90°, widok z różnych stron próbki (SN, pow. 8x).



Rysunek 4. Mikrostruktura prętów tworzących rusztowanie widoczna pod mikroskopem optycznym a) warstwa ukończona, b) widoczne ścieżki kolejnej warstwy (MB200, pow. 40x).

Zastosowanie konwencjonalnej drukarki, wymaga określenia podczas projektowania wymiarów poprzecznych prętów, odległości pomiędzy nimi oraz kąta zorientowania. Dzięki temu możliwe jest wytwarzanie rusztowań o różnym stopniu porowatości, różnej geometrii i rozmieszczeniu porów.

4. Podsumowanie

Zastosowanie metody druku 3D umożliwiło wytworzenie próbek różniących się wielkością porów. Przeprowadzone obserwacje mikroskopowe pozwoliły na ocenę mikrostruktury oraz jednorodności uzyskanych podłoży. Badania potwierdziły, że możliwe jest zastosowanie konwencjonalnej drukarki opartej o technologię FDM do wytwarzania materiałów o zaplanowanej geometrii i porowatości.

Podziękowania

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SYSTEM DO OCENY JAKOŚCI POWIETRZA W POMIESZCZENIACH ZAMKNIĘTYCH Z WYKORZYSTANIEM WNIOSKOWANIA ROZMYTEGO

Streszczenie: Niniejszy artykuł prezentuje układ mikroprocesorowy przeznaczony do pomiarów stężeń wybranych gazów i zanieczyszczeń występujących w powietrzu, negatywnie wpływających na poczucie komfortu osób przebywających w pomieszczeniach. Dane pozyskane z czujników są wykorzystywane przez algorytm oparty na wnioskowaniu rozmytym, który na ich podstawie wystawia ogólną ocenę komfortu w kontekście świeżości powietrza.

Słowa kluczowe: logika rozmyta, komfort, stężenie gazów, wentylacja, BMS

FUZZY INFERENCE SYSTEM FOR THE ASSESSMENT OF INDOOR AIR QUALITY

Summary: This paper presents a microprocessor system for measurement of concentration of selected gases and pollutants in the air, which have negative impact on the comfort of people in a room. The data acquired from sensors are used by fuzzy logic algorithm, which assesses the comfort in context of air freshness.

Keywords: fuzzy logic, comfort, gas concentration, air conditioning, BMS

1. Wstęp

Obecne trendy w gospodarce kładą duży nacisk na oszczędność energii. Z drugiej strony obserwujemy tendencję do informatyzacji wszelkich możliwych dziedzin życia. W związku z tym jesteśmy świadkami stałego wzrostu popularności budownictwa niskoenergetycznego i pasywnego oraz systemów BMS (ang. Building Management Systems). Konstrukcje tego typu są budowane z myślą o automatyzacji

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oraz jak najlepszej efektywności energetycznej (1). Dążąc do zmniejszenia zapotrzebowania na energię, nie można jednak zapomnieć, że tego typu budynek musi również nadawać się do stałego przebywania ludzi wewnątrz niego - zbyt duży nacisk na obniżenie nakładów na eksploatację może prowadzić do spadku komfortu osób przebywających wewnątrz (co może powodować spadek ich wydajności) lub nawet zagrożenia ich zdrowia i życia.

Szczególnie dużym zagrożeniem pozostaje w tej kwestii działanie systemów wentylacji. Liczne nowoczesne budynki są w pełni hermetyczne – osoby przebywające wewnątrz nie mają możliwości otwierania okien, w kwestii świeżości powietrza muszą więc zdać się na automatykę. Sprawność funkcjonowania systemów wentylacji pozostaje więc niezwykle istotna. Zazwyczaj sterowanie odbywa się na podstawie stężenia dwutlenku węgla w powietrzu, co jest słuszne, ponieważ substancja ta negatywnie wpływa na działanie ludzkiego organizmu, a także zwykle stanowi swoisty wskaźnik obecności innych zanieczyszczeń (2). Nie jest to jednak regułą – w pomieszczeniach przeznaczonych do stałego przebywania osób mogą pojawić również inne substancje – cząstki stałe bądź odory – bardzo obniżające jakość powietrza, natomiast niezwiązane bezpośrednio z obecnością CO_2, niewykrywalne dla powszechnie stosowanych systemów automatyki budynkowej.

W związku z tym podjęto decyzję o zaprojektowaniu i wykonaniu układu sensorycznego, mającego na celu identyfikację świeżości powietrza i przedstawienie jej w postaci wartości liczbowej, mogącej służyć weryfikacji poprawności działania systemów wentylacji lub stanowić podstawę działania algorytmu sterowania wentylacją w systemie BMS. Do tego celu wykorzystano elektroniczne czujniki określające obecność wybranych substancji w powietrzu oraz algorytm wnioskowania rozmytego pozwalający na analizę zmierzonych wartości.

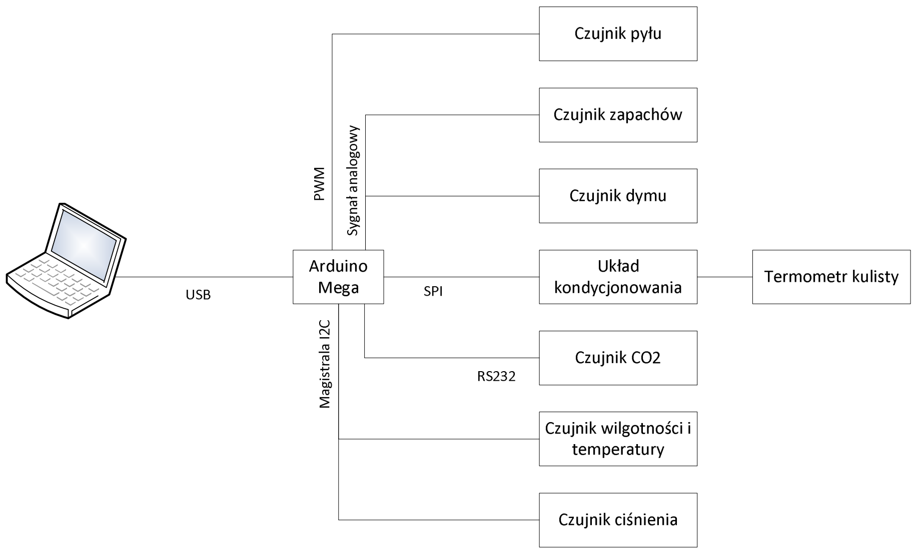
2. Układ pomiarowy

Centralną część systemu pomiarowego stanowi platforma Arduino Mega – płyta wyposażona w mikrokontroler AVR firmy Atmel oraz układy peryferyjne. Głównym jej celem jest obsługa czujników i przesyłanie zgromadzonych danych do komputera PC.

W urządzeniu wykorzystano następujące czujniki:

- GE Telaire T6615 – czujnik stężenia dwutlenku węgla;
- Figaro TGS2600 – czujnik substancji pochodzących z dymu, czuły m. in. na:
    - metan;
    - tlenek węgla;
    - izobutan (metylopropan);
- Figaro TGS2603 - czujnik substancji pochodzących z nieświeżej żywności, czuły m. in. na:
    - trimetyloaminę;
    - metanotiol (merkaptan metylowy);
    - siarkowodór;
- GE-SM-PWM-01A – czujnik obecności w powietrzu pyłów zawieszonych o średnicy mniejszej od 10 µm oraz od 2,5 µm (PM10 i PM2.5).

Powyższe czujniki zostały dobrane ze względu na znaczący wpływ odpowiednich wielkości mierzonych na samopoczucie człowieka. Dwutlenek węgla jest podstawową substancją wpływającą na odczuwalną świeżość powietrza. Wzrost jego stężenia powoduje uczucie znużenia, senność, a przy bardzo wysokich stężeniach pojawiają się duszności i problemy z oddychaniem.
Wykorzystane detektory nieprzyjemnych zapachów reagują jedynie na kilka substancji, a producent określa je jako pochodzące z nieświeżej żywności i dymu papierosowego. Są to jednak substancje, które mogą pochodzić z wielu innych źródeł, odpowiednio z procesów rozkładu substancji organicznych oraz spalania, i towarzyszyć licznym innym odorom.
Cząstki stałe natomiast mogą wywoływać u człowieka podrażnienie błon śluzowych oczu i dróg oddechowych, co stanowi niezaprzeczalny powód spadku komfortu, w wielu przypadkach nie jest natomiast możliwe do wykrycia przez pozostałe sensory.
Układ jest wyposażony również w czujniki umożliwiające ocenę komfortu termicznego: czujnik temperatury, wilgotności, ciśnienia i promieniowania cieplnego (termometr kulisty). Ocena komfortu cieplnego nie jest jednak przedmiotem niniejszego artykułu. Konfigurację i sposób podłączenia systemu przedstawia Rys. 1.

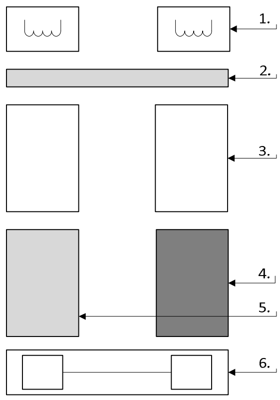


Rysunek 1. Schemat układu pomiarowego

2.1. Zasada działania zastosowanych sensorów

Czujnik dwutlenku węgla

Do pomiaru stężenia dwutlenku węgla zastosowano czujnik wykorzystujący zjawisko absorpcji w podczerwieni. Czujnik składa się ze źródła promieniowania podczerwonego, filtrów, komory porównawczej oraz pomiarowej i detektora (Rys. 2).



1. źródło promieniowania;
2. filtr wąskopasmowy;
3. komory eliminujące wpływ czynników zakłócających;
4. komora pomiarowa;
5. komora porównawcza;
6. detektor różnicowy.

Rysunek 2. Budowa czujnika na zasadzie absorpcji IR

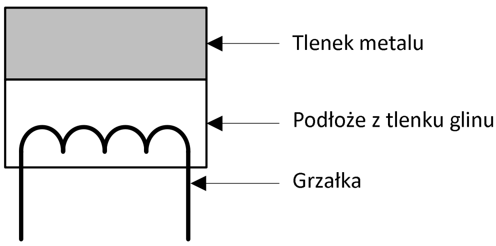
Wiązka promieniowania przechodzi przez komorę pomiarową, gdzie ulega absorpcji zgodnie z prawem Lamberta-Beera, oraz komorę porównawczą, w całości wypełnioną analizowanym składnikiem (w tym przypadku dwutlenkiem węgla), gdzie odpowiednie, charakterystyczne dla tej substancji pasmo ulega całkowitej absorpcji. Stopień absorpcji w komorze pomiarowej w stosunku do komory porównawczej pozwala określić stężenie badanego składnika (3).

Czujniki zanieczyszczeń powietrza

Do pomiaru stężenia zanieczyszczeń powietrza, wpływających na jego zapachową jakość, czyli tzw. odorów, często wykorzystuje się rezystancyjne czujniki elektrochemiczne na bazie tlenków metali (4).

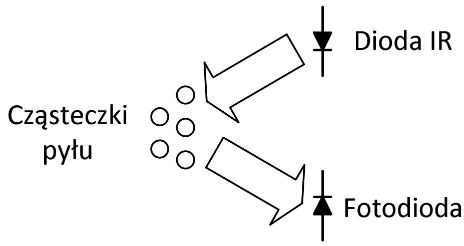
Podstawową zasadą działania tego typu czujników jest zmiana ich rezystancji zależna od składu otaczającej je atmosfery. Do ich budowy zwykle wykorzystuje się tlenek cyny domieszkowany tlenkami metali lub metalami szlachetnymi. Domieszki sprawiają, że sensor jest czuły na konkretne związki lub grupy związków chemicznych. Warto jednak zaznaczyć, że selektywność nie należy do zalet tych urządzeń - zazwyczaj reagują na kilka różnych substancji, co jednak w przypadku pomiarów zapachowego komfortu można uznać za zaletę - od konkretnego składu chemicznego zanieczyszczeń bardziej interesuje nas tutaj ich obecność.

Czujniki te zazwyczaj, aby zachować jak najlepsze własności metrologiczne, pracują w stabilizowanej, podwyższonej temperaturze, często utrzymywanej przez wbudowaną w układ grzałkę (Rys. 3). W obecności odpowiednich związków obserwuje się spadek rezystancji warstwy tlenku metalu zależny od rodzaju związku oraz jego stężenia.



Rysunek 3. Budowa rezystancyjnego czujnika chemicznego

Czujnik cząstek stałych
Zasadniczym elementem czujników pyłu są zazwyczaj dioda emitująca promieniowanie podczerwone (IR) oraz fotodioda, umieszczone jak na Rys. 4. Światło emitowane przez diodę odbija się od obecnych w powietrzu cząstek stałych i jest wykrywane przez fotodiodę, sygnał z której jest wzmacniany i interpretowany przez układ elektroniczny czujnika.



Rysunek 4. Zasada działania czujnik pyłu

2.2. Komunikacja z sensorami

Za obsługę czujników odpowiada platforma Arduino Mega. Jej głównym zadaniem jest odbieranie danych z sensorów, ich wstępne przetwarzanie i przekazywanie do komputera PC. Dzięki wbudowanemu przetwornikowi analogowo-cyfrowemu układ dokonuje pomiaru napięcia na dzielnikach rezystancyjnych, do których podłączone są czujniki zanieczyszczeń, następnie wartości te są przeliczane na odpowiednią wartość rezystancji.
Komunikacja z czujnikiem dwutlenku węgla odbywa się poprzez interfejs UART. Wykorzystano czujnik zintegrowany, który dzięki wbudowanemu procesorowi jest w stanie przesłać w formie cyfrowej dane poddane już kondycjonowaniu i nie wymagające dalszej obróbki.
Zastosowany czujnik cząstek stałych posiada wyjścia generujące sygnał PWM – stopień wypełnienia przebiegu prostokątnego jest proporcjonalny do masy cząsteczek pyłu przypadających na jednostkę objętości powietrza. Sensor posiada dwa wyjścia, dla małych i dużych cząstek, które są podłączone do wejść zegarowych Arduino, co pozwala na pomiar poziomu wypełnienia i przeliczenie go na informację o stężeniu cząstek stałych.
Czujniki związane z komfortem termicznym są podłączone do procesora z użyciem interfejsów cyfrowych: I^2C oraz SPI.
Pozyskane dane są przesyłane do komputera z użyciem protokołu Modbus RTU co pozwala także na integrację opracowanego układu z systemem BMS budynku lub połączenie z większością dostępnych na rynku sterowników PLC.

3. Analiza sygnałów

Pozyskane dane są odbierane i analizowane na komputerze PC przez skrypt uruchamiany w środowisku GNU Octave. Algorytmy wnioskowania rozmytego realizowane są przez Octave Fuzzy Logic Toolkit.

3.1. Podstawy wnioskowania rozmytego

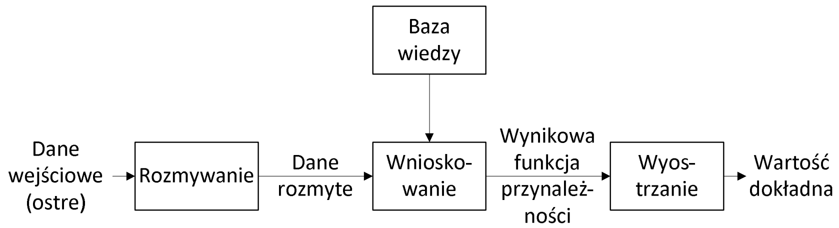
Logika klasyczna stanowi logikę dwuwartościową: każde zdanie może być prawdziwe lub fałszywe, w przeciwnym wypadku nie jest ono zdaniem logicznym. Rozszerzeniem tego rozumowania jest logika rozmyta: tutaj wartość logiczna zdania nie jest elementem ze zbioru {0, 1}, tylko ze zbioru [0, 1].

Powyższy sposób rozumowania można przenieść na pole teorii zbiorów (5). W przypadku klasycznego zbioru element może do niego należeć lub nie należeć. Gdy mamy do czynienia ze zbiorem rozmytym element może należeć, nie należeć lub należeć w pewnym stopniu. Wiąże się z tym pojęcie funkcji przynależności, czyli funkcji opisującej, w jakim stopniu dany element należy do danego zbioru.

Jest to spójne z postrzeganiem otoczenia przez organizmy żywe - w procesie przetwarzania danych posługują się one informacją nieprecyzyjną, jednak mimo to są w stanie na tej podstawie podejmować decyzje. W tym miejscu pojawia się pojęcie zmiennej lingwistycznej - wielkości przyjmującej wartość lingwistyczną. Przykładami takich zmiennych mogą być "temperatura", "prędkość", "wiek". Wartość lingwistyczna natomiast to słowny opis wartości zmiennej, np. "ciepło", "szybko", "młody" (6,7).

Decyzja o wykorzystaniu algorytmu bazującego na logice rozmytej zapadła na podstawie podobieństwa przebiegu procesu wnioskowania z jej użyciem do wnioskowania przez człowieka, co jest szczególnie użyteczne w przypadku analizy pojęcia poczucia komfortu (6,8).

Klasyczny system rozmyty składa się z czterech części: bazy wiedzy (reguł), bloku rozmywania, bloku wnioskowania i bloku wyostrzania (Rys.5).



Rysunek 5. Podstawowy schemat wnioskowania rozmytego

Baza wiedzy stanowi reprezentację wiedzy eksperta zapisaną w postaci funkcji przynależności oraz prostych reguł rozmytych. Zazwyczaj reguły te występują w postaci:

Jeżeli x_1 jest A_1 **i** x_2 jest A_2 **i** ... **i** x_n jest A_n **to** y_1 jest B_1 **i** ... **i** y_n jest B_n;

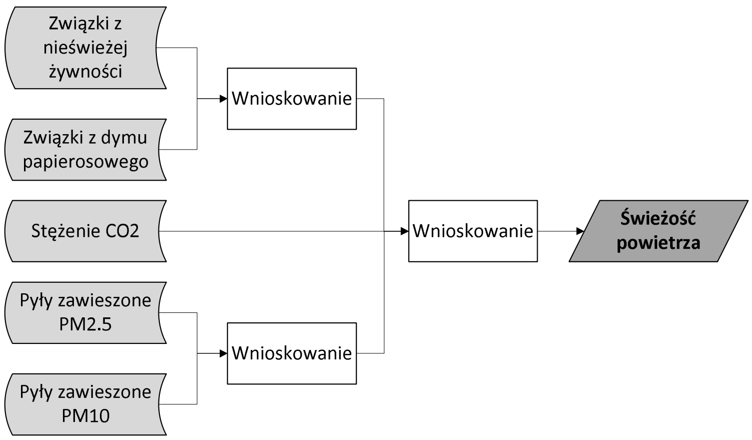
gdzie x_i to dane wejściowe, y_i stanowią zmienne wyjściowe modelu lingwistycznego, a A_i i B_i to zbiory rozmyte.

Rozmywanie polega na obliczeniu stopnia przynależności wartości wejść modelu do zbiorów rozmytych tych wejść na podstawie funkcji przynależności, tzn. konkretna wartość liczbowa jest w danym stopniu przypisywana do wartości lingwistycznej (np. 20°C to w 80% ciepło i w 20% zimno, gdzie "ciepło" i "zimno" to odpowiednie zbiory rozmyte).

Podczas wnioskowania oceniany jest stopień spełnienia przesłanek reguł, następnie określane są funkcje przynależności konkluzji. Ostatecznie dokonywana jest agregacja i określenie wynikowej funkcji przynależności wszystkich reguł.
W procesie wyostrzania natomiast wyjściowy zbiór rozmyty B'(y) zastępowany jest reprezentatywną wartością dokładną y'.

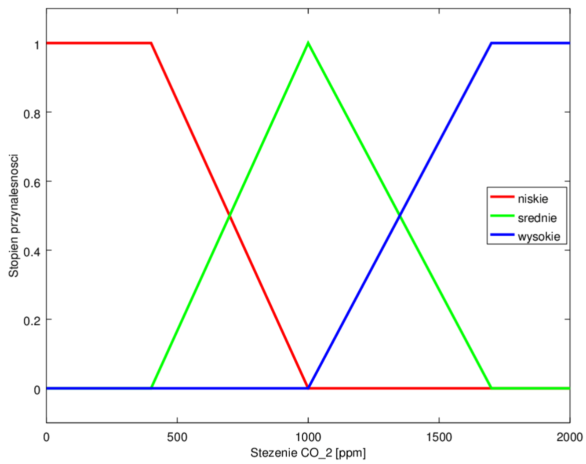
3.2. Wnioskowanie w systemie

Zaprojektowany system wystawiający ocenę świeżości powietrza ma strukturę kaskadową. Zapachy oraz obecność cząstek stałych w powietrzu są oceniane za pomocą osobnych podsystemów, po czym wraz z wartością pomiaru stężenia dwutlenku węgla są analizowane przez ostatni podsystem wnioskowania.



Rysunek 6. Schemat wnioskowania w systemie oceny świeżości powietrza.

W bazach wiedzy na poszczególnych etapach wnioskowania przyjęto trapezoidalne funkcje przynależności. Na Rys. 7 przedstawiono przykład funkcji przynależności dla stężenie dwutlenku węgla w powietrzu.



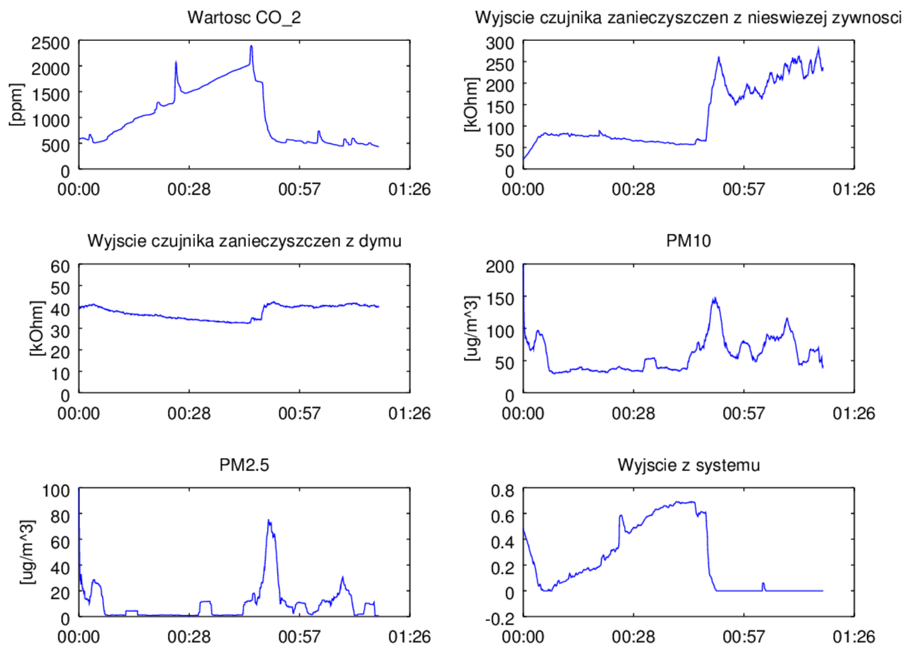
Rysunek 7. Funkcje przynależności wartości stężenia CO_2 w powietrzu.

Przyjęty optymalny schemat wnioskowania (9,10):

- Koniunkcja: iloczyn
- Implikacja: iloczyn
- Agregacja: suma algebraiczna (alternatywa probabilistyczna)
- Wyostrzanie: metoda środka ciężkości

4. Badania

System został zainstalowany w pomieszczeniu o powierzchni 55 m^2 w którym przebywało 28 osób. W pierwszej, trwającej 45 minut, fazie w pomieszczeniu funkcjonowała jedynie wentylacja grawitacyjna, następnie otwarte zostały okna i pomiary trwały przez kolejne 33 minuty.
Na Rys. 8 przedstawiono zarejestrowane podczas doświadczenia przebiegi wartości monitorowanych parametrów. Wyjścia z czujnika cząstek stałych oraz zanieczyszczeń pochodzących z dymu nie wpływały na wynik, ponieważ ich wartości nie wykraczały powyżej stanu komfortu w tych aspektach.



Rysunek 8. Zarejestrowane przebieg i wyjście systemu ekspertowego.

Ostatni wykres na Rys. 8 przedstawia wyjście ciągłe z systemu analizującego jakość powietrza. W wybranej skali 0 oznacza brak wyczuwalnych zanieczyszczeń, a stężenie CO_2 bliskie atmosferycznemu, czyli praktycznie najświeższe możliwe

powietrze. Wskazanie 1 natomiast reprezentuje arbitralnie dobrany poziom odczuwania bardzo dużego dyskomfortu.
Przez pierwsze 4 minuty obserwujemy spadek dyskomfortu. Niestety nie jest to efekt zmian w składzie powietrza, a jedynie manifestacja podstawowej wady czujników na bazie tlenku cyny – długi czas stabilizacji po uruchomieniu. Następnie obserwujemy stopniowe pogarszanie się warunków – widzimy, że zastosowana w pomieszczeniu wentylacja nie jest wystarczająca w stosunku do przebywającej w nim liczby osób. Po otwarciu okien obserwujemy natomiast bardzo szybką poprawę komfortu – widzimy znaczny spadek stężenia CO_2 oraz zawartości odorów. Zaobserwować można też wzrost ilości cząstek stałych w powietrzu, wywołany wzmożonym ruchem powietrza, nie jest jednak on na tyle duży, by wpływać na komfort. Zaprezentowana na Rys. 9 wartość wyjścia okazała się zbieżna z odczuciami osób przebywających w pomieszczeniu. Wyjątkiem są pewne maksima lokalne sygnału (np. w 25 minucie) – powodem ich pojawiania się było umiejscowienie systemu: sensory były umiejscowione w centralnej części pomieszczenia na wysokości 1,7 m, dzięki czemu bardzo dobrze mogły rejestrować sygnały docierające do człowieka, niestety były narażone na wpływ bliskiej obecności ludzi – skoki sygnałów, szczególnie stężenie CO_2 powstawały, gdy osoba przebywająca blisko sensorów np. coś powiedziała, przez co układ chwilowo mierzył parametry powietrza przez nią wydychanego.

5. Podsumowanie

W ramach zaprezentowanego w artykule projektu powstał prototyp systemu umożliwiającego estymowanie ludzkiego odczucia jakości powietrza w danych warunkach środowiskowych. Zastosowanie logiki rozmytej pozwoliło oprzeć obliczenia na prostych, czytelnych i łatwych do modyfikowania zależnościach, bez potrzeby budowy skomplikowanych, wielowejściowych modeli matematycznych. Wypracowany sygnał wyjściowy może służyć do oceny działania systemów uzdatniania powietrza, przede wszystkich w budynkach pasywnych, ich diagnostyki, a w dalszej kolejności także do sterowania nimi. System bardzo dobrze nadaje się jako element pętli sterowania np. centralą wentylacyjną – na podstawie jego wyjścia możliwe jest określenie optymalnej prędkości przepływu powietrza przez dane pomieszczenie opartej o jego wielokryterialną ocenę.
W systemie możliwe jest także wprowadzenie dodatkowej dynamiki – baza rozmyta może uwzględniać, jak długo dany czynnik występuje i jaki czas jego wystąpienia może mieć wpływ na człowieka. Pozwoli to uniknąć niechcianych skoków sygnału, a także wziąć pod uwagę dodatkowe cechy ludzkiej percepcji – przyzwyczajanie się do długotrwale panujących warunków lub znaczną zmianę odczuć w wyniku ich chwilowych wahań.

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Opiekun naukowy: Jacek RYSIŃSKI[5], Marcin SIDZINA[6]

PROJEKT I WYKONANIE WINDY TOWAROWEJ JAKO STANOWISKA DYDAKTYCZNEGO

Streszczenie: W artykule przedstawiono projekt oraz wykonanie stanowiska dydaktycznego windy towarowej napędzanej serwonapędem. We wstępie opisano podział, klasyfikację oraz typy wind. Następnie przedstawiono własny projekt wraz algorytmem sterowania. We wnioskach wykazano możliwe kierunki rozwoju projektu.

Słowa kluczowe: winda, sterowanie, systemy serwonapędowe, sterowanie, PacMotion

DESIGN AND IMPLEMENTATION OF THE FREIGHT ELEVATOR AS A TEST STAND

Summary: The paper describes a process of designing and implementation of the freight elevator. Analysis was performed on the base of own test stand. In the summary possible directions of development of the project are presented.

Keywords: elevator, motion control, PacMotion

1. Wstęp

Windy towarowe oraz do transportu osób stanowią powszechny element budynków mieszkalnych, biurowych i handlowych, a także wielu obiektów przemysłowych. Obszar rynku z nimi związany stanowi jednocześnie ważną dla automatyków branżę,

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gdzie trafiają urządzenia napędowe i produkty z zakresu sterowania oraz pomiarów. Podstawowe parametry wind to udźwig i szybkość przemieszczenia się, ale coraz istotniejsze dla użytkowników i właścicieli stają się też ich efektywność energetyczna, walory użytkowe i naturalnie bezpieczeństwo.

1.1. Zarys historyczny

Początki rozwiązań technicznych przypominających dźwig sięgają czasów starożytnych Rzymian. Ze źródeł historycznych wiadomo, że stosowano takie urządzenia w roku ok. 50 n.e. Konstrukcja tych dźwigów posiadała przeciwwagę, która podniesiona na pewną wysokość stanowiła po jej zwolnieniu siłę napędową urządzeń. Dodatkowo dźwigi poprzez odpowiednie olinowanie były połączone w jeden mechanizm dający możliwość jednoczesnego wjazdu na arenę 20 gladiatorów. Przez wieki stosowano różne rozwiązania urządzeń dźwigowych napędzane siłą ludzkich mięśni lub wykorzystując zwierzęta pociągowe. Z reguły były to rozwiązania bazujące na wykorzystaniu maszyn prostych, głównie wielokrążków. Choć już wtedy wykorzystuje się element przeciwwagi. Prawdziwy przełom przynosi wynalazek silnika parowego. Pojawia się szereg rozwiązań napędzanych pasami transmisyjnymi i wyposażonych w przekładnie zębate.
Sprawnie funkcjonujący dźwig osobowy wynalazł Elisha Otis pochodzący z Nowego Jorku. Do rozreklamowania go wykorzystał Wystawę Światową otwartą w Nowym Jorku w 1853 roku. Pierwszy dźwig osobowy zainstalowano w 1857 r. W 1880 r. Werner von Siemens dołączył do konstrukcji windy silnik elektryczny. Pierwsze windy towarowe służyły w kopalniach do wydobywania urobku, bądź pracowników na powierzchnię.
Obecnie stosuje się rozwiązania z napędem elektrycznym oraz hydraulicznym, rzadziej śrubowym. Popularność uzyskują również rozwiązania tzw. dźwigów bez maszynowni, które nie wymagają oddzielnego pomieszczenia maszynowni poza szybem dźwigowym. Są to urządzenia, których wszystkie elementy zostały umieszczone wewnątrz szybu dźwigowego.

1.2. Klasyfikacja wind

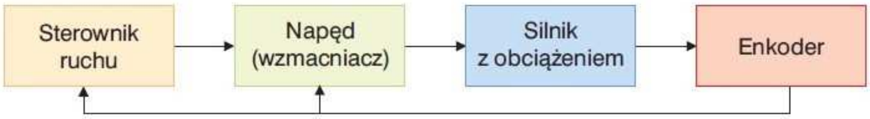
Windy najczęściej klasyfikuje się ze względu na rodzaj napędu - elektrycznego oraz hydraulicznego. W tych drugich kabinę z ładunkiem wprawia w ruch siłownik hydrauliczny zazwyczaj zasilany przez pompę hydrauliczną napędzaną silnikiem elektrycznym. Aby zatrzymać **windę** na wybranej wysokości, pompa jest wyłączana. Z kolei ruch w dół następuje po tym, gdy otwarty zostaje zawór, którym płyn hydrauliczny odpływa z przestrzeni roboczej siłownika.

Według danych **Urzędu Dozoru Technicznego** (UDT) w latach 2005-2011 ze wszystkich ponad 27 tys. nowych **wind osobowych** i osobowo- towarowych prawie 21 tys. było wyposażonych w napęd elektryczny. W dźwigach tego rodzaju na koła napędzane silnikiem elektrycznym nawinięte są liny, na których jednym końcu zawieszona jest kabina, a na drugim przeciwwaga. Ta ostatnia waży zwykle tylko tyle, ile kabina zapełniona do połowy. **Windy elektryczne** dzieli się na dwie grupy: dźwigi bezreduktorowe i z przekładnią.

1.3. Motion control – nowy trend w przemyśle dźwigowym

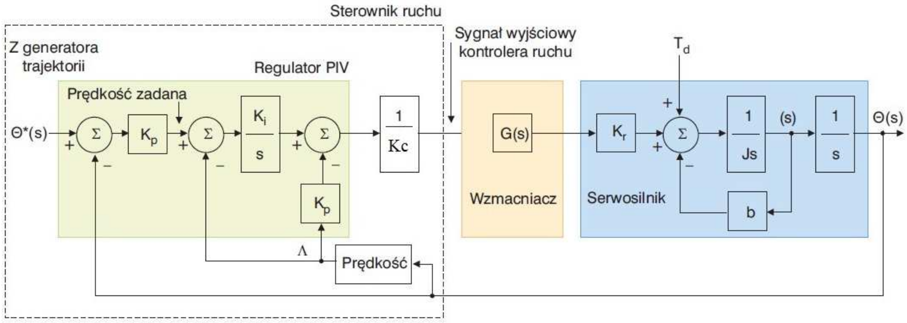
Serwonapędy stanowią układy sterowania ruchem o charakterze zamkniętym. W porównaniu z układami otwartymi charakteryzuje je krótszy czas odpowiedzi, większa dokładność sterowania oraz mniejsza wrażliwość na zaburzenia z zewnątrz i zmiany obciążenia. Dzięki temu są one popularnym elementem automatycznych maszyn pakujących, sortujących, tnących, dozujących oraz transportujących, w przypadku których najważniejsze są: wydajność, szybkość oraz precyzja ruchu.

Główne komponenty serwonapędu przedstawiono na rysunku 1 - są to: sterownik ruchu, wzmacniacz (inaczej napęd), silnik z dołączonym obciążeniem oraz element pomiarowy w pętli sprzężenia zwrotnego (na przykład enkoder lub resolwer).



Rysunek 1. Schemat blokowy serwonapędu [źródło własne]

Na rysunku 2 zamieszczono **uproszczony model serwonapędu** opracowany z wykorzystaniem transformaty Laplace'a.
Serwosilnik został w nim przedstawiony z uwzględnieniem momentów bezwładności wirnika silnika oraz jego obciążenia J, tłumienia lepkościowego b, stałej momentu napędowego K_t oraz jego zaburzeń z zewnątrz T_d. Podstawowe bloki funkcjonalne sterownika ruchu to natomiast: generator trajektorii oraz regulator.
Generator trajektorii wyznacza profil ruchu, a na jego podstawie obliczane są wartości zadane parametrów ruchu podawane na wejście układu regulacji. Wzmacniacz przetwarza z kolei sygnał wyjściowy kontrolera ruchu na sygnał sterujący silnikiem. Moment napędowy silnika (T) jest proporcjonalny do jego prądu (I) i wynosi $K_p\, T \approx K_t \cdot I + T_d$ [6].



Rysunek 2. Model serwonapędu [źródło własne]

W kontrolerze wartość zadana położenia $\Theta^*(s)$ obliczona w generatorze trajektorii jest porównywana z aktualną pozycją $\Theta(s)$ mierzoną przez enkoder lub inny czujnik sprzężony z wałem silnika.

Wynik tego zestawienia (błąd położenia) obliczany z zależności $e(t) = \Theta^{*}(s) - \Theta(s)$ jest sygnałem wejściowym bloku regulatora PID [6]. Sygnał wyjściowy tego ostatniego jest obliczany jako suma trzech składników proporcjonalnych do sygnału błędu położenia, całki z sygnału tego błędu oraz jego pochodnej [6]:

$$u(t) = K_p \cdot e(t) + K_i \cdot \int e(t)dt + K_d \cdot \frac{de(t)}{dt} \qquad (1)$$

W razie potrzeby sygnał wyjściowy kontrolera ruchu jest odpowiednio przeskalowywany (blok 1/Kc na rysunku 2).

1.4. Opis problemu

Podstawowym zadaniem tworzonego projektu było zaprojektowanie oraz wykonanie modelu windy towarowej z zastosowaniem serwosilnika jako elementu napędowego dźwigu.

2. Stanowisko badawcze

W celu przeprowadzenia badań doświadczalnych wykonano stanowisko laboratoryjne, w którym wykorzystano serwonapęd ß is 8/3000.

2.1. Projekt i wykonanie

Konstrukcja mechaniczna została opracowana z kształtowników oraz blach stalowych. Układ sterowania stanowi sterownik PACSystems RX3i wraz ze wzmacniaczem oraz silnikiem firmy Fanuc.

Rysysunek 3. Konstrukcja mechaniczna modelu windy [źródło własne]

Zastosowane elementy automatyki:

- Sterownik PACSystems RX3i – kontroler o budowie modułowej, którego główną cechą jest pełna skalowalność oraz uniwersalność, a więc możliwość realizacji układów sterowania każdego typu: od sterowania maszynami, poprzez prowadzenie procesu produkcyjnego w którym przeważają sygnały dyskretne, aż po sterowanie procesami analogowymi i wsadowymi wymagającymi ciągłej regulacji.

Rysunek 4. Sterownik PACSystems RX3i [źródło własne]

- Moduł IC695PMM335 – zaawansowany moduł do sterowania serwonapędami (zwany także modułem do pozycjonowania)

Rysunek 5. Moduł do pozycjonowania PMM335 [źródło własne]

-Wzmacniacz serwonapędu Fanuc Beta isV 20

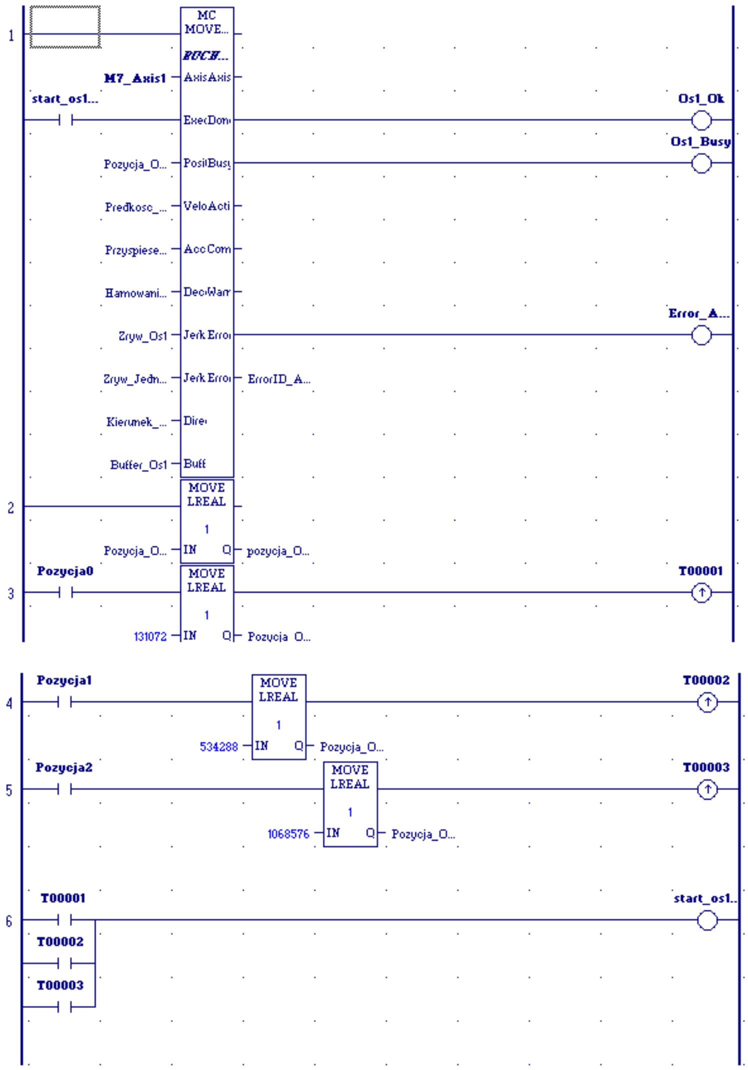
Rysunek 6. Zastosowany wzmacniacz serwonapędu [źródło własne]

- Serwonapęd ß is 8/3000

Rysunek 7. Zastosowany serwonapęd [źródło własne]

2.2. Algorytm sterujący

Program sterujący ma za zadanie sterować ruchem windy poruszającej się po trzech piętrach. Do obsługi windy została wykonana również prosta wizualizacja. Dzięki zastosowanemu serwonapędowi wyeliminowano występowanie czujników obecności windy na poszczególnych piętrach, jedynym sensorem występującym w układzie sterownia jest czujnik indukcyjny odpowiedzialny za pozycjonowanie serwonapędu. Pomimo założenia, iż w projekcie uwzględni się tylko trzy piętra to bezproblemowo można zaprogramować windę tak aby liczba obsługiwanych pięter była większa.
Na rysunku poniżej przedstawiono fragment kodu odpowiedzialny za programową realizację czujników położenia windy.



Rysunek 8. Fragment kodu programu [źródło własne]

3. Rozwój projektu

Po wykonaniu projektu i przeprowadzeniu testów pojawiło się kilka pomysłów na udoskonalenie projektu. Po pierwsze, można by poprawić kwestię wizualną modelu oraz poprawić estetykę wykonania. Po drugie, wykonanie nowej wizualizacji w oprogramowaniu klasy SCADA. Po trzecie, zintegrowanie systemu sterownia z urządzeniami mobilnymi typu tablet czy smartfon.

4. Podsumowanie

Wykonany projekt przedstawia nowy trend zwany windami bez maszynowni, prezentując tym samym zastosowanie serwonapędów w tej dziedzinie techniki. Serwonapęd bezwzględnie poprawia energooszczędność oraz efektywność windy. Ograniczona ilość sensorów znacząco wpływa również na awaryjność dźwigów. Ponadto zastosowanie serwonapędu daje szereg nowych możliwości, pozwala zwiększyć dynamikę pracy urządzenia, daje możliwość wpływania (wybierania) krzywej przyspieszenia i hamowania. W zależności od wyboru typu ustawień można wpływać na redukcję zużycia energii czy efektywność pracy windy. Niebagatelny wpływ na pracę windy ma również komfort podróżowania, poprzez redukcję nieprzyjemnych szarpnięć, wstrząsów czy minimalizację efektu „unoszenia" czy „wgniatania w podłogę" wywołane siłami bezwładności.

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ELECTROSPINNING OF HYALURONIC ACID FIBERS FOR TISSUE ENGINEERING APPLICATION

Summary: Hyaluronan-based porous scaffolds for tissue engineering have been developed through many methods and widely used for tissue engineering of a variety of tissues and organs such as skin, cartilage, and nerve. In this work an attempt to produce hyaluronic acid – based scaffold through electrospinning method was made. The obtained results showed that polymer concentration in solution was not sufficient to form fibers.

Słowa kluczowe: electrospinning, hyaluronic acid, scaffolds, tissue engineering

WYTWARZANIE METODĄ ELEKTROPRZĘDZENIA WŁÓKIEN Z KWASU HIALURONOWEGO DLA ZASTOSOWAŃ W INŻYNIERII TKANKOWEJ

Streszczenie: Porowate podłoża z kwasu hialuronowego mogą być wytwarzane wieloma metodami i znalazły zastosowanie w inżynierii tkankowej skóry, chrząstki i nerwów. W ramach niniejszej pracy podjęto próbę wytworzenia włóknistych rusztowań z kwasu hialuronowego metodą elektroprzędzenia. Otrzymane wyniki pokazały, że stężenie roztworu polimeru nie było wystarczająca do utworzenia rusztowania w postaci włókien.

Keywords: elektroprzędzenie, kwas hialuronowy, podłoża tkankowe – rusztowania, inżynieria tkankowa.

1. Introduction

Tissue engineering has been used as an attractive approach to treat the diseases and defects that are incurable or difficult to be treated by conventional drug administration, artificial prostheses, and organ transplantation [1]. The scaffolds serve as temporary supports to allow cell adhesion, promote cell proliferation and differentiation, assemble the cells and extracellular matrices, and guide the formation of functional tissues and organs [2]. A variety of methods can be used to prepare

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porous scaffolds of biodegradable polymers. Electrospinning uses an electrical field to draw very thin fibers from a charged polymer solution to prepare fibrous scaffolds (nonwovens). The goal of this research was to produce nanofibers of hyaluronic acid (HA) via electrospinning. Electrospun HA fibers, will provide a fibrous scaffold that can mimic the architecture of the native extracellular matrix. Hyaluronic acid is a glycosaminoglycan, distributed widely throughout connective, epithelial, and neural tissues. For example it can be found in vitreous body and synovial fluid. It is also one of the main components of the extracellular matrix.
Electrospinning process parameters are very important to understand not only the nature of electrospinning but also the conversion of polymer solutions into nanofibers through electrospinning. Those parameters can be divided into three parts: solution parameters, process parameters, and ambient parameters. Each of those parameters can affect the fibers morphologies and by proper control of those parameters it is possible to fabricate electrospun fibers with desired morphologies and diameters.
Hyaluronic acid (HA) is known to have a high viscosity at relatively low concentrations, therefore electrospinning the biopolymer is very challenging. Overcoming this high viscosity to successfully find the threshold between molecular weight, viscosity, and spinning parameters, are the challenges faced in fabricating nanofibers of HA for potential use in tissue engineering applications.

2. Materials

2.1. Materials

Sodium hyaluronate was obtained from Contipro Company (Dolni Dobrouć, Czech Republic) with a molecular weight of approximately 1.32 x 10^6 Da. The molecular weight of Sodium Hyaluronate is high, which means that it is composed with long-chain polymer, containing repeating units of Na-glucuronate-N-acetylglucosamine. Other properties of HA are presented in Table 1. Dimethylformamide (DMF, POCH, Poland) and deionized water (H_2O) were used as polymer solvents.

Table 1. Properties of sodium hyaluronate

Appearance	White or almost white powder, granules or fibrous aggregate
Molecular Weight (MDa)	1,32
pH	6,6
Intrinsic Viscosity (m^3/kg)	1,96
Sodium Hyaluronate (%)	97,6
Residual Isopropanol (%)	<0,5
Loss on drying (%)	3,4
Protein (%)	0,029
Chlorides (%)	<0,05

2.2. Solution preparation

At the beginning, a percentage of 3 wt.% of HA with a 1:1 mixture of DMF:H_20 was used (0,3g of HA and 5 mL of DMF and 5 mL of H_2O). The solution was mixed using a magnetic stirrer, until HA was completely dissolved (Fig. 1).

However after 24 hours the solution was very dense (it have gel-like form). Viscosity is an important parameter in electrospinning and to achieve successful spinning, a low viscosity and low concentration of polymer are needed. Therefore to make the solution less dense some more solvent was added (DMF: 2 mL, 3 mL, 5 mL more). However the solution was still too dense, even after adding 10 mL more of DMF. At this step the ratio of DMF and H_2O was 3:1. Then to make the solution less dense again, 10 mL of water was added in order to create 1:1 mixture of DMF:H_2O.The solution was almost at the good density therefore only 2,5 mL more of DMF and 2,5 mL more of water was added. Finally: 0,085% of HA (0,3 g) was used in a 1:1 mixture of DMF:H_2O. In this case 0,3g of HA was dissolved in 17,5 mL of DMF and H_2O (35 mL in total). A concentration of HA in the solution was about 8,57 g/L. After that, an ultrasonic homogenizer was used during 2 minutes to have a perfect homogeneity of the solution.

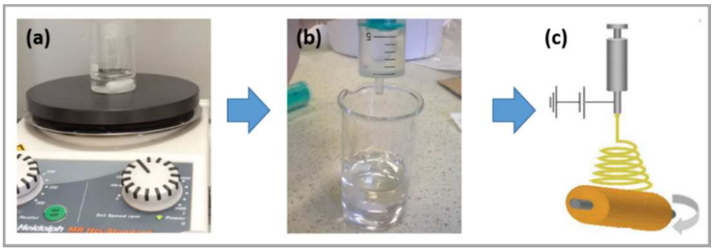

Figure 1. Sample preparation for electrospinning.

2.3. Samples preparation

In order to prepare fibrous scaffolds of HA solution, electrospinning machine (TIC 1092012, Bielsko-Biala) was applied. Electrospinning set-up consisted of a high voltage supply, a syringe pump and a collector (rotary drum). For scaffold fabrication, sample of prepared solution was placed in a syringe (10 ml) topped with a needle whose diameter was 0.22 mm and then connected to 30 kV voltage. The distance between needle and the collector was 15 cm. The rotary drum was wrapped in silica-coated paper. In this experiment, we make three tests of electrospinning, each time changing one parameter: the flow ratio. In order to investigate the effect of solution flow rate on microstructure of obtained materials; three different solution flow rates were applied: (1) 10 mL/h (2) 1 mL/h and (3) 1,5 mL/h. All the parameters used during electrospinning are presented in Table 2. For each test, 5 mL of the solution was used.

Table 2. Parameters used during electrospinning process

PARAMETER	**n°1**	**n°2**	**n°3**
Flow Rate (mL/h)	10	1	1,5
Distance (cm)	15	15	15
Voltage (kV)	30	30	30
Collector Speed (rpm)	415	415	415
Collector Diameter (mm)	20	20	20
Temperature (°C)	20,4	20,4	20,4
Humidity (%)	32	32	32
Polymer Concentration (g/L)	8,57	8,57	8,57

3. Results and Discussion

Polymer concentration has been known as one of the key parameters in electrospinning because it determines the solution viscosity, the polymer chain entanglements that are essential for successful fiber fabrication and the amount of solvent that must be removed in the electrospinning process. At the beginning of the experiment, the 3 wt.% HA solutions was prepared which was difficult to electrospin, thus providing that this sample was too viscous for electrospinning. Therefore, in order to electrospin the solution, the viscosity was reduced by means of dilution (chapter 2.2). A significant decrease in solutions viscosity with lower concentrations at 0,085 wt% HA was observed. The flow rate of solution during electrospinning is another factor affecting the electrospinning process. It is known that the flow rate of the polymer solution determines the morphology of the electrospun nanofibers. When the flow rate is too high, very fine fibers but with many beads can be observed. When the flow rate is too low, there is no beads but fibers have large diameters. Therefore the purpose was to find a compromise, to have the better flow rate and in this way, to have fine fibers without beads. For the first test, the flow rate of the polymer solution was 10 mL/h. The test lasted 10 min. During the electrospinning, none fiber came on the collector. Only drops falling from the metallic needle were observed. For second and third tests, the polymer solution flow rate was much lower (1 mL/h and 1.5 mL/h), and the tests lasted during 20 min each. None fiber were produced.

4. Conclusion

Electrospinning of hyaluronic acid is very challenging. The effects of solution flow rate on the electrospinning process of hyaluronic acid (HA) was investigated. None test gave suitable results. Indeed none test produced fiber, only drops falling from the metallic needle were observed. The authors suppose that the problem is the polymer solution, not appropriate ratio between water and DMF or proportion of HA in the solution. Therefore other experiments will be carried out in order to successfully produce HA fibers.

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WPŁYW STĘŻENIA ROZTWORU ŻELATYNY NA MIKROSTRUKTURĘ WŁÓKNIN WYTWORZONYCH METODĄ ELEKTROPRZĘDZENIA

Streszczenie: Przeprowadzono badania mikroskopowe pozwalające na analizę wpływu dodatku 3%, 6% i 9% wt. żelatyny, obecnej w roztworze służącym do wytwarzania nanowłókien metodą elektroprzędzenia, na mikrostrukturę wytwarzanych włóknin. Wykazano, że wraz ze wzrostem zawartości żelatyny w roztworze zwiększasię średnica wytworzonych włókien.

Słowa kluczowe: elektroprzędzenie, inżynieria tkankowa, podłoża, żelatyna

EFFECT OF GELATIN CONCENTRATION ON MICROSTRUCTURE OF ELECTROSPUN NONWOVENS

Summary: Microscopic studies were carried out to allow for an analysis of the influence of 3%, 6% and 9% wt. gelatin present in the solution, on the microstructure of the electrospun nonwovens. It has been shown that with increasing concentration of the gelatin solution, the fibers diameter increased.

Keywords: electrospinning, tissue engineering, scaffolds, gelatin

1. Wprowadzenie

Proces wytwarzania włókien o średnicach rzędu kilkuset nanometrów lub kilku mikrometrów przy wykorzystaniu sił pola elektrycznego (proces elektroprzędzenia) jest obecnie jedną z najczęściej stosowanych metod wytwarzania polimerowych włókien [1]. Proces elektroprzędzenia umożliwia wytworzenie materiałów o odpowiedniej porowatości i dużym rozwinięciu powierzchni. Niewątpliwym atutem

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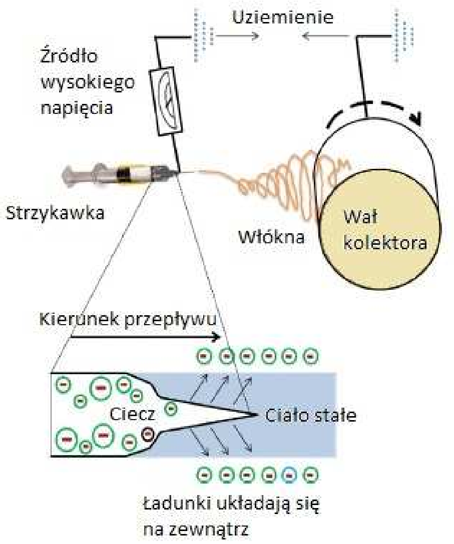
tej metody jest jej prostota oraz wszechstronność. W procesie elektroprzędzenia można stosować zarówno polimery pochodzenia naturalnego jak i syntetyczne, dodatkowo istnieje możliwość wytwarzania materiałów kompozytowych. Poprzez dobór odpowiednich parametrów procesu możliwe jest wytwarzanie włókien o pożądanych średnicach, spełniających przyjęte założenia [2]. Możliwe jest więc wytworzenie podłoża dla inżynierii tkankowej, czyli materiału o mikrostrukturze podobnej do tkanki naturalnie występującej w ludzkim organizmie, którego zadaniem jest przywrócenie funkcji i właściwości uszkodzonej w wyniku wypadku czy choroby tkanki pacjenta. Wytworzone metodą elektroprzędzenia materiały są biomimetyczne, tzn. dzięki podobieństwu do zastępowanych tkanek (nanometryczne średnice włókien), wspomagają i przyśpieszają proces ich regeneracji [3]. Na uwagę zasługuje również możliwość zastosowania tej metody do formowania włóknistych nośników leków. Elektroprzędzenie jest zatem niezwykle interesującym sposobem wytwarzania materiałów dla bioinżynierii, który również znalazł zastosowanie w formowaniu membran dla przemysłu motoryzacyjnego oraz chemicznych i biologicznych nanosensorów o wysokim rozwinięciu powierzchni [6, 7, 8].

1.1. Charakterystyka procesu elektroprzędzenia

Urządzenie do elektroprzędzenia włókien składa się z trzech niezbędnych elementów:
1 - dozownika roztworu polimeru zakończonego strzykawką, podającego roztwór w określonym tempie;
2 - źródła wysokiego napięcia;
3 - uziemionego kolektora (Rys. 1).



Rysunek 1. Schemat procesu elektroprzędzenia [1]

Podawany ze strzykawki roztwór, pod wpływem działania sił napięcia powierzchniowego, tworzy na końcu igły kroplę. Gdy do igły przyłożone jest odpowiednio wysokie napięcie, to na powierzchni kropli znajdą się jednoimienne ładunki, które będą odpychały się z siłą większą niż napięcie powierzchniowe. Na końcu igły pojawi się stożek Taylora, z którego końca uformuje się cienkie włókno rozpuszczonego polimeru. Włókno to jest przyciągane do oddalonego kolektora. W przestrzeni między igłą a kolektorem rozpuszczalnik odparowuje i zostaje uformowany włóknisty materiał polimerowy [1-3]. Możliwe są liczne modyfikacje procesu elektroprzędzenia, na przykład poprzez zastosowanie dwóch podajników z dwoma różnymi roztworami, użycie roztworu w postaci emulsji lub zastosowanie źródła prądu stałego. Na średnicę formowanego włókna, a tym samym na mikrostrukturę wytworzonego materiału, mają wpływ różne parametry, które można podzielić na trzy grupy: (1) parametry procesu, (2) parametry roztworu oraz (3) parametry środowiska. Do parametrów procesu zalicza się przyłożone napięcie, odległość igły od kolektora, objętość podawanego roztworu w jednostce czasu, średnicę wewnętrzną igły oraz rodzaj użytego kolektora. Wśród parametrów roztworu, które mają wpływ na proces formowania, należy wyróżnić: stężenie roztworu, jego lepkość, przewodnictwo oraz napięcie powierzchniowe. Ponadto podczas procesu wytwarzania włókien należy uwzględnić również takie parametry jak temperatura oraz względna wilgotność panująca w przestrzeni gdzie zachodzi proces [9, 10].

1.2. Właściwości i oddziaływanie żelatyny

Żelatyna jest naturalnym, włóknistym białkiem pozyskiwanym z kolagenu w procesie jego hydrolizy. W czasie tego procesu rozpadowi ulegają wiązania między molekułami i zniszczeniu ulega struktura drugorzędowa białka. Żelatyna wykazuje dobrą biokompatybilność i biodegradowalność, co tłumaczy jej szerokie zastosowanie w przemyśle spożywczym i farmaceutycznym. Ponadto w literaturze wspomina się, że obecność tego białka znacząco wspomaga osadzanie i rozmnażanie komórek na podłożach tkankowych. Problemem związanym z wykorzystaniem żelatyny jest jej pęcznienie w obecności wody. Aby temu przeciwdziałać stosuje się chemiczne sieciowanie lub fizyczne mieszanie z innymi polimerami. Jednak stosowanie związków sieciujących ma niepożądane skutki. Po pierwsze zmieniają one strukturę żelatyny a po drugie nieprzereagowane substancje mogą być toksyczne dla komórek i tkanek. Pod wpływem środków sieciujących może również nastąpić zwiększenie średnic włókien żelatyny kosztem porowatości materiału [3].

W ramach niniejszej pracy badano zależności pomiędzy mikrostrukturą włókien uzyskanych w wyniku procesu elektroprzędzenia z roztworu a stężeniem procentowym żelatyny w roztworze polimeru.

2. Metodyka badań

2.1. Zastosowane materiały

Do wykonania roztworu wykorzystano żelatynę typu A (firmy POCH) oraz 2,2,2-Trifluoroetanol ekstra czysty (TFE, ACROS). Przygotowano trzy różne roztwory żelatyny o stężeniach: 3 %, 6 % i 9 % wagowych. Odpowiednią masę żelatyny w postaci proszku odważano i dodano do 10 ml TFE. Proszek był mieszany przez dobę na mieszadle magnetycznym, aż do całkowitego rozpuszczenia biopolimeru. Proces formowania włókien prowadzono na urządzeniu do elektroprzędzenia TIC

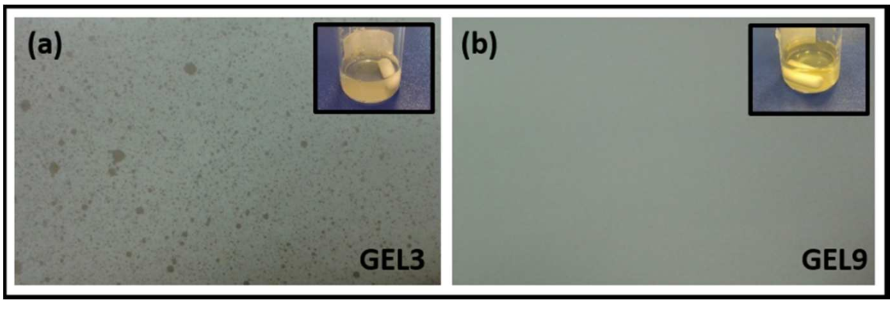
1092012 (ATH, Bielsko-Biała), przy przyłożonym napięciu prądu stałego wynoszącym 20 kV, prędkości dozowania roztworu 1,5 ml/h. Do dozowania zastosowano igłę o średnicy wewnętrznej 0,22 mm, oddaloną o 200 mm od kolektora oraz kolektor (stalowy wałek) o średnicy 20 mm obracający się z prędkością 415 obrotów/min. Proces prowadzono przez 135 minut w porównywalnych warunkach atmosferycznych (temperatura 20°C, wilgotność względna 42%). W rezultacie z trzech roztworów żelatyna/TFE o stężeniu procentowym odpowiednio 3%, 6%, 9% wt. otrzymano trzy włókniste próbki żelatyny oznaczone jako GEL3, GEL6 i GEL9.

2.2. Badania mikroskopowe

Elektroprzędzone nanowłókniste materiały z żelatyny zostały poddane ocenie mikrostruktury przy użyciu skaningowego mikroskopu elektronowego NOVA NANO SEM 200 (producent FEI EUROPE COMPANY). Obserwacje prowadzono w warunkach niskiej próżni 60 Pa w trybie elektronów wtórnych SE, po uprzednim. przygotowaniu próbek na „holderach” i napyleniu przewodzącej cienkiej warstwy węgla w celu lepszego odprowadzenia ładunku elektrycznego z powierzchni próbki. Obserwacje prowadzono w zakresie powiększeń od 1000 x do 50 000x. W oparciu o obrazy z mikroskopu skaningowego wyznaczono średnice włókien. Średnią średnicę włókien wyznaczono wykonując pomiary na 50 włóknach.

3. Analiza wyników

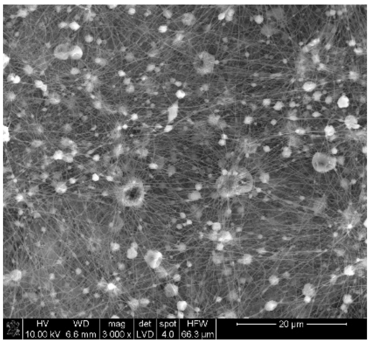
W niniejszej pracy zastosowano identyczne parametry procesu elektroprzędzenia dla przygotowanych wcześniej trzech roztworów polimerowych różniących się procentową zawartością żelatyny. Zastosowane parametry umożliwiły skuteczne wytworzenie trzech włóknistych materiałów z żelatyny. Niemniej jednak już podczas procesu elektroprzędzenia można było zaobserwować pewne różnice między wytwarzanymi materiałami (Rys. 2). W przypadku próbki GEL3 udało się wytworzyć jedynie bardzo cienką warstwę włókniny na której powierzchni widoczne były liczne pory utworzone przez krople rozpuszczalnika. Pozostałe włókniny (GEL6 i GEL9) były znacznie grubsze i charakteryzowały się gładką powierzchnią.



Rysunek 2. Zdjęcia wytworzonych próbek: a) 3% żelatyny, b) 9% żelatyny

Wyniki obserwacji mikroskopowych przedstawiono na rysunku 3. Analizując uzyskane obrazy można zauważyć znaczne różnice również w mikrostrukturze wytworzonych metodą elektroprzędzenia próbek. Z obserwacji mikroskopowych wynika, że wszystkie wytworzone podłoża tworzą sieć złożoną z przestrzennie ułożonych, splątanych ze sobą włókien o różnej średnicy.

a)



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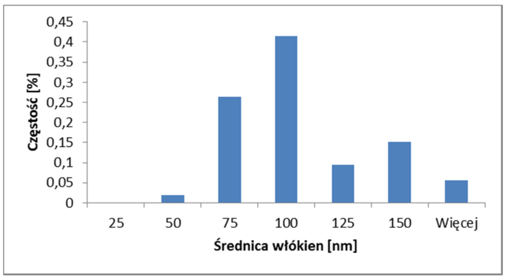

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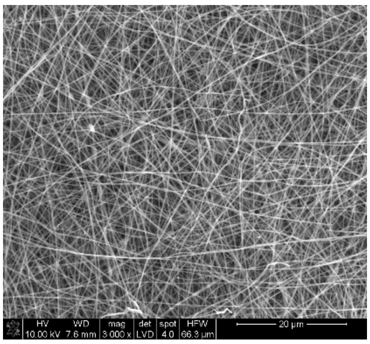

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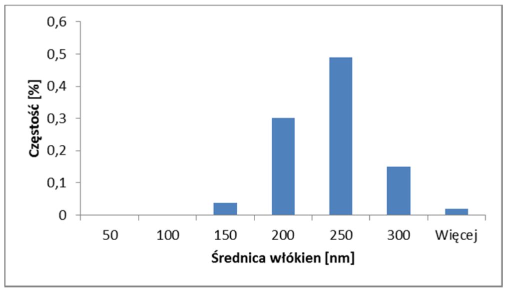

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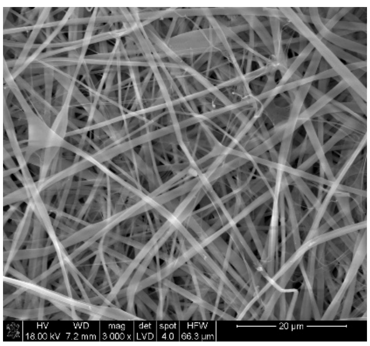

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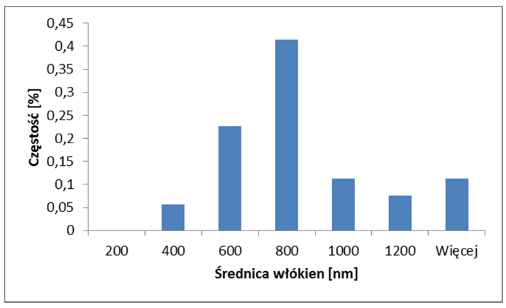
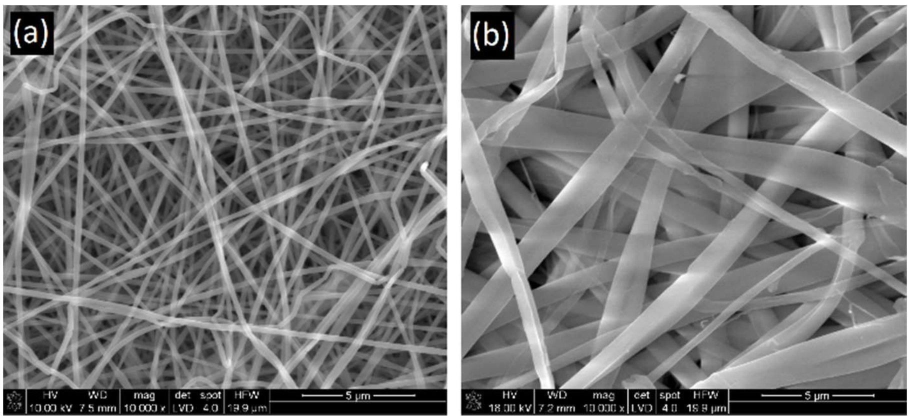


Rysunek 3. Mikrostruktura wytworzonych próbek (SEM): a) GEL3, b) GEL6, c) GEL9 oraz histogramy przedstawiające rozkład wielkości średnic dla próbek: d) GEL3, e) GEL6, f) GEL9

W przypadku włókniny GEL3, można zaobserwować występowanie licznych zgrubień o różnych kształtach oraz tzw. koralików. Przyczyną ich powstawania jest prawdopodobnie zbyt niska lepkość roztworu. W związku z tym struga polimeru zostaje rozerwana i zamiast niej tworzą się liczne grube krople. Rozpuszczalnik w tym przypadku nie zdążył odparować w przestrzeni pomiędzy igłą a kolektorem i dopiero na powierzchni kolektora nastąpiło jego odparowanie oraz zestalenie kropli w postaci zgrubień lub koralików. Efekt ten również zaobserwowano makroskopowo (Rys. 2a). W wyniku procesu elektroprzędzenia z roztworu o 6 % wt. zawartości żelatyny udało uzyskać się nanowłókna o regularnych, porównywalnych średnicach (Rys. 3b, Rys. 4a). Nie zaobserwowano zgrubień ani koralików jak miało to miejsce w włókninie o mniejszej zawartości polimeru. W tym przypadku w przestrzeni pomiędzy dyszą a kolektorem, z rozciąganej strugi, odparowuje rozpuszczalnik doprowadzając do zestalenia jednolitych, gładkich włókien. Większe stężenie procentowe żelatyny w roztworze (9% wt.) umożliwiło otrzymanie próbki o zróżnicowanej morfologii włókien (Rys. 3c). Włóknina GEL9 zbudowana jest z włókien wstążkowych o różnych średnicach (Rys. 4b). Przyczyną powstawania włókien o takim kształcie jest szybkie odparowanie rozpuszczalnika z powierzchni strugi podczas procesu elektroprzędzenia. Szybkie odparowanie rozpuszczalnika powoduje formowanie się skórki w postaci wydrążonej tuby. W wyniku dalszego parowania rozpuszczalnika, skórka zapada się i mokre włókna spłaszczają się podczas zderzenia z kolektorem formując płaską wstążkę.



Rysunek 4. Mikrostruktura włóknin GEL6 (a) i GEL 9 (b)

Na rysunku 3 (d-f) przedstawiono rozkłady wielkości średnicy włókien dla wytworzonych próbek. Próbka GEL3, pomimo obecności licznych pierścieni i zgrubień, charakteryzuje się występowaniem bardzo cienkich włókien. Obliczona na podstawie pomiarów mikroskopowych średnia średnica włókien wynosi w tym przypadku 96 ± 31 nm. Zwiększenie stężenia procentowego roztworu żelatyny spowodowało zwiększenie średnicy włókien. W przypadku włókniny GEL6 średnia średnica włókien wynosi 222 ± 37 nm, próbka charakteryzuje się jednolitymi, gładkimi włóknami. Natomiast obliczona średnica włókien wstążkowych występujących w próbce GEL 9 wynosi 782 ± 327nm. W przypadku tej próbki rozkład wielkości średnic był najbardziej zróżnicowany. Oprócz nanowłókien w próbce występowały również włókna o średnicy większej od 1µm.

4. Wnioski

Na podstawie przeprowadzonych obserwacji wyciągnięto następujące wnioski:

(1) Wraz ze zwiększeniem zawartości żelatyny w roztworze zwiększa się średnica elektroprzędzonych włókien;
(2) Zbyt niskie stężenie polimeru (3% wt.) uniemożliwia otrzymanie makroskopowo jednolitej próbki;
(3) Zbyt duże stężenie polimeru sprzyja otrzymywaniu włókien wstążkowych o różnych średnicach. Przeprowadzone badania umożliwiły wyznaczenie wpływu parametrów wytwarzania metodą elektroprzędzenia włóknin z włókien żelatynowych na morfologię otrzymywanych włokien.

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PROJEKT ZASTOSOWANIA ZAAWANSOWANEGO SKANERA INFINITEFOCUS W PRAKTYCE PRODUKCYJNEJ

Streszczenie: Artykuł zawiera projekt wdrożenia nowoczesnego skanera 3D celem wsparcia kontroli narzędzi w przemyśle produkcyjnym. W niniejszej publikacji zawarte zostało przedstawienie skanera InfiniteFocus, będącego produktem oferowanym przez firmę Alicona oraz sposób wykorzystania tego urządzenia w praktyce produkcyjnej na przykładzie branży motoryzacyjnej.

Słowa kluczowe: skanowanie 3D, InfiniteFocus, Alicona, różnicowanie ogniskowe

APPLICATION OF THE ADVANCED SCANNER INFINITEFOCUS IN MANUFACTURING OPERATIONS

Summary: The article presents project of high resolution optical 3D surface measurement implementation in manufacturing system in order to support tool controlling. The paper presents system InfiniteFocus, which is a product of Alicona company and also describes the way how manufacturing enterprises can use this system in manufacturing practice on the example of automotive industry.

Keywords: 3D scanning, InfiniteFocus, Alicona, focus variation

1. Wstęp

Do najbardziej znaczących sektorów w gospodarce światowej zaliczany jest branża motoryzacyjna, która charakteryzuje się wysokim poziomem innowacyjności oraz stosowaniem nowych technologii. W związku z tym, przedsiębiorstwa muszą ciągle

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szukać nowych rozwiązań w zakresie optymalizacji procesów, zmniejszania kosztów przy jednoczesnym zwiększaniu wydajności, a także muszą liczyć się z ciągłym wdrażaniem rozwiązań w swojej działalności wykraczających poza kanony klasyczne, celem zachowania konkurencyjności. Kluczem w rozwoju innowacyjnej produkcji jest umiejętność stosowania nowoczesnych technologii, między innymi technologii skanowania 3D.
Technologia ta znajduje zastosowanie w wielu gałęziach działalności – zarówno w przemyśle, nauce, jak i w życiu codziennym. Technologia ta pozwala na odwzorowanie rzeczywistego obiektu w wirtualnej rzeczywistości poprzez tworzenie kompletnego cyfrowego modelu przedmiotu przy zachowaniu jego wymiarów, kształtu, czy kolorystyki. Powstały model może być w późniejszych działaniach przetwarzany i edytowany przez programy klasy CAD/CAM, programy do wizualizacji, prototypowania czy animacji komputerowej. Skanowanie 3D zyskuje coraz większą popularność, dzięki swoim niezaprzeczalnym atutom, do których należą przede wszystkim redukcja kosztów, oszczędność czasu i materiału.[3]

2. Skaner InfiniteFocus

Tradycyjnie pomiary narzędzi są wykonywane poprzez stykowe narzędzia pomiarowe. Wadą tego sposobu jest długi czas procedury pomiarowej. Innym minusem jest to, że geometria igły, końcówki głowicy w układach optycznych, może fałszować uzyskiwane wyniki pomiarów. Ponadto zużycie końcówki dotykowej oraz zużycie mierzonego obiektu są niepożądanym skutkiem ubocznym stosowania tradycyjnej metody. Oprócz tego, systemów stykowych nie można zastosować dla większości bardzo małych narzędzi skrawających.
Nowy system pomiaru złożonych narzędzi to skaner InfiniteFocus firmy Alicona (rysunek 1). Jest to optyczny system bazujący na technologii różnicowania ogniskowego, wyposażony w urządzenie z napędem obrotowym. Urządzenie jest w stanie zebrać nawet kilkadziesiąt milionów punktów pomiarowych w relatywnie krótkim czasie. W pierwszym kroku prowadzone pomiary są przedstawione pod kilkoma kątami. Drugi krok dotyczy automatycznego dopasowania do siebie pojedynczych pomiarów. W rezultacie pełny zestaw danych, w pełnym zakresie obrotu mierzonego przedmiotu, jest dostępny do dalszych pomiarów. Mierzone przedmioty mogą charakteryzować się bardzo różną chropowatością powierzchni oraz refleksyjnością. [1]

Rysunek 1. Skaner InfiniteFocus G5 firmy Alicona [1]

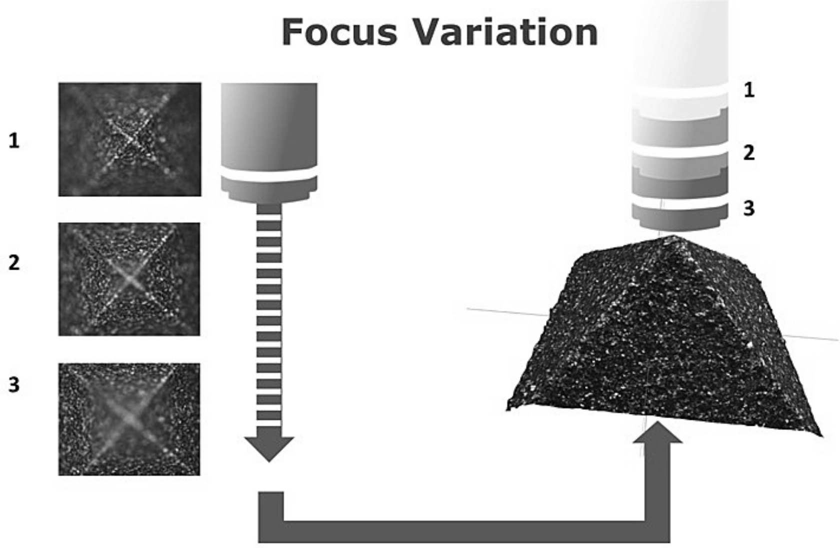
Większość dotychczas stosowanych systemów pomiarowych posiada zasadniczą wadę, mianowicie mogą one mierzyć niezbyt skomplikowane parametry jak na przykład główną średnicę. W przypadku bardziej złożonych parametrów musi być wykonany wysoce zaawansowany i czasochłonny proces pomiarowy. Przedstawiony system jest w stanie nie tylko zmierzyć pełny, trójwymiarowy zestaw danych w wysokiej rozdzielczości, ale także dostarcza kompleksowe parametry narzędzi. Parametry te to między innymi średnica zwojów (w przypadku gwintowników), kąt wykruszenia lub średnica gwintu. Dodatkowo mierzone mogą być również różne parametry chropowatości. [1]

Standardowy system pomiarowy jest w stanie mierzyć powierzchnię z jednego punktu i dostarczać wartości wysokości dla każdego położenia w osiach x i y, w polu widzenia tego punktu. Do pomiaru narzędzia w 360^{o} została opracowana specjalna rotacja, a także urządzenie do obracania i rotacji próbki. Urządzenie to umożliwia przechylanie narzędzia w zakresie pomiędzy 0^{o} a 90^{o} i nieograniczoną rotację wokół 360^{o}.[1]

Zespół obrotowy zawiera specjalny uchwyt zaciskowy, który pozwala na bardzo dokładne pozycjonowanie narzędzia. Liczba wymaganych pomiarów jest przeliczana automatycznie i zależy od wielu parametrów. Ważnymi czynnikami są rozmiar pola widzenia, średnica narzędzia, pochylenie i wysokość skanowania. Podczas pomiarów odbywa się ustawianie w celu uzyskania wysokiej dokładności trójwymiarowego zestawu danych, a także wyeliminowania małych, ale powstających błędów kalibracji osi obrotu. W ostatnim etapie pomiaru wszystkie pojedyncze pomiary są połączone w specjalnym algorytmie, co w ostatecznym wyniku daje kompletny, 360^{o} zbiór danych mierzonego przedmiotu. Po otrzymaniu trójwymiarowego zestawu danych można określić szeroką gamę parametrów geometrii narzędzia takich, jak różne średnice, kąty czy promienie krawędzi na krawędziach tnących.

Technologia różnicowania ogniskowego, na której bazuje skaner InfiniteFocus w szczególności dobrze sprawdza się w pomiarach ostrych krawędzi. Polega ona na wykorzystywaniu ostrości powierzchni (bądź innej właściwości światła odbitego przy najlepszym zogniskowaniu) do oceny wysokości nierówności powierzchni. Mierzony

przedmiot zostaje oświetlony światłem o odpowiedniej modulacji, które jest transmitowane przez optykę i ogniskowane na powierzchni. Odbite przez powierzchnię światło, wraca przez układ optyczny urządzenia i dociera do detektora cyfrowego, który wyszukuje wiązkę zogniskowaną. System optyczny kształtujący obraz powierzchni, umożliwia uzyskanie zarówno informacji fotometrycznych (kolor, jasność), jak i geometrycznych (kształt, odległości). [2]
Technologia różnicowania ogniskowego doskonale nadaje się do pomiarów mikrowierteł, komponentów o bardzo małych wymiarach, bądź gwintowników. Skaner jest w stanie uzyskać obrazy o rozdzielczości pionowej do 10nm, nawet przy skomplikowanym kształcie i dużych obszarach pomiaru. Różnicowanie ogniskowe łączy małą głębokość ogniskowania z systemem optycznym zawierającym pionowe skanowanie, aby dostarczać informację o topografii i kolorze. W celu przeprowadzenia pomiarów trójwymiarowych urządzenie pionowo skanuje próbki poprzez czujnik, przy ciągłym pozyskiwaniu danych. Dzięki temu, że system ma ograniczoną głębokość pola, tylko małe części obiektu są obrazowane dokładnie w tym samym czasie. Poprzez analizę różnicowania ogniskowego podczas procesu skanowania uzyskiwany jest trójwymiarowy zestaw danych. Schemat działania technologii różnicowania ogniskowego został przedstawiony na rysunku 2. [1]



Rysunek 2. Technologia różnicowania ogniskowego w skanerze InfiniteFocus [1]

System firmy Alicona obejmuje między innymi następujące moduły do pomiarów niektórych parametrów [1]:

- moduł do wyodrębniania konturów powierzchni do pomiarów parametrów takich jak średnice, wcięcia i skomplikowane parametry gwintowników,
- moduł do pomiarów geometrii ostrzy skrawających, w tym do pomiarów promienia krawędzi i różnych kątów,
- moduł do mierzenia różnych cech kształtów (promień kuli, kąt stożka, promień walca), na przykład do określania średnicy wału lub dopasowania kąta fazowania,

- dwa moduły do pomiaru chropowatości powierzchni, jeden dla profili powierzchni i jeden dla całych obszarów, jak to zostało określone w ostatnich normach ISO dla pomiarów struktury powierzchni.

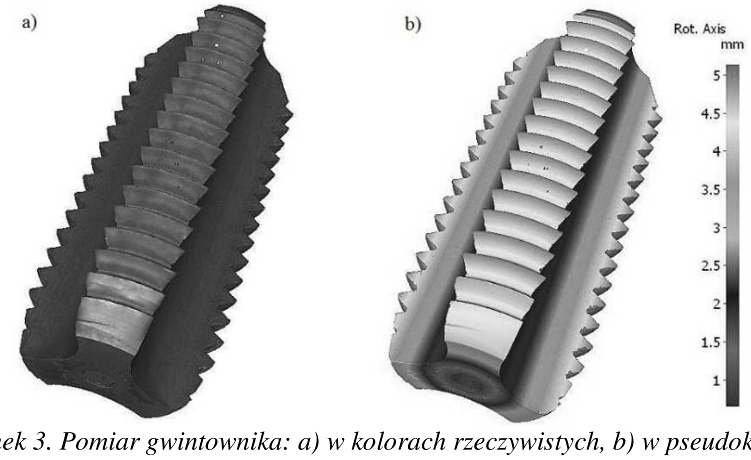
W związku z powyższym skaner InfiniteFocus dostarcza kompleksowych informacji na temat geometrii i struktury przedmiotu mierzonego.

3. Zastosowanie skanera InfiniteFocus w praktyce produkcyjnej

Przedsiębiorstwa prowadzące działalność produkcyjną, zwłaszcza te działające w branży samochodowej, muszą liczyć się z koniecznością prowadzenia badań stanu narzędzi obróbczych, półwyrobów, wyrobów gotowych i innych elementów obecnych w procesach wytwórczych. Jedyną możliwością w takim przypadku jest prowadzenie badań nieniszczących. Jednym ze sposobów przeprowadzenia tego typu badań jest właśnie skanowanie 3D. Aby móc wdrożyć w omawiane działania skaner trójwymiarowy, musi być on na tyle precyzyjny, żeby był w stanie zbadać mikrostrukturę nawet bardzo małych elementów. W związku z tym zastosowanie skanera InfiniteFocus wydaje się być rozwiązaniem idealnym.

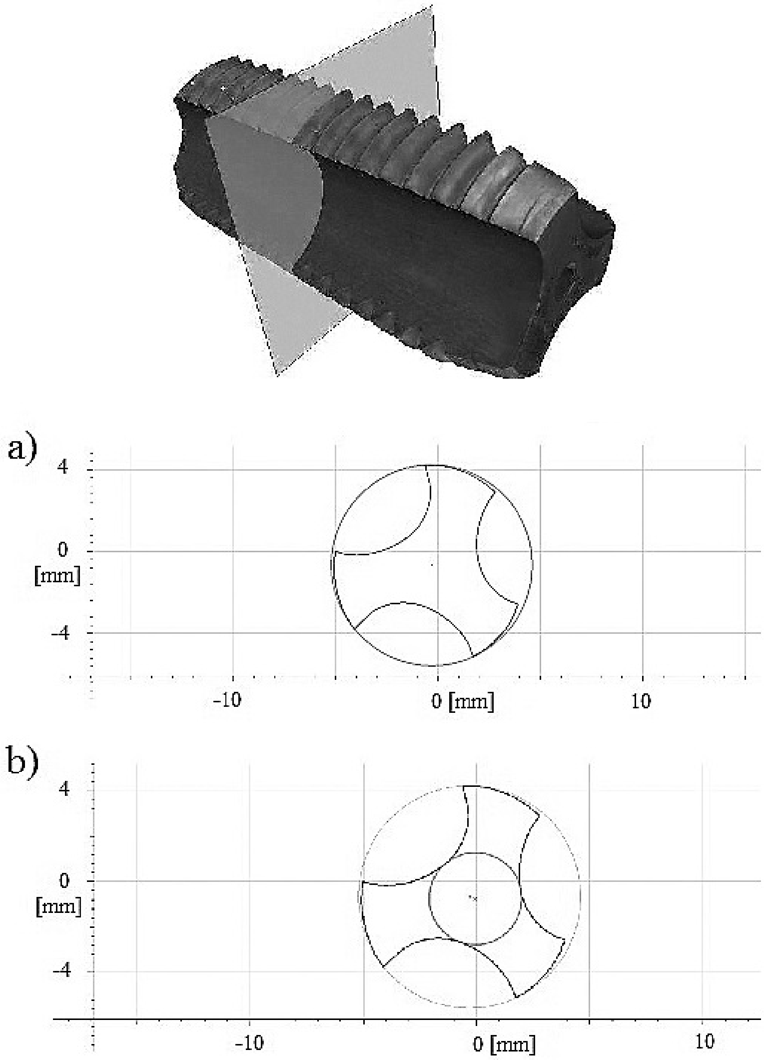
3.1. Badanie gwintownika

Celem oceny użyteczności systemu InfiniteFocus do badania narzędzi dla przedsiębiorstwa branży motoryzacyjnej, zostało przeprowadzone przykładowe badanie gwintownika M10x1,25. Pomiar został przeprowadzony przy pomocy obiektywu Alicona 5x, liczba zebranych punktów wynosi 0,26 miliona, natomiast rozdzielczość w pionie wynosiła 350 nm. Po zbadaniu narzędzia skanerem otrzymano trójwymiarowy zestaw danych odzwierciedlający badany gwintownik w rzeczywistych kolorach oraz zbiór danych w pseudokolorach odzwierciedlających odległość danego punktu od wzdłużnej osi gwintownika (rysunek 3). [4]



Rysunek 3. Pomiar gwintownika: a) w kolorach rzeczywistych, b) w pseudokolorach wraz z legendą [1]

Skaner firmy Alicona daje możliwość pomiaru powierzchni wzdłuż przekroju równoległego do osi wzdłużnej mierzonego przedmiotu. Tego typu pomiary mogą pomóc w sprawdzeniu kształtu i jego odchyłek związanych z prostoliniowością wykonania narzędzia. Skaner InfiniteFocus pozwala także na pomiar średnicy zewnętrznej oraz wewnętrznej wzdłuż wskazanego przekroju poprzecznego (rys. 4). Pozwala to na wykazanie odchyłek okrągłości w badanym przedmiocie.



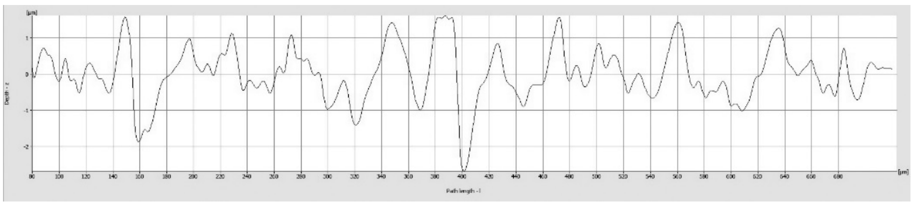
Rysunek 4. Pomiar przekroju gwintownika: a) średnica zewnętrzna, b) średnica wewnętrzna [1]

Pomiar wskazał, iż średnica zewnętrzna gwintownika ma wymiar równy 9,82 mm, zaś średnica wewnętrzna jest równa 4,06 mm.

Dokładność skanera InfiniteFocus pozwala na pomiar parametrów powierzchni mierzonego przedmiotu i daje możliwość uzyskania zarówno rzeczywistych obrazów badanej powierzchni, jak i wyodrębnionych profili. Rysunek 5 przedstawia rzeczywisty obraz powierzchni badanego gwintownika, w prawdziwych kolorach. Jest to powiększenie obszaru gwintownika o szerokości 2μm.

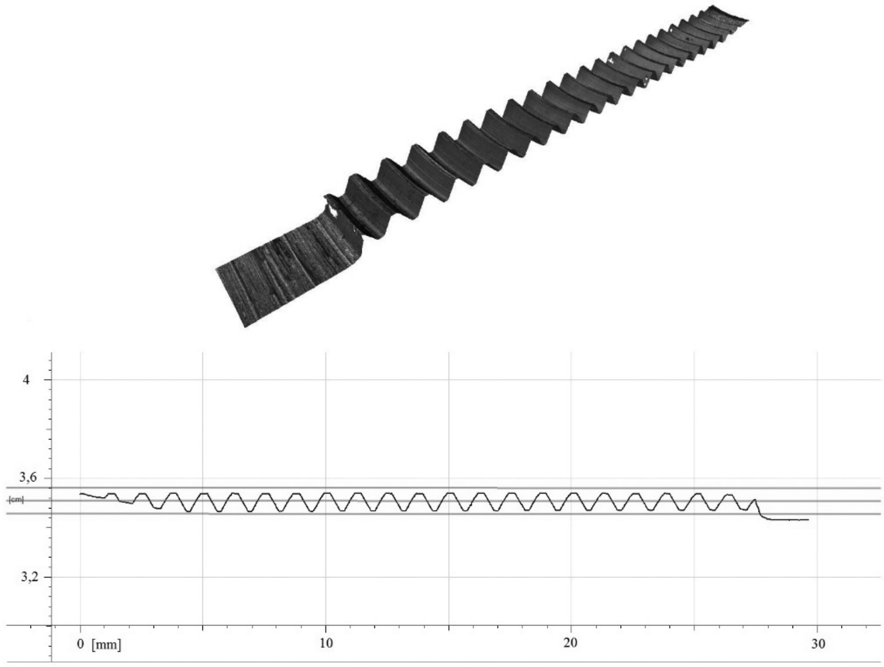
Rysunek 5. Powierzchnia gwintownika o szerokości 2μm [1]

Rysunek 7 przedstawia profil chropowatości powierzchni gwintownika. Tego typu badanie daje informacje na temat parametrów takich jak średnia chropowatość profilu (Ra), średnie kwadratowe odchylenie profilu (Rq), odległość najwyższego punktu profilu do najniższego na odcinku elementarnym (Rt), wysokość najwyższego wzniesienia profilu (Rp) oraz innych parametrów wyznaczanych z profilu chropowatości, w tym także informacje na temat falistości. Badanie także daje możliwość otrzymania wartości współczynników jak na przykład współczynnika skośności profilu chropowatości (Rsk). Pomiary chropowatości mogą dostarczyć informacji na temat powierzchni narzędzia, które mogą stać się przyczyną niedopuszczenia narzędzia do wykorzystania w procesach obróbczych, ze względu na wykazane błędy powierzchni. Dla przykładu odchylenie powierzchni narzędzia lub jego zbyt duża falistość może doprowadzić do produkcji serii wadliwych wyrobów, a co za tym idzie, przedsiębiorstwo poniesie niepożądane koszty związane z produkcją braków.



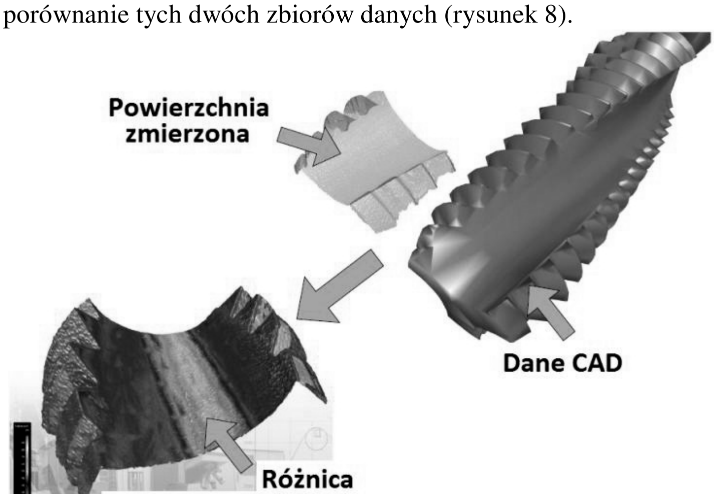
Rysunek 6. Profil chropowatości powierzchni gwintownika [1]

W przypadku gwintownika, niezwykle użyteczne jest badanie przekroju samego gwintu. Może on wykazać błędy związane z kształtem, zanim narzędzie zostanie przeznaczone do produkcji, a w następstwie dane narzędzie lub cała partia, z której ono pochodzi, może nie zostać dopuszczone do obróbki, co uchroni przedsiębiorstwo przed produkcją detali niezgodnych z wymaganiami jakościowymi. Skaner InfiniteFocus umożliwia badanie gwintów dzięki dużemu zakresowi pomiarowemu w osi Z oraz dobrej rozdzielczości pionowej (rysunek 7).



Rysunek 7. Pomiar gwintu [1]

Wszelkiego typu pomiary i analizy można rozwinąć o porównanie uzyskanych wartości, z założeniami zawartymi w modelu CAD. W wyniku nałożenia na siebie powierzchni zmierzonej i danych nominalnych można uzyskać mapę odchyłek, które stanowi porównanie tych dwóch zbiorów danych (rysunek 8).

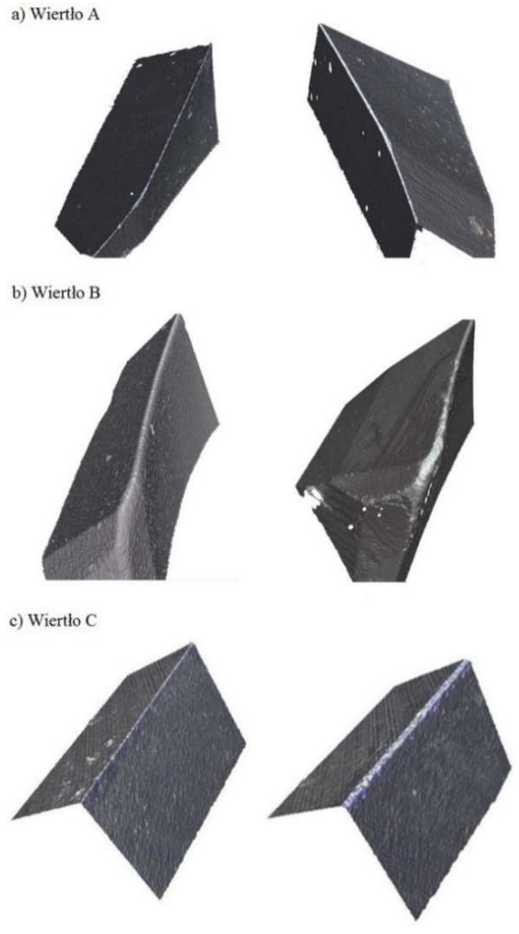


Rysunek 8. Porównanie danych zmierzonych i zaprojektowanych [1]

Tego typu analiza, w bardzo wyraźny sposób wykazuje, która część badanego narzędzia została wykonana w sposób nieprawidłowy.

3.2. Badanie wiertła

Celem sprawdzenia użyteczności stosowania skanera InfiniteFocus w praktyce produkcyjnej została przeprowadzona analiza jakości i żywotności narzędzi na przykładzie 3 wierteł od różnych dostawców. We wszystkich 3 wiertłach zostały zmierzone parametry takie jak promień krawędzi tnącej, chropowatość i zużycie na wierzchołku narzędzia w wiertłach nowych oraz używanych. Poszczególne wiertła oznaczone zostały oznaczeniami A, B oraz C. Rysunek 9 przedstawia badanie krawędzi tnących we wszystkich, trzech wiertłach. Po lewej stronie przedstawione zostały wiertła nowe, po prawej zaś te same wiertła po użyciu. Jak można zaobserwować najgorszą jakością charakteryzuje się wiertło B, którego krawędź tnąca, zarówno w stanie nowym jak i po użyciu odbiega znacząco jakością od narzędzi A oraz C.



Rysunek 9. Badanie krawędzi tnącej wierteł A, B i C, po lewej stronie przedstawione zostały powierzchnie nowych wierteł, po prawej - wierteł zużytych [1]

Analiza krawędzi tnącej i jej zużycia oraz chropowatości powierzchni w wiertłach pozwoliła na wybranie najlepszego narzędzia z oferowanych przez dostawców. Badanie zużycia pozwoliło na znaczne zwiększenie żywotności narzędzi w maszynach, nie dopuszczając do pracy narzędzi niezgodnych z wymaganiami rysunkowymi. Tego typu porównanie i ocena mierzonych narzędzi obróbczych wykazała, że wszystkie analizowane parametry mogą być użyteczne w kontroli nowych wierteł, jak również dla poprawy stabilności procesu.

4. Podsumowanie

Przedsiębiorstwa wykorzystujące w swojej działalności produkcyjnej narzędzia skrawające, takie jak wiertła, czy gwintowniki, coraz częściej zmagają się z wyzwaniami dotyczącymi defektów krawędzi tnących, zbyt szybkiego zużywania się narzędzi, długich czasów obróbki, czy niesatysfakcjonujących parametrów jakościowych uzyskanych na przedmiotach obrabianych. W większości przypadków uszkodzenia wyrobów są spowodowane wadami powierzchni narzędzi obrabiających. Z tego powodu niezbędne jest prowadzanie ścisłej kontroli jakości, wykonywanie pomiarów, badań, i testów różnych parametrów, zjawisk, celem ich zrozumienia i zlokalizowania źródła problemu.

Firmy, których nadrzędnym celem jest zapewnienie jakości swoich produktów, powinny rozważyć wdrożenie optycznego urządzenia pomiarowego 3D do automatycznego pomiaru krawędzi i powierzchni. Tego typu system oferowany jest m.in. przez firmę Alicona i nosi nazwę InfiniteFocus. Może on znaleźć zastosowanie nie tylko w badaniu i kontroli narzędzi wykorzystywanych do produkcji, ale także do badania wyrobów przed dostarczeniem ich do odbiorcy. System oferuje możliwość zbadania przekrojów przedmiotu mierzonego, jego powierzchni, chropowatości oraz kształtu, w relatywnie krótkim czasie, z bardzo dużą dokładnością, obrazując zmierzone zjawiska w jasny i przyswajalny sposób. Alicona oferuje rozwiązania dla przedsiębiorstw, zwłaszcza z branży motoryzacyjnej, dla których ogromne znaczenie ma precyzja wykonywania produktów przy jednoczesnym ograniczaniu niepożądanych kosztów.

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SYSTEM SZTUCZNEJ INTELIGENCJI DO MONITORINGU ROBOTA MOBILNEGO

Streszczenie: W niniejszym artykule opisano budowę wielopoziomowego systemu monitoringu robota mobilnego. Omówiono zastosowane oprogramowanie. Przeprowadzono eksperymenty używając różnych wersji oprogramowania.

Słowa kluczowe: OD, ISOMM, IT, GMDH

INTELLECTUAL SYSTEM OF MULTILEVEL MONITORING OF MOBILE ROBOT

Summary: The article deals with the construction of the multilevel monitoring system of mobile robot. Considered software core. Experiments using different approaches.

Keywords: OD, ISOMM, IT, GMDH

1. Introduction

In recent decades largely due to increased interest in the recognition and image analysis. This interest has created a growing need for theoretical methods and software development as well as creating new hardware, the combination of which there were new possibilities for analysis and recognition of digital images. One of the application areas is robotics and automated systems.

Pattern recognition as a methodology for making decisions on the basis of observations of objects and processes of the environment, there is a long time, but with the development of computer technology began to develop quite rapidly and used in mobile robotics.

In case of lack of information on the environment, the mobile robot can operate on strictly specified algorithms. The main disadvantage of this system is that it can not adequately respond and adapt to change. Quite often there are situations when the

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mobile robot has to operate and carry out their task in conditions of limited informative.
In this case, provided decisions based on the available sensors or commands from the operator, if possible, or on the basis of pattern recognition.
For image data processing system - a collection of data about the object, including options and connections between them. Options are numerical characteristics obtained using measuring devices such as ultrasonic sensor for distance measurement , microphone, camera, etc., or mathematical models. Links can be described as the internal structure of the object and its behavior if we are dealing with dynamic objects. So in computer pattern recognition problem arises task to find already previously known images and specify them into classes.

2. Formulation of the problem

Depending on the application to the intelligent system of multilevel monitoring mobile robot (ISOMM) put forward various demands. For example, for military tasks are the basic requirements of the system low cost, reliability and ease of management. For systems that are focused on research and remote management, the basic requirements are:

1) minimum possible size and weight;
2) high mobility;
3) the possibility of operator intervention at any time;
4) reducing energy consumption;
5) increase battery life.

The main components of a mobile robot for remote study sites are: vision systems, sensors, actuators platform, control module, data processing module and in some cases managing computer.
The main requirements for vision systems are providing high performance due to deterioration or change in external conditions and circular vision to obtain more complete information about the objects of the environment by means of a rotary mechanism.
Overall mobile robot system for remote research facilities must provide [1-3]: autonomous operation in deterministic and non-determined, static or dynamically variable conditions; achieve their goals by making decisions based on incomplete or noisy data; adaptation to external changes; parallel execution of multiple tasks; high precision movement; the ability to connect new components and more. For movement control and effective decision-making should be used intelligence methods and technologies of artificial intelligence.
To ensure the above requirements to implement a system of multi-level monitoring is advisable mobile robot based on the following principles [4]:

1) modularity that involves the implementation of mobile robot components in a completed functional blocks, which will provide decision-making system more information;
2) hierarchy, providing building information systems transformation and decision-making by the layout of different levels of hierarchy;
3) consistency, providing the possibility of combining different levels of hierarchy and relations between them;

4) abstraction that provides application developed systems on different hardware;
5) consistency.

To ensure a wide range of tasks solution architecture ISOMM should have a permanent structure that provides for appropriate microcontroller with hardware or software core and interchangeable hardware and software modules. Based on the foregoing, reflected the architecture of the software core of intellectual multilevel monitoring system [5] in Fig. 1.

One of the main components of the kernel subsystem are data consolidation and data processing subsystems.

Correct control of mobile robot can operate in case of available information about the parameters of the ISOMM environment and data coming from the sensors.

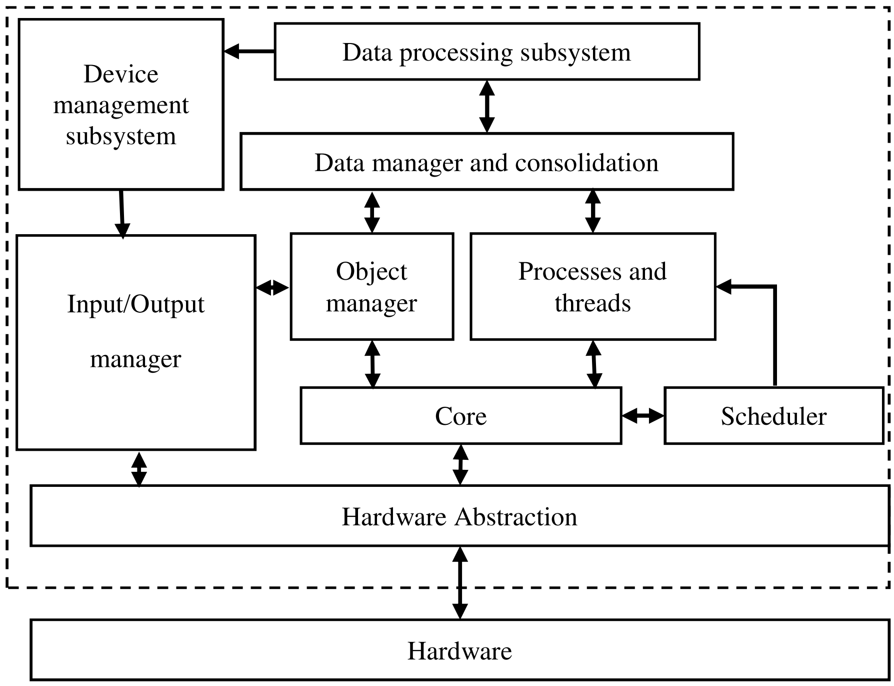

Figure 1. Architecture software kernel

The main purpose of constructing multi-level monitoring system is to obtain the best technical solution among the possible alternatives that would provide high performance and quality.

IT hierarchical construction of mathematical models includes several stages [6-9]. In the first phase formed the original description (OD) results of a comprehensive environmental monitoring sensors mobile robot. OD looks like a two-dimensional tables containing numerical characteristics of objects that caught the attention of sensors.

The research results obtained in the first stage and use IT as an integral element to the next stage. In the first phase of models building is columns which contains data from sensors.

$$X = \{x_1, x_2, \ldots, x_n\} \tag{1}$$

where:

x_1 - signals registered by sensors,

n – number of sensors.

As defined object modeling functionality dependency $y_i = f(X)$.. Where y_i is the input signal for the higher levels of the monitoring system, which was obtained as a result of processing input signals from sensors.

Multi-level monitoring system was built using GMDH algorithm. The adequacy of each model in structure was assessed by the criterion of regularity [6].

$$e = \sqrt{\sum_{i=1}^{N} (y_i - f(x_i))^2 \Big/ \sum_{i=1}^{N} (f(x_i))^2} * 100\% \tag{2}$$

Let the initial state of the system is determined by a set of values (x_0, y_0), where x_0 - one sensor signal at the time of system startup and initial state of the system, which is based on the sensor signal. Then we can build on a set of signals multiparameter model of our system that will describe the most faithful state according to the input signal at a time and perform adjustments by changing the state of the whole system.

Figure 2 shows a graph of the calculated signals for rigidly predetermined algorithms, according to the distance and checked with the expected signals. In this case the calculation error is 15-20%.

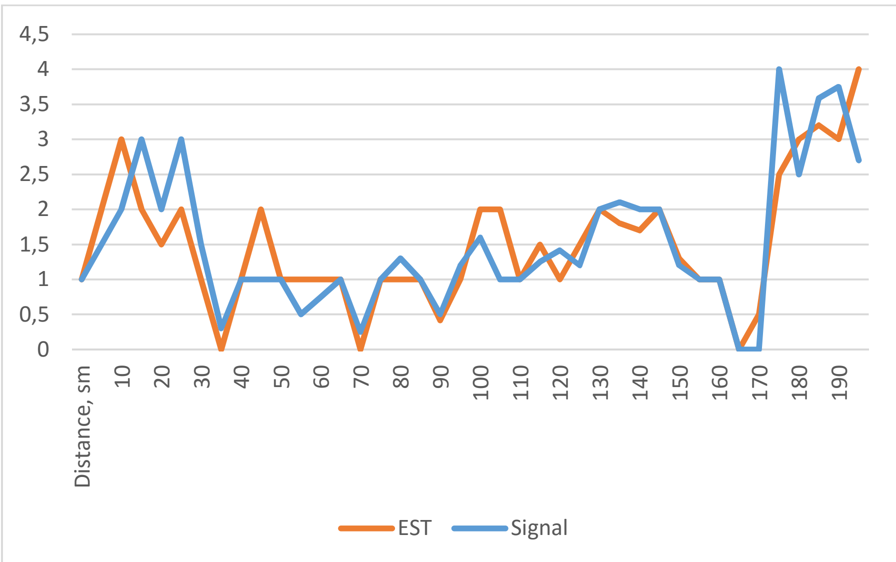

Figure 2. Results of the system of strictly according to the rules

Otherwise, the system was tested using automatic creation of hierarchy and using all models that enables more precise description and calculation system states. In this case, the error signals calculated from the expected 8%.

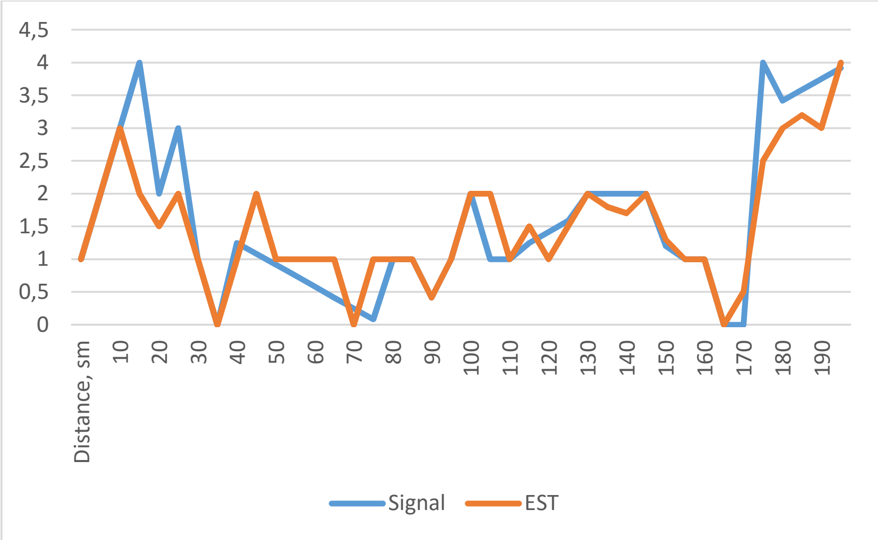

Figure 3. The received signal from the multi-level system

3. Conclusions

In this paper basic requirements to the software architecture core of the monitoring system ware formulated.
On the basis of the multilevel monitoring proposed to put such principles: hierarchical systems, building management, system, variable composition software modules consistency and consolidation of data.
Enhanced automatic generation of multi-sensor monitoring system.
As a result of testing a new method of automatic formation of hierarchies, showed 12% better than the method of rigidly predetermined algorithms and control systems.

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PROJEKTOWANIE ZROBOTYZOWANYCH STANOWISK

Streszczenie: W pracy przedstawiono proces tworzenia zrobotyzowanego stanowiska pracy począwszy od koncepcji, modelowania stanowiska w dedykowanych do tego systemach, symulacji, kończąc na wykonaniu oraz zaprogramowaniu całego stanowiska. Opisano przykładowe stanowisko montażu zabawek dla dzieci.

Słowa kluczowe: KUKA, roboty, CNC, KRL, CAD, RobCad, programowanie, robotyzacja, automatyzacja, SimPro, modelowanie

DESIGNING ROBOTISED STATIONS

Summary: The paper describes a process of creating robotized stations (workplace). The process consists of the consecutive tasks: creation of the initial concept, modeling workstation by means of dedicated (to this operation) systems, simulation, and the last activity: building and programming of the entire station. Analysis was performed on the base of assembling toys for children.

Keywords: KUKA, robots, CNC, KRL, CAD, RobCad, programming, robotization

1. Wstęp

Szybki rozwój technik komputerowych, mikroprocesorowych oraz ogólny postęp techniczny powodują, że coraz więcej powstaje zrobotyzowanych oraz w pełni lub częściowo zautomatyzowanych stanowisk pracy. Istnieje wiele powodów stosowania tego typu rozwiązań. Do najważniejszych z nich zalicza się polepszenie warunków pracy, wyręczanie ludzi z monotonnych, ciężkich lub niebezpiecznych prac, oszczędność w płacach, zwiększona dokładność oraz powtarzalność czynności, a także skrócenie czasu produkcji [12, 13].

Możliwe jest różnorodne podejście do procesu projektowania zrobotyzowanych stanowisk produkcji, jednakże zawsze należy uwzględnić takie czynniki jak np. sposób obróbki, transportu przedmiotów, wielkość produkcji, różnorodność operacji.

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Na wstępie należy dokonać wyboru oraz typu projektowanego stanowiska. Mogą to być:

- Elastyczne linie obróbkowe - stacje obróbkowe połączone są liniowo transporterami, przepływ przedmiotów jest jednostronny, dlatego nadają się głównie do produkcji masowej przedmiotów o zbliżonym sposobie obróbki.
- Elastyczne systemy obróbkowe - jest to zbiór urządzeń, połączonych transporterami w sposób elastyczny. Przepływ przedmiotów bardzo często jest zmienny, w zależności od wykonywanego przedmiotu, poprawności wykonania i innych czynników. Może być wykonywanych kilka przedmiotów. Tego typu rozwiązania stosowane są w produkcji masowej przy dużej różnorodności produkcji oraz przy jednoczesnej produkcji wielu przedmiotów.
- Elastyczne gniazda obróbkowe - urządzenia ustawione są gniazdowo, połączone różnego rodzaju transporterami, np. przenośnikiem taśmowym lub robotem. Jest to dobre rozwiązanie w produkcjach średnio oraz wielkoseryjnych.

W pierwszej kolejności należy przygotować nie jedną, lecz kilka różnych koncepcji stanowiska. Na tym etapie konieczna jest podstawowa wiedza z dziedziny projektowanego procesu obróbki lub produkcji. Należy rozważyć plusy i minusy każdej z koncepcji, wstępnie odrzucić te najgorsze i dokładniej przeanalizować te najlepsze. Na tym etapie korzystne jest zamodelowanie wybranego rozwiązania w programie typu CAD lub w jednym z programów dedykowanych do projektowania zrobotyzowanych stanowisk pracy. W większości przypadków są ode dedykowane pod konkretnego robota. Przykładowe aplikacje zostaną omówione w dalszej części. W kolejnym kroku należy rozpatrzyć możliwość oszacowania np. liczby wytworzonych przedmiotów, łatwości w przezbrajaniu maszyny, czasu trwania cyklu, kosztów wytworzenia itp. Po dokładnej analizie należy wybrać najkorzystniejszą koncepcję.

Jednym z najważniejszych zadań, które należy wykonać podczas projektowania zrobotyzowanego stanowiska jest dobór robota lub robotów. Aby tego dokonać należy wziąć pod uwagę wiele czynników. Najważniejsze z nich to: ciężar oraz rodzaj przedmiotu obrabianego oraz obszar pracy. Na tej podstawie należy dobrać zasięg robota, nośność oraz liczby osi. Kolejne ważne parametry to prędkość oraz przyspieszenie a także odporność na warunki zewnętrzne. Przy tych czynnościach dodatkowo należy dobrać odpowiedni chwytak lub chwytaki a także rodzaj napędu. Kolejnym zadaniem jest dobór pozostałych elementów stanowiska, np. obrabiarek, klejarek, przenośników taśmowych, stołów obrotowych, etykieciarek, systemów wizyjnych, systemów pomiarowych, pozycjonerów, laserów itd. Na dobór tych czynników składa się doskonała znajomość procesu wytwarzania danego przedmiotu. Aby móc dobrać te elementy, należy zgłębić wiedzę z wielu dziedzin nauki związanych z danym procesem wytwarzania czy też obróbki.

Następnym etapem projektowania powinna być analiza zagrożeń związanych z danym procesem oraz dobór odpowiednich systemów zabezpieczeń. Na rynku można znaleźć sporą ilość różnorodnych gotowych systemów bezpieczeństwa jak i również pojedynczych elementów systemów bezpieczeństwa takich jak np. kurtyny świetlne, elementy klatek zabezpieczających, platformy sensoryczne, wiele różnych czujników.

Po przeanalizowaniu zagrożeń i doborze odpowiednich zabezpieczeń zostanie jeszcze dobór odpowiednich systemów sterowania oraz komunikacji.

2. Przegląd programów do komputerowego modelowania stanowisk

Na rynku można znaleźć ogromną ilość programów do projektowania elementów oraz całych zrobotyzowanych lub też zautomatyzowanych stanowisk, a także do programowania robotów. Część z nich jest bardzo uniwersalna i posiada wiele różnorodnych funkcji, inne są dedykowane typowo pod konkretną czynność lub markę.

Z uniwersalnych programów można wyróżnić np.:

- Robcad(EM-workplace), posiada wiele różnych przydatnych funkcji dedykowanych dla projektanta jak i programisty. Pozwala optymalizować, analizować, projektować oraz programować zrobotyzowane oraz zautomatyzowane stanowiska offline. Nadaje się do modelowania stanowisk o bardzo różnym charakterze, np. montażu, spawania, obróbki, klejenia, oraz wielu innych. Program ten posiada funkcje modelowania 3D także szczegółów stanowiska np. więzów kinematycznych, planowanie rozmieszczenia obiektów, planowanie trajektorii oraz ruchów. Pozwala na zaplanowanie synchronizacji poszczególnych elementów stanowiska oraz wizualizację działania gotowego już modelu. Istnieje wiele bibliotek zawierających modele wiodących producentów robotów, obrabiarek oraz innych urządzeń.
- Cosimir(Mitsubishi), pozwala symulować działanie zrobotyzowanych systemów oraz poszczególnych ich elementów. Umożliwia symulację sterowników PLC oraz różnorodnego oprzyrządowania np. mierników, czujników i innych sensorów. Pozwala planować, programować oraz testować procesy lub ich poszczególne fazy. Tak jak Robcad również posiada bogatą bibliotekę z danymi od wiodących producentów maszyn.

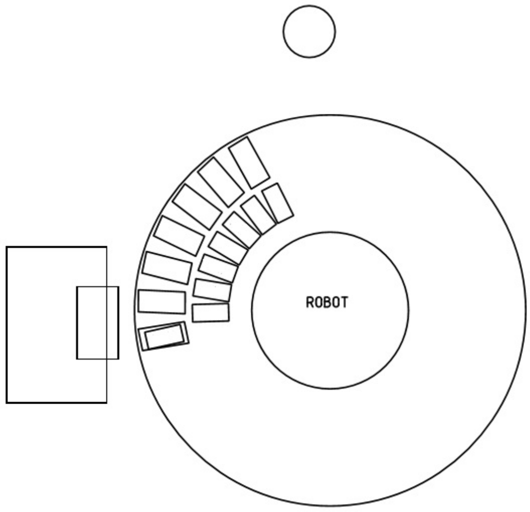
Wybierając konkretną markę robota, można posłużyć się dedykowanym programem, ułatwia to w dużym stopniu wymianę danych w przypadku programowania offline. Przykładowe programy dedykowane pod roboty:

- KUKA Sim Pro- do tworzenia oraz programowania stanowisk zawierających robota firmy KUKA. Możemy w nim odtworzyć przygotowane w systemach CAD elementy stanowiska, modelować chwytaki oraz nawet całe struktury kinematyczne. Posiada funkcje symulacji i optymalizacji ruchów robota, oraz wykrywania ewentualnych kolizji.
- ABB RobotStudio - program dedykowany dla robotów firmy ABB, posiada podobne funkcje jak poprzednio omówiony program. Pozwala programować, symulować a także optymalizować zrobotyzowane stanowisko. Dodatkową funkcją jest posiadanie wirtualnego kontrolera ABB, co ułatwia realistyczne symulowanie działania robota, z uwzględnieniem jednakowego języka programowania jak w rzeczywistości.

Komputerowa symulacja zrobotyzowanych stanowisk pozwala na obliczenie wielu parametrów oraz wykrycie i wyeliminowanie niekorzystnych rozwiązań przed wdrażaniem stanowiska do produkcji. Można ocenić wydajność danego stanowiska i zmienić wcześniejszą koncepcję w taki sposób aby otrzymać najkorzystniejsze dla nas rozwiązanie. Drugą bardzo ważną korzyścią jest możliwość programowania offline, dzięki temu czas procesu wdrażania stanowiska do produkcji jest wielokrotnie krótszy. Co więcej unikamy w ten sposób rzeczywistych kolizji, gdyż symulacje w trakcie programowania offline skutecznie nam je obrazują.

3. Przykład - stanowisko do montażu zabawek dziecięcych.

Na etapie tworzenia koncepcji stanowiska należy wykonać wszystkie możliwe schematy rozwiązań - odręcznie bądź przy wykorzystaniu komputera. Należy tutaj zwrócić uwagę na fakt, iż w większości przypadków (około 80%) większość zaproponowanych rozwiązań zostanie od razu odrzucona. Przykładowe rozwiązanie stanowiska przedstawiono na rys. 1.



Rysunek 1. Wstępny schemat stanowiska

Podczas wstępnej analizy częstymi powodami do odrzucenia danego rozwiązania jest:

- Zbyt duże stanowisko pracy - niedostateczna ilość wolnego miejsca w zakładzie może spowodować odrzucenie danego rozwiązania.
- Koszty inwestycji - gdy zdecydowanie przekraczają możliwości wkładu finansowego firmy.
- Proces technologiczny – w niektórych przypadkach jak na przykład podczas klejenia, łatwiejsze będzie zastosowanie mechanizmów typu stół obrotowy niż przenośnik taśmowy, gdyż dostanie się kleju pod taśmę spowoduje natychmiastowe unieruchomienie stanowiska, natomiast blat stołu wystarczy co jakiś czas przetrzeć.

- Możliwość wykonania urządzenia przy wykorzystaniu własnego parku maszynowego.

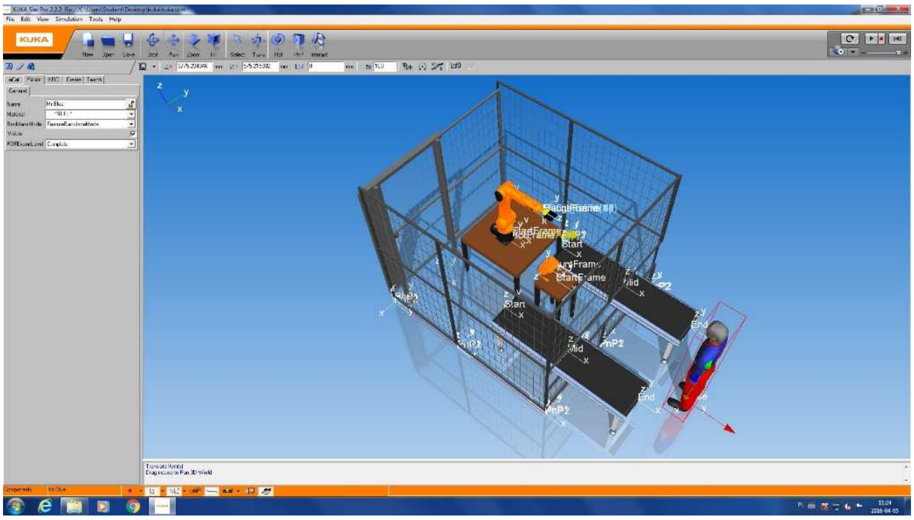
Podczas wstępnego etapu projektowania należy dokładnie poznać proces technologiczny, zastanowić się nad takimi aspektami jak wielkość produkcji a także poziomem automatyzacji. W przypadku klejenia zabawek należy przeanalizować wielkość przedmiotu, optymalny czas nakładania oraz wiązania kleju oraz siłę docisku. W przypadku doboru długości przenośników taśmowych do transportu gotowych elementów należy określić sposób pakowania oraz liczby sztuk w jednym pojemniku.

Kolejnym etapem jest wykonanie projektu wraz z symulacją w wybranym programie. Jeżeli nie sprecyzowano marki urządzenia (w tym przypadku robota) to lepiej wybrać program ogólny.
W omawianym przykładzie wykorzystano KUKA SimPro. Przystępując do pracy w pierwszej kolejności najlepiej dodać posiadanego (lub planowanego do zakupu) robota – wybieramy go z biblioteki obiektów. Następnie wybieramy pozostałe elementy stanowiska z biblioteki - jest to wariant łatwiejszy, gdyż przedmioty te posiadają zaprogramowane sposoby ruchu, albo wczytujemy utworzony model 3D w jednym z obsługiwanych formatów: STL (binarne/ASCII), 3DS, VRML1, Robface i Google Sketchup. Jeżeli pobieramy rysunki komponentów z systemów CAD, a chcemy je animować, musimy w tym celu samodzielnie napisać odpowiednie funkcje.

Po dodaniu wszystkich komponentów stanowiska, a także po wyborze chwytaka, projektujemy systemy bezpieczeństwa takie jak klatka, kurtyny świetlne itp. Gdy mamy zamodelowane stanowisko, możemy przystąpić do programowania ruchów robota, przenośników taśmowych i innych ruchomych komponentów. Korzystając z funkcji programu KUKA.Sim Pro i KUKA.OfficeLite, można utworzyć skrypt uruchomieniowy KRL (w języku programowania robotów KUKA) robota. W połączeniu z KUKA.OfficeLite można tworzyć przykładowe symulacje pracy w celu weryfikacji zaproponowanego rozwiązania. Można np. otrzymać przybliżony czas wykonania konkretnej operacji, dzięki czemu łatwo będzie obliczyć wydajność i opłacalność danej danego rozwiązania, a także wykryć ewentualne kolizje ruchów, oraz w dalszej kolejności zaprogramować robota off-line [6, 14, 15].

Przykładowo do sklejania elementów zabawek dziecięcych, dodano robota, 2 przenośniki taśmowe, klejarkę, podstawę robota, podstawę pod klejarkę, elementy klatki bezpieczeństwa oraz pracownika obsługującego dane stanowisko. Następnie zaprogramowano przenośniki oraz trajektorie ruchów robota, uwzględniając czas pracy robota oraz wykorzystując czujniki optyczne wykrywające obecność przedmiotu na pożądanej pozycji, aby robot mógł pobrać potrzebny element. Uwzględniono także czas przejazdu pod klejarką a także czas przetrzymania robota przy docisku. Schemat zamodelowanego stanowiska, a także struktury programu obrazuje rysunek 2.

Na bazie zamodelowanego stanowiska można łatwo ocenić opłacalność poszczególnych rozwiązań, koszt wykonania stanowiska, czas wykonania elementów, a także możemy oszacować przezbrajalność oraz uniwersalność stanowiska, w przypadku montażu różnego rodzaju elementów (zabawek), oraz ewentualną późniejszą rozbudowę stanowiska.



Rysunek 2. Przykładowe rozwiązanie

Ponadto, można również oszacować wskaźnik OEE(Overall Equipment Effectivenes), mówiący o przewidywanej efektywności stanowiska. W powyższym przypadku obliczenia mogłyby wyglądać następująco:

- W pierwszej kolejności należy obliczyć dostępność (Availability) stanowiska. Przyjmijmy, jako czas obliczeń jeden tydzień. Biorąc pod uwagę 3 zmianowy tryb pracy, stanowisko mogłoby pracować:
  7dni x 24h x 60min= 10 080min

  Przyjmując, że w niedzielę zakład jest zamknięty:
  6dni x 24h x 60min= 8640min

  Dostępność: $\frac{8640}{10080} \times 100\% = 85.71\%$

- Następnie możemy obliczyć wydajność (performance). Przyjmując, że czas montażu 1 przedmiotu wynosi 8s, w 8400min powinniśmy wykonać:

  $$\frac{8400 \times 60}{8} = 63000\ sztuk$$

  W rzeczywistości z powodu zmiany osób pomiędzy zmianami, przezbrajania maszyny na inne elementy, przerw pracowników, ewentualnych zabiegów czyszczenia, konserwacji itp. wykonano 56000 sztuk (w tej fazie wartość ta musi zostać w przybliżeniu wyliczona, natomiast po uruchomieniu stanowiska w to miejsce należy wstawić rzeczywistą wartość wykonanych elementów).

  Wydajność: $\frac{56000}{63000} \times 100\% = 88.89\%$

- Ostatnią składową do wyliczenia jest wskaźnik jakości (Quality rate). Tę wartość na tym etapie również ciężko jest oszacować, gdyż liczy się go na podstawie informacji o ilości wybrakowanych, złych przedmiotów. Aktualnie musimy go oszacować. Zakładamy, że wyprodukowanych zostało 56000 zabawek, w tym 250 sztuk do odrzucenia.

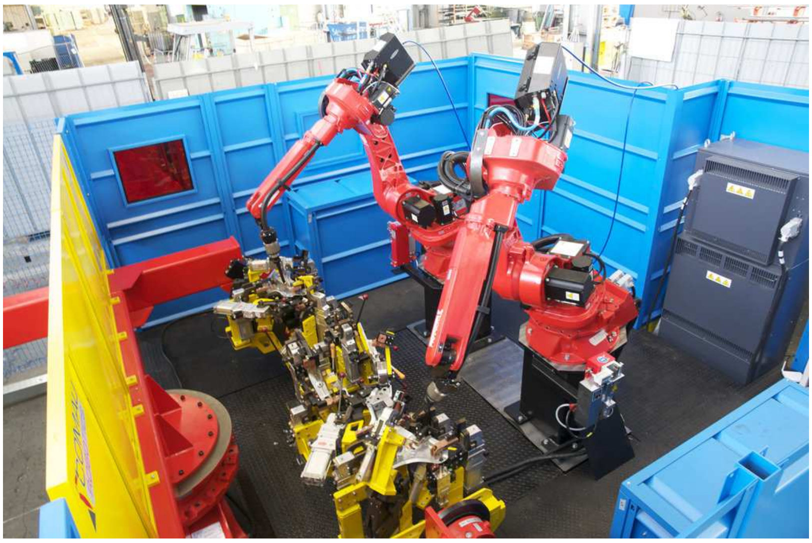
Wskaźnik jakości: $\frac{56000-250}{56000} \times 100\%$ =99.55%

- Na podstawie tych parametrów możemy obliczyć efektywność naszego stanowiska:

Efektywność=Dostępność x Wydajność x Wskaźnik jakości

OEE = 85.71%x88.89%x99.55% = 75.84%

Po tym etapie można przejść do fizycznej realizacji stanowiska oraz do zaprogramowania robota.

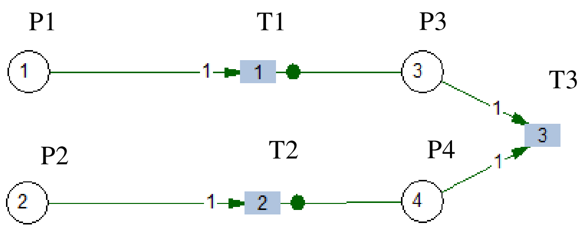


Rysunek 3. Przykładowe stanowisko robocze [16]

Robota możemy zaprogramować w trybie offline, używając wcześniej utworzonej symulacji albo ręcznie za pomocą TouchPad'a. Musimy zastanowić się czy lepszym rozwiązaniem w naszym przypadku będzie programowanie robota parametrycznie, czy też poprzez ręczne określanie konkretnych pozycji. Jeżeli mamy kilka produktów, dla których ruchy są bardzo zbliżone, różniące się np. przesunięciem pozycji pracy, warto wymyślić algorytmy, wyliczające potrzebne współrzędne ruchów po podaniu jako zmienne wymiarów przedmiotu. Dzięki takiemu rozwiązaniu nie ma konieczności pisania nowego programu. Jeżeli jednak na danym stanowisku wykonujemy tylko jeden konkretny przedmiot, bądź wykonywane przedmioty wymagają zupełnie innych trajektorii ruchów program można wykonać „na sztywno", ucząc robota dokładnych ruchów punkt po punkcie. Jest to metoda zdecydowanie łatwiejsza.

W trakcie produkcji dobrze jest ponownie obliczyć wskaźnik OEE, przy wykorzystaniu rzeczywistych danych – otrzymamy wtedy faktyczną efektywność stanowiska. Po jego obliczeniu, warto się zastanowić nad polepszeniem efektywności, poprzez eliminację słabych punktów stanowiska.

Istnieje również dodatkowe narzędzie, bardzo ułatwiające proces projektowania zrobotyzowanego stanowiska. Za pomocą Sieci Petriego, możemy zamodelować proces produkcyjny, poprzez analizę warunków oraz zdarzeń. Do tego służy nam dwudzielny graf, składający się z miejsc (Pi) oraz Translacji (Tj) połączonych ze sobą łukami. Miejsca odpowiadają pewnym ustalonym przez nas warunkom, sytuacjom, natomiast translacje są to pewne zdarzenia, czynności do wykonania. Połączenia od miejsca do translacji łukami wejściowymi, odpowiadają pewnym warunkom wejściowym, natomiast łuki wyjściowe są połączeniami od translacji do miejsc i zawierają efekty zdarzeń. Do modelowania sieci petri wykorzystano programu autorstwa prof. ATH dr hab. inż. Romana Stryczka [10]. Aby pokazać przykładowe działanie sieci petri, przeanalizowano układ, który odpowiada za przesuw przenośnika taśmowego. Na rysunku 3 rozrysowany jest analizowany fragment sieci.



Rysunek 4. Przykładowy szkielet sieci

Gdzie:

P1-paleta górnej części zabawki
P2-paleta dolnej części zabawki
P3-obecność górnej części na taśmociągu
P4-obecność dolnej części na taśmociągu
T1- pobranie górnej części z palety oraz ułożenie jej na przenośniku taśmowym
T2- pobranie górnej części z palety oraz ułożenie jej na przenośniku taśmowym
T3- przesuw przenośnika taśmowego
Marker- oznacza obecność danego przedmiotu

Program działa w taki sposób, że jeżeli na P1 występuje marker (oznacza to, że część górna jest na palecie) oraz w wyznaczonym miejscu na przenośniku taśmowym nie ma jeszcze górnej części (łuk wzbraniający od P3 do T1) to robot pobiera z palety przedmiot i kładzie na przenośniku. Analogicznie rozwiązana jest druga paleta.

Następnie, gdy części górna oraz dolna są wykryte na palecie, przenośnik włącza się na 3 sekundy.

Dzięki tworzeniu takich sieci, możemy symulować cały proces produkcyjny, wyłapując wszelkie błędy w działaniu, synchronizować poszczególne etapy produkcji na danym stanowisku obliczyć czas produkcji oraz ilość wyprodukowanych przedmiotów.

4. Podsumowanie i wnioski

Techniki komputerowego projektowania oraz wspomagania modelowania zrobotyzowanych stanowisk rozwijają się w sposób dynamiczny. Nowe programy uwzględniają zapotrzebowanie projektantów poprzez dodanie nowych komponentów oraz sposobów komunikacji czy też programowania. Od osoby zajmującej się projektowaniem wymagane jest, aby posiadała wiedzę, z wielu fundamentalnych, dziedzin nauki, a także aktualną wiedzę z innowacyjnych rozwiązań. Dodatkowo konieczne jest dogłębne poznanie wielu procesów technologicznych związanych z danym zadaniem projektowym. Pomimo ogromnych możliwości programów wspomagających procesy projektowania oraz symulacji, do stworzenia wieloprocesowych stanowisk, niezbędna jest współpraca ekspertów z różnych dziedzin np. specjalisty znającego różne języki programowania, elektronika zajmującego się uruchomieniem wszelkiego rodzaju czujników cyfrowych czy też analogowych itd.

Bardzo ważnym aspektem jest zaprojektowanie odpowiednich systemów bezpieczeństwa, zgodnych z aktualnymi normami. Dodatkowo, warto dla każdego stanowiska obliczyć wskaźnik bezpieczeństwa. Innowacyjnym rozwiązaniem jest użycie na danym stanowisku robota przeznaczonego do współpracy z człowiekiem. Jego programowanie jest zdecydowanie trudniejsze, nie wymaga natomiast stosowania klatek bezpieczeństwa, kurtyn itp. zabezpieczeń.

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Aleksandra KŁOS-WITKOWSKA[1]

BADANIA STABILNOŚCI ALBUMINY SUROWICY WOŁOWEJ JAKO KOMPONENTA WARSTW RECEPTOROWYCH W BIOSENSORACH

Streszczenie: W poniższym artykule zostały przedstawione badania stabilności Albuminy Surowicy Wołowej (BSA) jako komponenta warstwy receptorowej w biosensorach. Poprzez analizę widm UV/Vis badano zmiany w czasie oraz wpływ czynnika zewnętrznego jakim była obniżona temperatura. Zaobserwowano wzrost absorpcji BSA wraz z czasem oraz wpływ obniżonej temperatury na stabilność proteiny.

Słowa kluczowe: biosensor, UV/Vis, warstwa receptorowa

STUDY OF STABILIZATION BOVINE SERUM ALBUMIN AS A COMPONENT OF BIOSENSOR RECEPTOR LAYER

Summary: The article presents stability studies of Bovine Serum Albumin (BSA) as a component of biosensor receptor layer. The UV/Vis spectrum analysis were used for testing the changes in time and the impact of external factor. Increase in BSA absorption with time and influence of reduce temperature on protein stability was observed.

Keywords: biosensor, UV/Vis, receptor layer

1. Wprowadzenie

Biosensory ze względu na szerokie możliwości zastosowań oraz łatwość obsługi tego typu urządzeń są nowej generacji czujnikami, których rozwój w ostatnim 20-leciu następuje bardzo dynamicznie. Powszechnie wykorzystywane są w ochronie środowiska, gdzie stosuje się je do badania zanieczyszczenia wód [1-3], w przemyśle spożywczym, gdzie używane są do detekcji toksyn w pożywieniu [4], bakterii [5] , wykrywania obecności alergicznych komponentów [6], czy metali ciężkich [7], a także w medycynie gdzie pomocne są przy stawianiu diagnoz, wykrywając czynniki chorobotwórcze takie jak markery choroby nowotworowej [8] czy wykrywanie wirusa HIV[9].

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W dobie coraz szybszego tempa życia oraz szczególnej troski o jakość wykonywanych pomiarów, biosensory stanowią ciekawą alternatywę do powszechnie stosowanych długotrwałych metod detekcyjnych.
Czujniki te są łatwe w użyciu, a stosowanie ich nie wymaga specjalistycznego laboratorium czy wyszkolonego personelu. Z tego też względu są odpowiedzią na istniejące potrzeby i ze względu na swoją uniwersalność stanowią obszar godny uwagi z perspektywy finansowej. Na podstawie analizy ekonomicznej przeprowadzonej przez firmę Transparenty Marked Research , szacuje się, że wartość rynku biosensorowego w 2018 roku osiągnie wartość 18,9 biliona USD [10]. Jak podaje przyjęta w 1999 roku definicja podawana przez IUPAC
(International Union of Pure and Applied Chemistry).
Biosensor to samowystarczalne zintegrowane urządzenie, dostarczające specyficznych ilościowych lub półilościowych informacji analitycznych przy użyciu składników umieszczonych w bezpośrednim kontakcie z elementem przetwarzającym [11]. Biosensor to rodzaj czujnika bazujący na procesie rozpoznawania biochemicznego /biologicznego składający się z selektywnej części receptorowej i części przetwornikowej.
W części receptorowej następuje selektywny wychwyt cząsteczki analizowanej (analitu) a proces ten jest możliwy dzięki znajdującej się w tej warstwie matrycy na powierzchni której znajdują się receptory będące zazwyczaj niestabilnymi molekułami biologicznymi na przykład: enzymami, kwasami nukleinowymi, antygenami, organellami komórkowymi [12]
Warstwa receptorowa jest bardzo ważnym elementem biosensora, decydującym o czasie odpowiedzi oraz czasie użyteczności urządzenia [13]
W części przetwornikowej, następuje zamiana wyniku biologicznego oddziaływania (pomiędzy molekułami receptora a analitami) na sygnał mierzalny.
Wychwyt analitu na powierzchni biosensora można porównać do zamka i klucza, gdzie zamkiem jest biosensor, a w szczególności warstwa receptorowa a kluczem analit (lock-fit mechanizm). Albumina Surowicy Wołowej jest białkiem, które oprócz szerokiego zastosowania w badaniach nad farmakokinetyką i farmakodynamiką leków jest bardzo często używana w konstrukcji biosensorów w warstwach receptorowych [14,15] do sieciowania [16]. Stanowi składnik matrycy, w której następuje wychwyt. Proteina ta o masie cząsteczkowej 66 kDa składa się z 550 rezyduów. Jej krystalograficzna struktura zawiera dziewięć α- heliks z sercową trzeciorzędową konformacją [17].
Biorąc pod uwagę najnowsze trendy w rozwoju biosensorów można wyróżnić kilka kierunków badań, w których obecnie prowadzone są prace. Są to: prace nad rozwojem biosensorów , które mogłyby dokonywać detekcji kilku analitów w tym samym czasie [18], zastosowanie grafenu w biosensorach [19], poprawa biodetekcji poprzez użycie osiągnięć nanotechnologii [20], oraz udoskonalenie już istniejących czujników poprzez poprawę ich parametrów pracy: (czułości, powtarzalności, selektywności a także stabilności) [21].
Dlatego też w prezentowanej pracy, biorąc pod uwagę istniejące problemy konstruktorskie związane ze stabilnością warstwy receptorowej biosensorów, zbadano wpływ czynnika zewnętrznego jakim była obniżona temperatura na komponent warstwy receptorowej jakim jest Albumina Surowicy Wołowej.

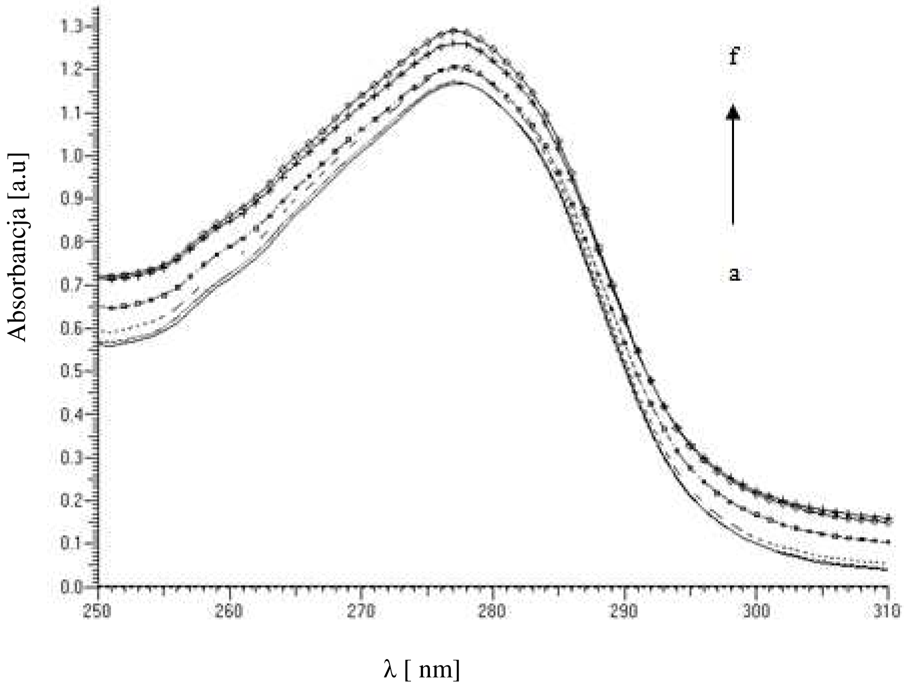
2. Materiały i metody

Bovine Serum Albumin w postaci ciała stałego; skrystalizowany i liofilizowany proszek (czystość 99%, lot: SLBK3063V) otrzymano z firmy Sigma Aldrich. Eksperymentowi poddano wodne roztwory białka o stężeniu 2 mg/mL.
Wybór stężania BSA 2 mg/mL był konsekwencją już wcześniej prowadzonych badań [22].
Za pomocą dwuwiązkowego spektrofotometru UV/Vis (Hallo DB-20 R) firmy Dynamica. Badano widma absorpcyjne wodnych roztworów BSA w zakresie 220-350 nm, chcąc śledzić zmiany w piku absorpcyjnym roztworu białkowego pochodzącego od występowania w badanej proteinie aromatycznych rezyduów takich jak: tryptofan (Trp), tyrozyna (Tyr) oraz fenyloalanina (Phe) [23].
Badano zmiany w czasie zachodzące pod wpływem czynnika zewnętrznego jakim była obniżona temperatura. Jednorazowa ekspozycja trwała 60 minut w temperaturze (-18°C).
W pierwszym dniu trwania eksperymentu wykonano 40 mL wodnego roztworu BSA o stężeniu 2 mg/mL).
Następnie roztwór ten podzielono na cztery grupy po 10 mL
Pierwszą z nich była próbka kontrolna, która nie była poddana ekspozycji na czynnik zewnętrzny.
Próbkę oznaczoną BSAx1 poddano działaniu obniżonej temperatury przez okres 60 min tylko raz w pierwszym dniu trwania eksperymentu.
Próbkę BSAx2 poddano działaniu czynnika zewnętrznego dwukrotnie. W pierwszym i drugim dniu trwania eksperymentu.
BSAx3 to próbka poddana ekspozycji trójkrotnej. W pierwszy, drugim, trzecim dniu trwania eksperymentu.
Następnie za pomocą spektrofotometru UV/Vis badano widma absorpcyjne roztworów w zakresie 220-350 nm.
Pomiaru dokonywano w pierwszym dniu eksperymentu (oznaczony jako 0 dzień bez ekspozycji na czynnik), w oraz kolejnych dniach następujących po ekspozycji (tzn ekspozycja wykonana w 0 dniu, pomiar UV/Vis dzień 1). Zabieg ten wykonywano po to aby badane roztwory miały jednakową temperaturę (22°C).
Zbadano widma próbek eksponowanych jednokrotnie, dwukrotnie, trzykrotnie kolejno w 1, 2, 3, 4, 5 dniu trwania badania.

3. Rezultaty i dyskusja

Rysunek 1 przedstawia widma UV/Vis w zakresie 250-310 nm wykonane dla próbek kontrolnych wodnych roztworów BSA o stężeniu 2 mg/mL. Badano zmiany w czasie zachodzące w piku 277 nm, który pochodzi od występowania w białku aromatycznych aminokwasowych rezyduów takich jak tryptofan (Trp), tyrozyna (Tyr) czy fenyloalanina (Phe). Prezentowane widma zebrane zostały w 0, 1, 2, 3, 4, 5 dniu trwania eksperymentu.
Zaobserwowano, wzrost absorpcji wraz ze starzeniem się próbki. Co świadczyć może o zmianach konformacyjnych zachodzących w proteinie wraz z czasem.
Efekt ten odzwierciedla spadek w stabilności proteiny i jest najprawdopodobniej związany ze zmianami konformacyjnymi BSA oraz zmianą siły oddziaływań

elektrostatycznych pomiędzy tworzącymi ją aminokwasami. Jednocześnie stwierdzono brak przesunięcia piku absorpcyjnego, co może świadczyć o braku zmian w mikrośrodowisku dookoła aromatycznych aminokwasowych rezyduów takich jak tryptofan (Trp), tyrozyna (Tyr) czy fenyloalanina (Phe) i braku ich ekspozycji na polarne grupy rozpuszczalnika.

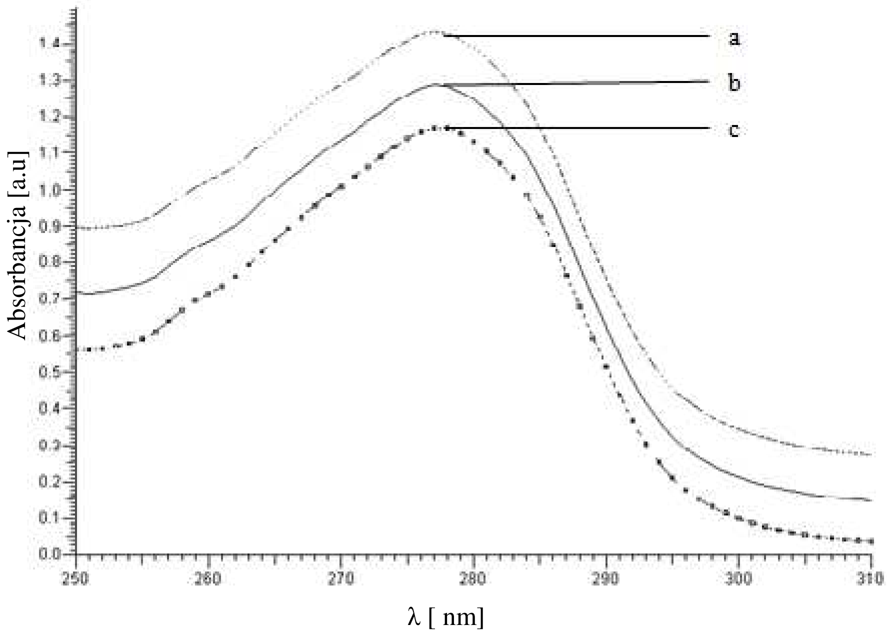


Rysunek 1. Widma UV/Vis wodnych roztworów BSA (2 mg/mL) bez ekspozycji na czynnik zewnętrzny w kolejnych dniach : a) 0 dzień, b) 1 dzień, c) 2 dzień, d) 3 dzień, e) 4 dzień, f) 5 dzień

W drugim etapie eksperymentu badano wpływ czynnika zewnętrznego takim była obniżona temperatura, na stabilność BSA, która wykorzystywana jest w matrycach biosensorowych do sieciowania. Przeprowadzony eksperyment miał na celu odpowiedzieć na pytanie czy aplikując czynniki zewnętrzne na komponent warstwy receptorowej biosensorów, jesteśmy w stanie wpłynąć na jej stabilność.

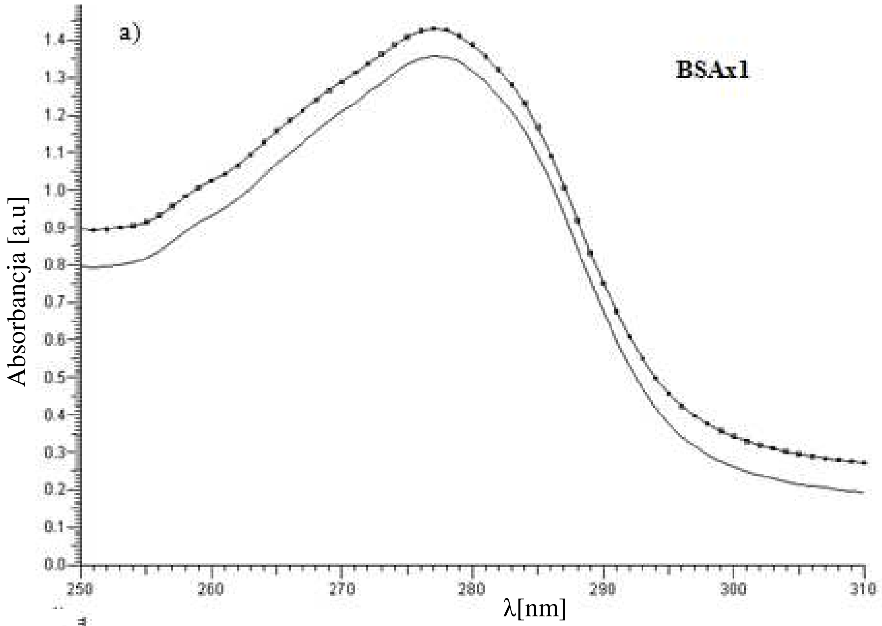
Czynnik podawano frakcyjnie: w pierwszym ((x1)- ekspozycja jednokrotna), drugim ((x2)- ekspozycja dwukrotna), trzecim (x3)- ekspozycja trójkrotna) dniu trwania eksperymentu.

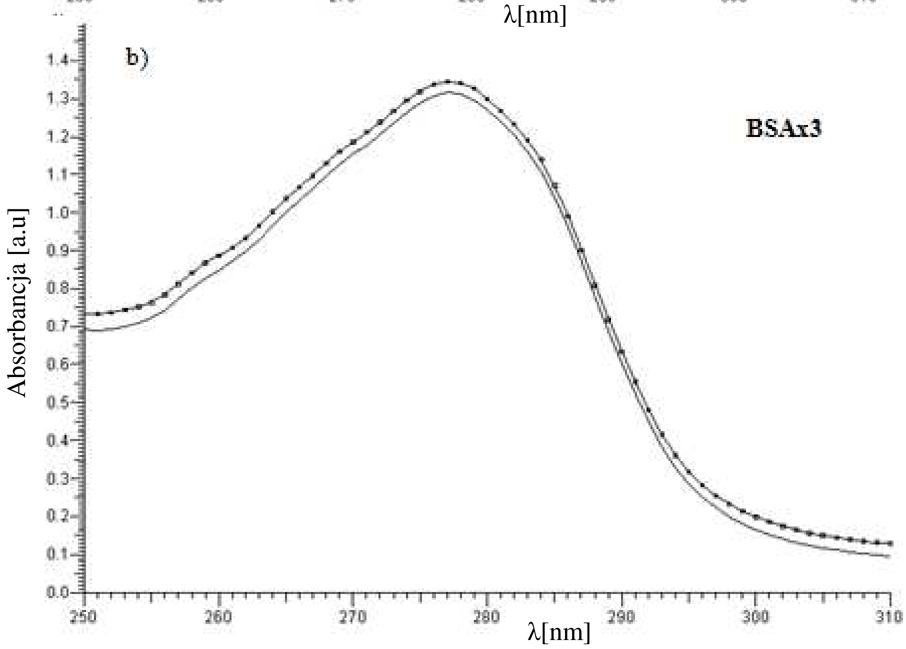
Rysunek 2 przedstawia zmiany zachodzące w piątym dniu trwania eksperymentu. Przedstawiono różnicę pomiędzy próbkami eksponowanymi na czynnik zewnętrzny tylko raz BSAx1 a próbkami kontrolnymi. Dla porównania na wykresie umieszczono również widmo absorpcyjne świeżej próbki kontrolnej w 0 dniu eksperymentu.



Rysunek 2. W idma UV/Vis BSA 2 mg/mL w piątym dniu eksperymentu dla próbki poddanej ekspozycji na czynnik zewnętrzny (a) i próbki kontrolnej (b). Dla porównania widmo próbki świeżej (bez czynnika zewnętrznego) w 0 dniu eksperymentu(c)

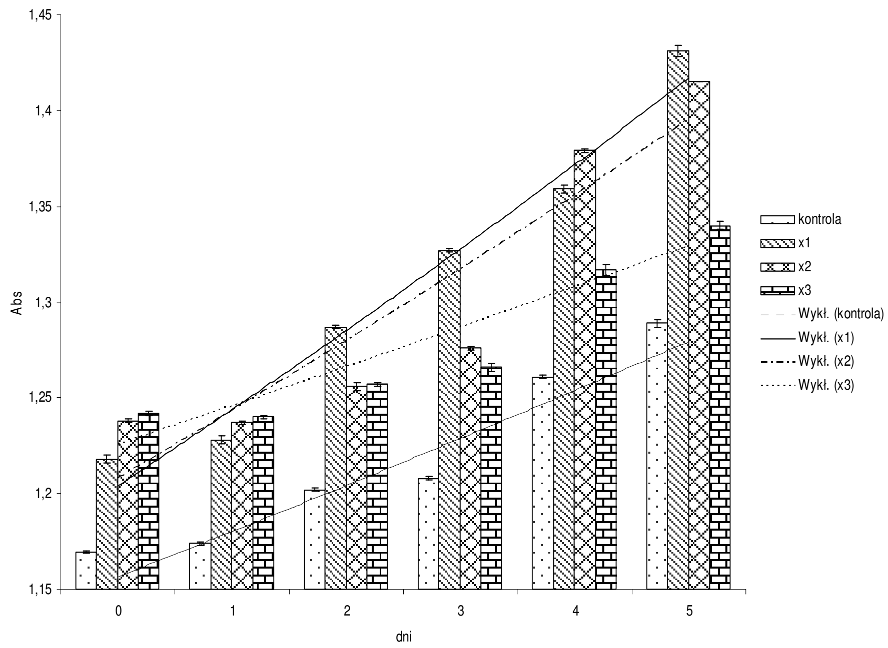
Przedstawione rezultaty obrazują wpływ czynnika zewnętrznego na proteinę.
Widać, że znacznie obniżona temperatura wpływa na stabilność białka, przyspieszając zmiany konformacyjne zachodzące w proteinie.
Na rysunku 3 przedstawiono porównanie widm absorpcyjnych BSA (2 mg/ml) poddanej jednorazowej i trójkrotnej ekspozycji na czynnik zewnętrzny w czwartym i piątym dniu eksperymentu.
Zauważono wiekszy wzrost absorpcji w BSAx1 niż w BSAx3. Trend ten dostrzezono również w pozostałych dniach eksperymentu.





Rysunek 3. Porównanie widm absorpcyjnych BSA (2mg/mL) poddanej jednorazowej (a) i trójkrotnej (b) ekspozycji na czynnik zewnętrzny w czwartym i piątym dniu eksperymentu.

Biorąc pod uwagę próbki o jednorazowej frakcji czynnika oraz zmiany zachodzące pomiędzy dniem czwartym a piątym i porównując je z próbkami o trójkrotnej frakcji czynnika oraz zmianami w dniu czwartym i piątym. Można jednoznacznie stwierdzić większe różnice w BSA poddanej działaniu czynnika zewnętrznego tylko raz niż trójkrotnie co świadczyć może o większej dynamice zmian zachodzących w BSAx1 niż BSA x3 i większym wpływie wywieranym na stabilność białka ekspozycji jednorazowej.



Rysunek 4. Średnia absorpcja BSA 2 mg/mL próbki kontrolnej oraz poddanej jednokrotnej , dwukrotnej, trzykrotnej ekspozycji na czynnik zewnętrzny w 0, 1, 2, 3,4, 5 dniu eksperymentu wraz z odchyleniem standardowym

Rysunek 4 oraz tabela 1 przedstawiają średnią z trzech pomiarów wraz z odchyleniem standardowym , absorpcję BSA 2 mg/mL badaną poprzez maksimum piku pochodzącego od aminokwasów aromatycznych takich jak tyrozyna, tryptofan, phenyloanalnina w piku 277 nm.

Wraz z upływem czasu zaobserwowano wzrost wartości absorpcji, co odzwierciedla zmianę w układzie atomów w cząsteczce z czasem.

Biorąc pod uwagę wpływ czynnika zewnętrznego na zmiany zachodzące w białku w kolejnych dniach trwania eksperymentu, można powiedzieć, że ekspozycja na czynnik przyspiesza zmiany konformacyjne zachodzące w proteinie z upływem czasu. Czyli sprzyja procesowi denaturyzacji białka. Największą różnicę pomiędzy próbkami kontrolnymi a eksponowanymi, zauważono po jednokrotnej ekspozycji mniejszą dla roztworów w których frakcja czynnika była wielokrotna.

Porównując próbki eksponowane jednokrotnie z próbkami poddawanymi ekspozycji wielokrotnej można zauważyć różnicę, która jest większa pomiędzy próbkami BSAx1 i BSAx3 niż BSAx1 i BSAx2. Efekt ten jest wyraźniejszy z czasem.

Fitując otrzymane wartości funkcją wykładniczą $y=e^{ax}$, biorąc pod uwagę parametr a jako czynnik świadczący o dynamice zmian, można powiedzieć, że zmiany zachodzą szybciej w proteinie pod wpływem czynnika zewnętrznego i są one bardziej wyraźne po ekspozycji jednokrotnej niż wielokrotnej..

Tabela 1. Wartości średnie wraz z odchyleniem standardowym maximum piku absorpcyjnego (277nm) próbki kontrolnej oraz poddanej jednokrotnej i wielokrotnej ekspozycji na czynnik zewnętrzny w 0 ,1, 2, 3,4, 5 dniu eksperymentu

dni	BSA kontrola			BSA x 1			BSA x 2			BSA x 3		
0	1,169	±	0,001	1,218	±	0,002	1,238	±	0,001	1,24	±	0,001
1	1,174	±	0,001	1,228	±	0,002	1,237	±	0,001	1,24	±	0,001
2	1,202	±	0,001	1,287	±	0,001	1,256	±	0,002	1,26	±	0,001
3	1,208	±	0,001	1,327	±	0,001	1,276	±	0,001	1,27	±	0,002
4	1,261	±	0,001	1,359	±	0,002	1,379	±	0,001	1,32	±	0,003
5	1,289	±	0,002	1,431	±	0,003	1,415	±	0	1,34	±	0,002

4. Podsumowanie

Reasumując, przeprowadzone badania wykazały wzrost absorpcji związany ze zmianami konformacyjnymi w BSA wraz z czasem.
Zaobserwowano wpływ czynnika zewnętrznego na stabilność białka; można zatem powiedzieć, że ekspozycja na czynnik przyspiesza zmiany konformacyjne zachodzące w proteinie z upływem czasu i wpływa na jej strukturalną modyfikację.
Porównując wpływ czynnika poddawanego na proteinę w frakcjach (jednokrotnych, dwukrotnych, trzykrotnych), zaobserwowano większy wpływ na stabilizację BSA czynnika podawanego jednokrotnie niż wielokrotnie. Zmiany te były wyraźniejsze wraz z upływem czasu.
Odnosząc otrzymane wyniki do badań nad biosensorami można powiedzieć, że warunki zewnętrzne mają wpływ na stabilność komponenta warstwy receptorowej jakim jest BSA.

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ANALIZA SYGNAŁÓW STERUJĄCYCH WTRYSKIWACZAMI W ZASOBNIKOWYM UKŁADZIE ZASILANIA W PALIWO

Streszczenie: Artykuł dotyczy analizy sygnałów sterujących elektromagnetycznymi wtryskiwaczami zasobnikowego układu zasilania typu Common Rail. W analizie uwzględniono napięciowe i prądowe przebiegi sygnałów, dla różnych wartości czasu przerwy pomiędzy częściami dawki. Wyniki pomiarów zostały odniesione do parametrów pracy wtryskiwaczy stosowanych w pojazdach samochodowych.

Słowa kluczowe: zasobnikowy układ zasilania, sygnał sterujący

INJECTORS CONTROL SIGNALS ANALYSIS OF COMMON RAIL FUEL INJECTION SYSTEM

Summary: The article concerns the analysis of the control signals of electromagnetic of Common Rail fuel supply system. The analysis includes voltage and current waveforms for different values of time interval between dose portions. The measurement results were related to the operating parameters of the injectors used in motor vehicles.

Keywords: Common Rail, control signal

1. Wprowadzenie

Nowoczesne silniki o zapłonie samoczynnym powinny dzisiaj, wobec konieczności spełnienia norm, cechować się wysoką mocą, jednocześnie zapewniając niski poziom emisji toksycznych składników spalin. Nie byłoby to możliwe bez wykorzystania najwyższej jakości podzespołów. Z punktu widzenia poprawności przebiegu procesu spalania, bardzo ważnym czynnikiem jest określenie natężenia wypływu oleju napędowego z rozpylacza do komory spalania silnika. Proces ten powinien odbywać się w sposób założony przez konstruktora, powinien być dokładnie sterowalny oraz przewidywalny. Dawniej było to zapewniane przez mechaniczne pompy wtryskowe,

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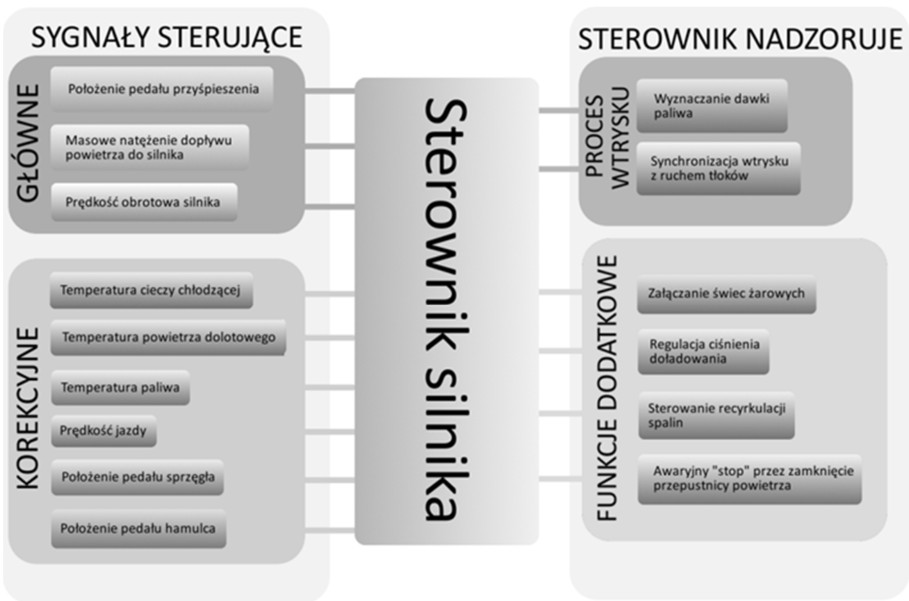
które nie mogły być precyzyjnie sterowane przez elektroniczne układy. Dzisiaj dzięki zastosowaniu odpowiedniej aparatury technicznej w połączeniu z zasobnikowym układem zasilania, stało się możliwe bardzo precyzyjne sterowanie procesem spalania, poprzez wpływ na ilość wtryskiwanego paliwa. Układ zasobnikowy jest układem gdzie zgromadzone pod dużym ciśnieniem paliwo jest podawane z zasobnika do wtryskiwaczy, a w momencie ich otwarcia do komory spalania silnika. Otwarcie wtryskiwacza jest sterowane za pomocą impulsów napięciowych. Impulsy są podawane ze sterownika. Układ Common Rail, umożliwia podział wymaganej ilości paliwa wtryskiwanego przez wtryskiwacze. Dzięki temu możliwe jest przeprowadzenie procesu spalania w danym punkcie pracy silnika w najbardziej efektywny sposób. Ten proces jest zależny od różnych czynników np. obciążenia silnika oraz jego temperatury. Z punktu widzenia sterowania istotnym zagadnieniem jest zapewnienie odpowiedniego sygnału sterujący pracą wtryskiwaczy. Za jego wysterowanie w odpowiednim czasie odpowiada sterownik. Odbywa się to na podstawie informacji z szeregu różnych czujników, na przykład mierzących prędkość obrotową czy wyznaczających początek wtrysku.

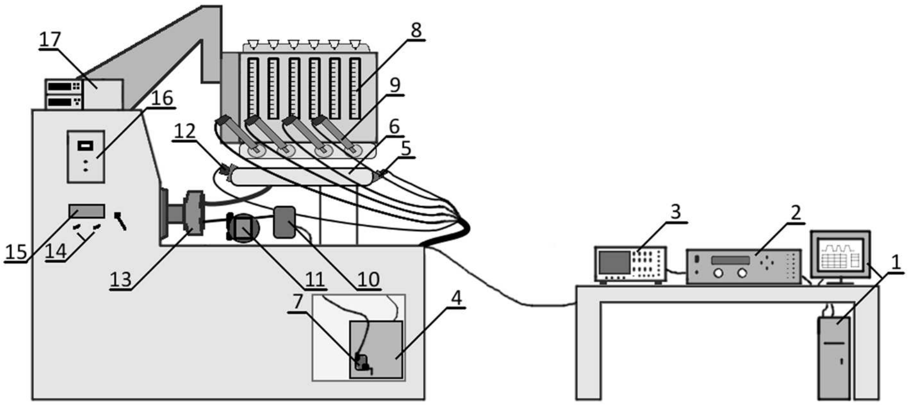
Sterownik silnika odpowiada za nadzorowanie szeregu różnych procesów (rys. 1). Oprócz procesu wtrysku realizowane są też funkcje dodatkowe. Z punktu widzenia sterowania ważnym punktem układu są sygnały sterujące. Na podstawie tych sygnałów oraz ich analizy, sterownik realizuje procesy zapewniające prawidłową pracę silnika. W pracy skupiono się głównie na zagadnieniach dotyczących procesu wtrysku [1, 2, 3, 4, 5].



Rysunek 1. Schemat układu sterowania silnika

2. Cel pracy i stanowisko badawcze

Celem pracy była analiza sygnałów sterujących elektromagnetycznymi wtryskiwaczami zasobnikowego układu zasilania typu Common Rail. Przeprowadzono analizę zarówno napięciowych, jak i prądowych przebiegów. Zmierzone wielkości obejmowały pracę układu w warunkach podziału dawki na dwie części.
Pomiary zostały wykonane na odpowiednio przystosowanym w tym celu stanowisku probierczym Star 8 (rys. 2), wyposażonym w osprzęt umożliwiający pracę układu zasobnikowego Common Rail.



Rysunek 2. Poglądowy schemat stanowiska badawczego. 1 – komputer, 2 – główny sterownik, 3 – oscyloskop cyfrowy, 4 – zbiornik paliwa, 5 – czujnik wysokiego ciśnienia, 6 – zasobnik wysokiego ciśnienia, 7 – pompa niskiego ciśnienia, 8 – miernica, 9 – wtryskiwacz, 10 – filtr paliwa, 11 – stabilizator ciśnienia paliwa, 12 – elektromagnetyczny zawór upustowy ciśnienia, 13 – pompa wysokiego ciśnienia, 14 – wyłączniki zasilania pompy i regulacji temperatury, 15 – regulator temperatury, 16 – falownik, 17 – sterownik liczby cykli pomiarowych

Stanowisko umożliwiało zadawanie podziału dawki wtryskiwanego paliwa na części, ja k i zmiany czasów wtrysku. Modyfikacji można było również poddawać wartość ciśnienia zasilania pompy wysokiego ciśnienia, temperaturę paliwa, ilość mierzonych cykli oraz prędkość obrotową pompy wysokiego ciśnienia. Za pomocą oscyloskopu cyfrowego Tektronix TDS 3014 było możliwe bieżące monitorowanie i rejestracja przebiegu sygnałów sterujących, podawanych przez główny sterownik. Do pomiaru przebiegów prądowych wykorzystano oscyloskopową sondę pomiarową typu Tektronix A622. Wyświetlane sygnały mogą być sygnałami prądu stałego jak i zmiennego, o wartościach szczytowych do 100 A wartości skutecznej 70 A.

3. Program badań i metodyka pomiarów

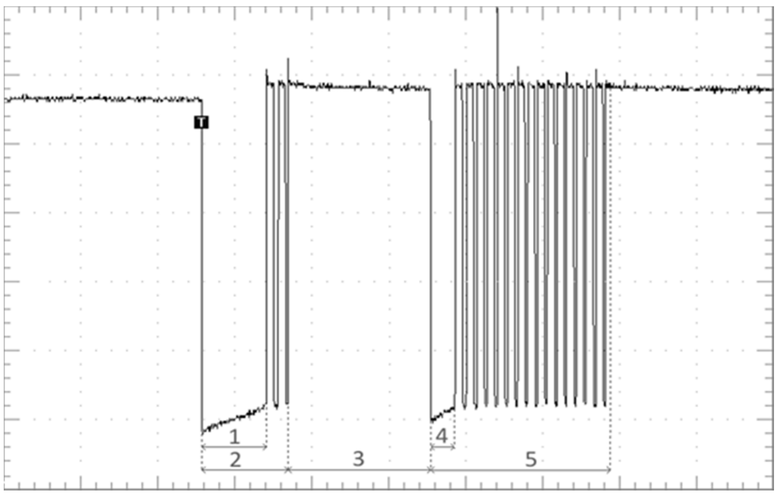
Pomiary przeprowadzono według opracowanego wcześniej programu badań (tab. 1). Po odpowiednim nastawieniu parametrów dotyczących ciśnienia paliwa w zasobniku, prędkości obrotowej oraz zadaniu czasów dla poszczególnych części dawek, rejestrowano przebiegi sterujące. Masa paliwa, które było dawkowane przez wtryskiwacze, była mierzona za pomocą laboratoryjnej wagi Radwag WPE 600. Jednostkową dawkę wtrysku wyznaczano w oparciu o masę paliwa podaną przez 250 cykli pracy układu wtryskowego.

Tabela 1. Program badań wpływu czasu przerwy na parametry układu zasilania

lp.	Pilot ET [μs]	Pilot DT [μs]	Main ET [μs]	Ciśnienie paliwa w kolektorze [bar]	Prędkość obrotowa [obr/min]	Ciśnienie zasilania [MPa]	Liczba cykli wtrysku
1	262	250	464	700	600	0,2	250
2	262	300	464	700	600	0,2	250
3	262	337	464	700	600	0,2	250
4	262	346	464	700	600	0,2	250
5	262	377	464	700	600	0,2	250
6	262	500	464	700	600	0,2	250
7	262	800	464	700	600	0,2	250
8	262	1100	464	700	600	0,2	250
9	262	1400	464	700	600	0,2	250
10	262	2152	464	700	600	0,2	250

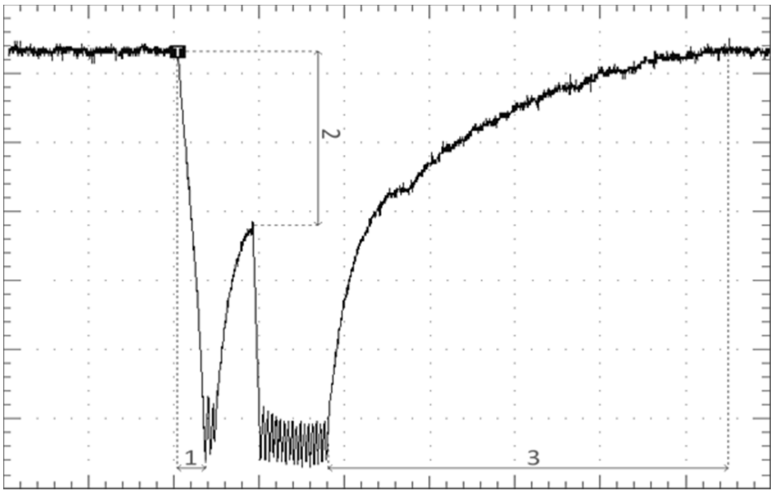
ET – (Energizing Time) czas podawania na cewkę sygnału sterującego,
DT – (Dwell Time) czas przerwy w podawaniu na cewkę sygnału sterującego.

Przeprowadzone serie pomiarów dotyczyły wpływu czasu przerwy pomiędzy częściami dawki na parametry układu zasilania. Rysunki 4 i 5 przedstawiają sposób odczytywania charakterystycznych parametrów, z napięciowych i prądowych przebiegów.



Rysunek 3. Parametry przebiegu sygnału sterującego dla dzielonej dawki wtrysku; przebieg napięciowy

Przyjęto następujący opis sygnału napięciowego (rys. 4): 1 – czas sterowania fazą przyciągania pierwszej części dawki, 2 – całkowity czas sterowania pierwszej części dawki, 3 – czas przerwy między częściami dawki, 4 – czas sterowania fazą przyciągania drugiej części dawki, 5 – całkowity czas sterowania drugiej części dawki.



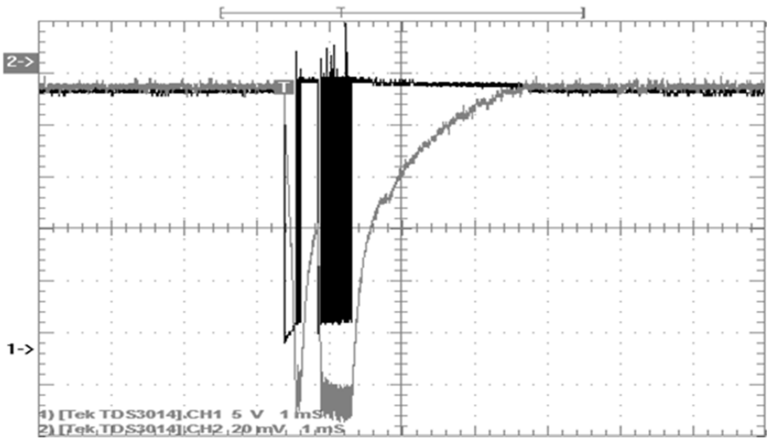
Rysunek 4. Parametry przebiegu sygnału sterującego dla dzielonej dawki wtrysku, przebieg prądu sterowania.

Przebieg prądu sterowania opisano następująco (rys. 5): 1 – czas narastania prądu cewki elektromagnesu, 2 – wartość prądu przed drugim wymuszeniem, 3 – czas zanikania prądu cewki elektromagnesu. W trakcie pracy stanowiska, po osiągnięciu założonych parametrów, przebiegi sygnałów sterujących były odczytywane z oscyloskopu. Rejestrowano je za pomocą specjalistycznego oprogramowania WaveStar 2.4 firmy Tektronix oraz zapisywano na dysku komputera.

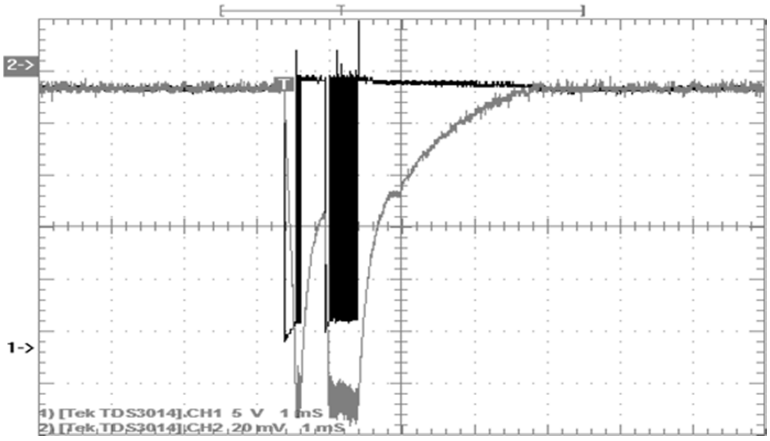
Przy przeprowadzaniu pomiarów wymagana była manualna korekcja ciśnienia paliwa w zasobniku, w celu uzyskania wartości najbliższej założonej. Dawki wtryskiwane przez poszczególne wtryskiwacze w trakcie trwania cykli pomiarowych, były podawane do miernic. Po upływie określonej liczby cykli, menzurki z odmierzonym paliwem były ważone na wadze.

4. Wyniki pomiarów

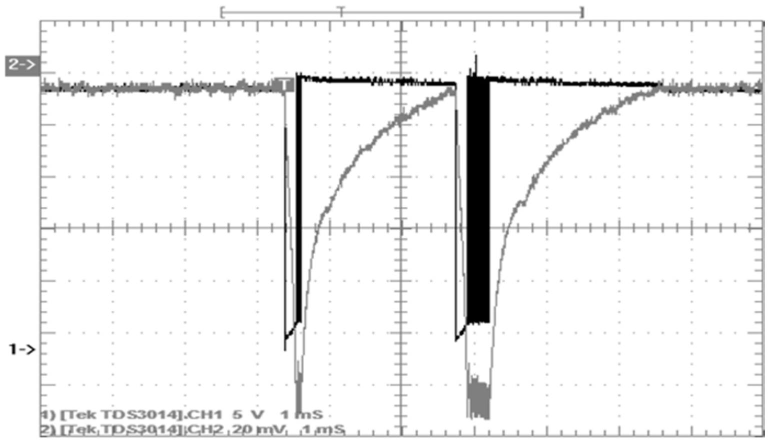
Na rysunkach 5÷7 zaprezentowano wybrane przebiegi zarejestrowane podczas pomiarów. Zestawiono zarówno napięciowe, jak i odpowiadające im prądowe przebiegi, zmierzone dla różnych wartości zadanych czasów przerw.



Rysunek 5. Przebieg sygnałów napięciowego i prądowego, dla czasu przerwy 250 μs



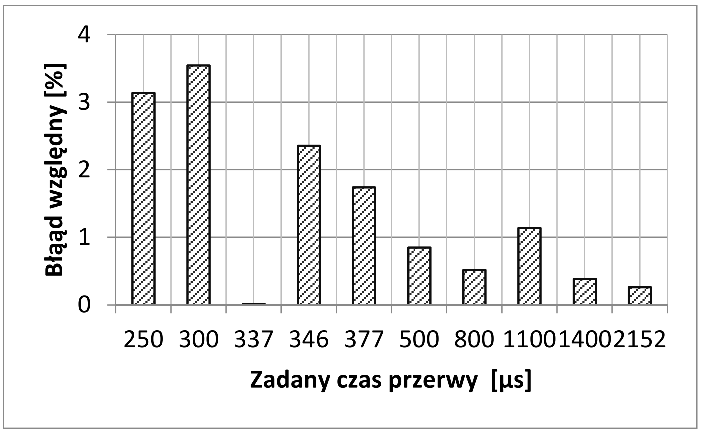
Rysunek 6. Przebieg sygnałów napięciowego i prądowego dla czasu przerwy 346 μs



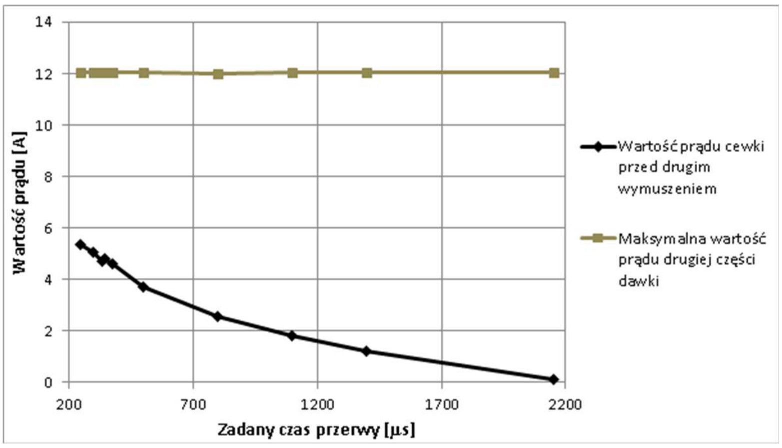
Rysunek 7. Przebieg sygnałów sterujących dla czasu przerwy 2152 μs

5. Analiza wyników pomiarów

Analizę przebiegów przeprowadzono w oparciu o metodykę przedstawioną w p. 3. Na podstawie tych wartości sporządzono rys. 8÷9.
Analizując rysunek 9, przedstawiający błąd względny między zadanymi, a zrealizowanymi wartościami czasu przerwy można zauważyć, że wartość błędu względnego zmniejsza się wraz ze zwiększaniem czasu przerwy pomiędzy częściami dawki. Dla czasu przerwy między częściami dawki 337 µs, wyznaczony błąd jest równy zeru. W tym punkcie należy w przyszłości powtórzyć pomiary.
Poddając analizie przebiegi przedstawione na rysunku 9 można zauważyć, że wartość prądu cewki przed impulsem napięciowym dla drugiej części dawki jest wyraźnie zależna od czasu przerwy między częściami dawki. Im krótszy czas przerwy, tym wartość prądu cewki pozostaje na wyższym poziomie. Natomiast maksymalna wartość prądu drugiej części dawki pozostaje niezmieniona.



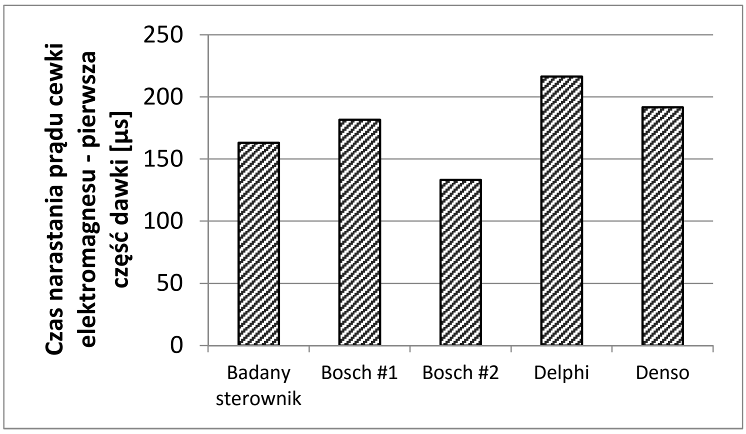
Rysunek 8. Błąd względny, pomiędzy zadaną wartością czasu przerwy, a wartością odczytaną z przebiegu napięciowego



Rysunek 9. Wartość prądu cewki przed drugim wymuszeniem oraz maksymalna wartość prądu drugiej części dawki

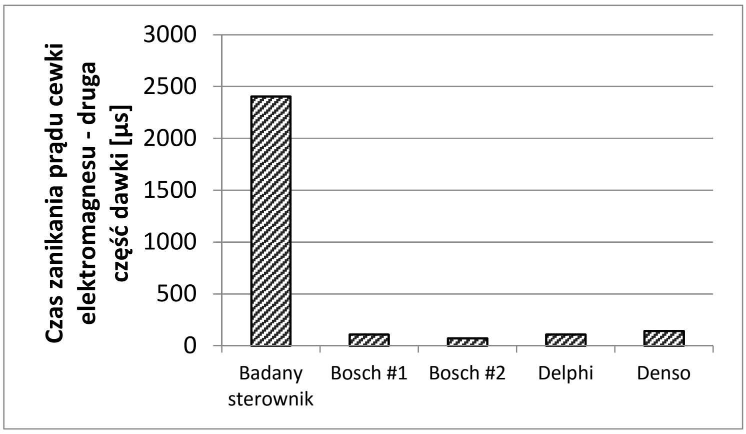
Pozostałe charakterystyczne parametry przebiegów porównano z danymi literaturowymi, które odnoszą się do sterowników wyprodukowanych przez wiodących producentów samochodów. Zestawione wartości przedstawiono na rys. 10÷12.

Czas narastania prądu cewki elektromagnesu pierwszej części dawki (rys. 10), dla badanego sterownika wynoszący 163,2 µs jest mniejszy od średniej wartości dla wszystkich rozważanych przypadków (173,7 µs). W przypadku wtryskiwaczy firmy Bosch podczas pracy dla gwałtownego wciśnięcia pedału przyśpieszenia (Bosch#2), czas ten jest najkrótszy (115,2 µs). Prąd cewki elektromagnesu zwiększa się najdłużej w przypadku wtryskiwaczy firmy Delphi.



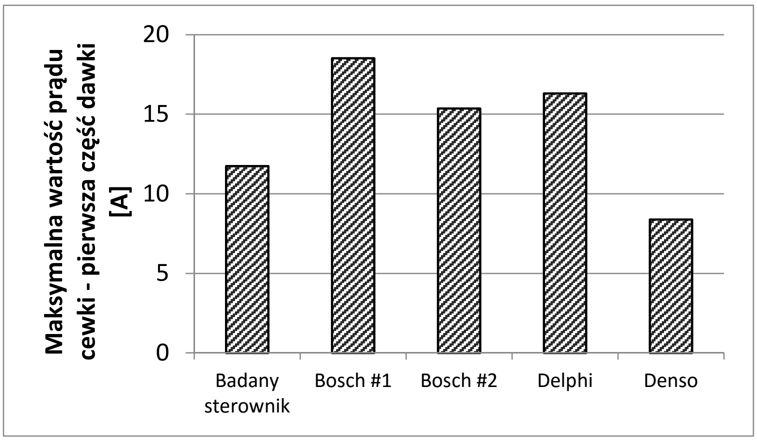
Rysunek 10. Porównanie czasu narastania prądu cewki elektromagnesu w przypadku pierwszej części dawki dla poszczególnych sterowników

Z rys. 11 wynika, że badany sterownik charakteryzował się najdłuższym czasem zaniku prądu w cewce zaworu wtryskiwacza. Dla pozostałych sterowników czas ten był znacząco krótszy i wynosił około 200 µs.



Rysunek 11. Porównanie czasu zanikania prądu cewek elektromagnesu w przypadku drugiej części dawki dla poszczególnych sterowników

Najdłużej – w przypadku sterowników samochodowych – trwał zanik prądu cewki elektromagnesu wtryskiwaczy Denso, jednak w porównaniu do sterownika badawczego, czas ten jest ponad 16 razy krótszy. Zanik prądu cewki elektromagnesu trwał najkrócej w przypadku wtryskiwaczy Bosch, podczas sterowania zarejestrowanego dla próby z gwałtownie wciśniętym pedałem przyśpieszenia.
Maksymalna wartość prądu zaworu generowana przez analizowany układ sterowania (rys. 12) jest porównywalna ze stosowanymi przez światowych producentów. Można zauważyć, że największą wartością prądu, cechują się wtryskiwacze firmy Bosch podczas pracy na biegu jałowym. Podczas sterowania przy gwałtownym wciśnięciu pedału przyśpieszenia – w przypadku tych samych wtryskiwaczy firmy Bosch – wartość prądu jest mniejsza o około 3 A. Najmniejszą wartość prądu – 8,4 A – stosuje się we wtryskiwaczach firmy Denso.



Rysunek 12. Porównanie maksymalnych wartości prądu cewki elektromagnesu w przypadku pierwszej części dawki dla poszczególnych sterowników

6. Podsumowanie

Oceniając urządzenie sterujące należy zawsze poddać analizie generowane przez nie przebiegi zarówno napięciowe, jak i prądowe.
Zwiększanie się czasu sterowania napięciem fazy oderwania w przypadku drugiej części dawki, wraz ze zwiększaniem się czasu przerwy pomiędzy częściami dawki, wynika z równoczesnego zmniejszania się wartości prądu cewki elektromagnesu. Sytuacja ta wymusza dłuższy czas sterowania napięciem fazy oderwania, aby można było uzyskać w określonym czasie odpowiednią wartość prądu cewki elektromagnesu.
Czas, po którym zostaje osiągnięta maksymalna wartość prądu cewki dla pierwszej części dawki oraz czas zaniku prądu w cewce w przypadku drugiej części dawki, nie ulegają zmianie mimo zadawania różnych czasów przerwy pomiędzy częściami dawki. Dzieje się tak dlatego, że wspomniane wielkości zależną jedynie od maksymalnej wartości prądu w cewce, a ta wynika z konstrukcji układu sterującego. Podobnie jest w przypadku czasu zaniku prądu cewki dla drugiej części dawki. Maksymalna wartość prądu także nie zmienia się mimo zmian czasu przerwy

pomiędzy częściami dawki. Ponieważ czas narastania prądu cewki elektromagnesu, jak i czas zaniku prądu w obu przypadkach zależy głównie od wartości maksymalnej prądu, oba odczytywane parametry pozostają na podobnym poziomie, mimo zmian czasu przerwy

Wartości błędu względnego pomiędzy czasem przerwy zadanym, a odczytanym z przebiegów, maleją wraz z zwiększaniem się czasu przerwy. Zależność ta wynika z przybliżonej stałej wartości błędów bezwzględnych dla każdego z pomiarów, które w odniesieniu do zwiększającej się wartości czasu przerwy pomiędzy częściami dawki, prowadzą do zmniejszania się wartości błędu względnego.

Przebiegi sygnałów pochodzących z układów sterowania czołowych producentów światowych układów zasilania różnią się od zmierzonych podczas badań na stanowisku probierczym. Różne są przede wszystkim końcowe fragmenty przebiegów. W tych generowanych przez sterowniki samochodowe zmiana polaryzacji w końcowej części służy do zamknięcia elektromagnesu wtryskiwacza, a przez to do zmniejszania lub zakończenia podawania paliwa. W tym fragmencie sygnału, wartość prądu cewki elektromagnesu zostaje znacznie szybciej zmniejszona niż ma to miejsce w sterowniku badawczym. Dzięki takiej formule sterowania, części dawki są podawane bardziej precyzyjnie i nie zachodzi efekt wtryskiwania paliwa także po zakończeniu czasu sterowania danej części dawki. Jak wynika z badań przeprowadzonych na sterowniku badawczym, czas przerwy pomiędzy częściami dawki, nie oznacza zakończenia procesu wtrysku, z powodu zbyt powolnego zaniku wartości prądu w cewce elektromagnesu wtryskiwacza.

Sterownik użyty w badaniach, nie powinien być stosowany do zadawania krótkich czasów przerw pomiędzy częściami dawki, gdzie błąd względny sterowania jest na poziomie wyższym niż dla czasów dłuższych. Jednak zasadniczą wadą sterownika jest brak możliwości podawania sygnału napięcia o przeciwnej polaryzacji – dla końca danej części dawki – która pozwalałaby na szybki zanik prądu w cewce elektromagnesu. Przez brak tej właściwości sterowanie jest mało precyzyjne, ponieważ przerwy czasowe pomiędzy częściami dawki, nie stanowią przerwy w dawkowaniu paliwa przez wtryskiwacze, lecz tylko zmniejszenie wydatku paliwa.

Badany sterownik może mieć zastosowanie w silnikach o długim czasie przerwy pomiędzy częściami dawki lub przy podawaniu jednoczęściowej dawki. Przy zadawaniu czasu dla pojedynczej dawki, trzeba jednak pamiętać, że zrealizowany czas dawkowania będzie większy od zadanego.

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NIEKONWENCJONALNE PODEJŚCIE DO BADANIA JAKOŚCI ORAZ PARAMETRYZOWANIA PRACY NARZĘDZI SKRAWAJĄCYCH NA PRZYKŁADZIE BRANŻY MOTORYZACYJNEJ

Streszczenie: Niniejszy artykuł jest prezentacją kolejnego fragmentu prowadzonych prac badawczych z wykorzystaniem specjalistycznego sprzętu i oprogramowania firmy Digital Way, służącego do monitorowania pracy narzędzi na obrabiarkach. Przedstawiona w tym tekście problematyka jest aktualnym odzwierciedleniem jednego z wielu wyzwań stojących przed przedsiębiorstwami branży motoryzacyjnej. W strefie działalności sektora samochodowego ciągle są poszukiwane innowacyjne rozwiązania napotykanych problemów, a przedstawione wyniki badań są jednym z takich przykładów.

Słowa kluczowe: badanie i testowanie narzędzi, bieżąca kontrola procesu, testy obrabialności, parametryzowanie procesu skrawania

UNCONVENTIONAL APPROACH TO QUALITY TESTS AND PARAMETERIZATION OF CUTTING TOOLS ON THE EXAMPLE OF AUTOMOTIVE INDUSTRY

Summary: This article is a presentation of next part of experimental work with using specialistic hardware and software developed by Digital Way in order to monitor tool work on the machines. The paper describes issue, which is the actual reflection of one from many challenges which automotive companies have to face. There is continuous search of innovative solutions to solve problems in automotive industry, article presents results of research done in this area.

Keywords: tools testing, current process control, machinability tests, parameterization of cutting process

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1. Wprowadzenie – analiza stanu obecnego

W branży motoryzacyjnej wiele już zostało osiągnięte, a mimo to producenci samochodów będą nadal dążyć do zwiększania wydajności własnych procesów, aby utrzymać poziom rentowności i osiągać przewagę konkurencyjną. Pośród licznych procesów produkcyjnych, jakie branża motoryzacyjna wykorzystuje w celu wytwarzania samochodów, wyróżnić jako główne można byłoby m.in. wytłaczanie, spawanie, lakierowanie, montaż, czy obróbkę skrawaniem, która jest jedną z najstarszych i do dzisiaj stosowanych metod wytwarzania przedmiotów. Pomiędzy wszystkimi stosowanymi technikami mechanicznego wytwarzania jest najczęściej wykorzystywaną (60-70%) oraz pochłania ponad połowę zużytej energii w procesach produkcyjnych. Wiele wskazuje na to, że jeszcze długo będzie metodą dominującą – przewiduje się w najbliższych latach dalszy rozwój skrawania z wysoką precyzją oraz wysokimi prędkościami, szczególnie w wytwarzaniu części form i matryc w przemyśle motoryzacyjnym i lotniczym. Aspekty ekonomiczne związane z redukcją kosztów produkcji oraz ciągle rosnące wymagania klientów prowadzą do tworzenia coraz to bardziej skomplikowanych kształtów produktów przez projektantów oraz konstruktorów. Często z tego powodu zmniejsza się masa elementów, a w następstwie pojawiają się trudności podczas wytwarzania (problem ten dotyczy również narzędzi). Problematyka narzędziowa ma tutaj jeszcze logistyczne ujęcie w postaci gospodarki narzędziowej. W swoich pracach naukowych wielu autorów z dziedziny ekonomii obróbki, zakłada koszty narzędziowe na poziomie 2-5% ogólnych kosztów wytwarzania. Z tego powodu sporo analiz pomija wpływ kosztu narzędziowego na ogólny koszt wytwarzania, co w rezultacie skutkuje błędnym szacowaniem kosztów produkcji. Natrafić również można na takich autorów, którzy zakładają udział kosztów narzędziowych w ogólnych kosztach wytwarzania na poziomie 8%. Analiza rynku narzędzi skrawających i badania praktyczne procesów wytwarzania pokazują, że faktyczny koszt udziału narzędzi sięga nawet kilkunastu procent. Mimo niedokładnych danych można stwierdzić, że są one raczej wysokie, a za tym racjonalna gospodarka narzędziowa jest jednym z rozwiązań dla obniżenia kosztów produkcji. Przez pojęcie racjonalna, należy tutaj rozumieć kształtowanie działań i podejmowanie decyzji w jej obrębie na podstawie empirycznej wiedzy związanej z elementami mającymi wpływ na procesy i narzędzia [1,2].

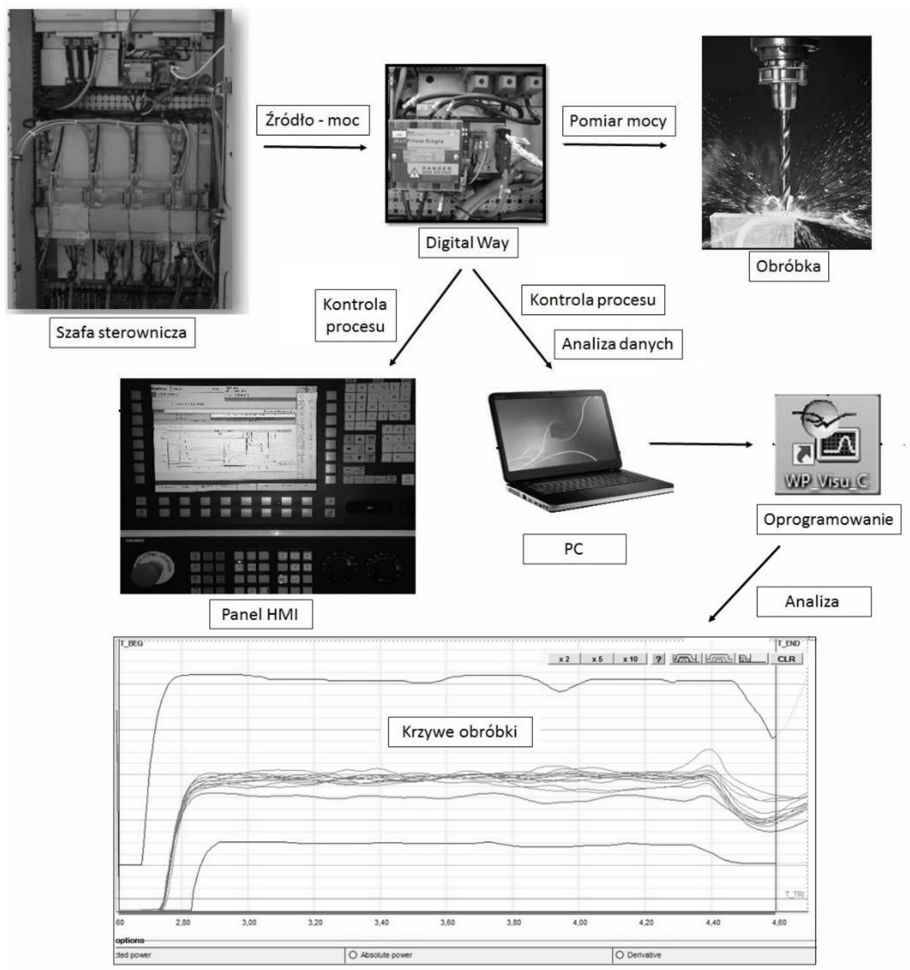
Postępujące zmiany jakościowe zmuszają dzisiejsze zakłady produkcyjne do kompleksowej kontroli każdego etapu produkcyjnego. Chociaż wiele ośrodków naukowych jest zaangażowanych w budowę układów monitorowania procesu skrawania, to należy uznać, że problematyka monitorowania, czy prognozowania stanu narzędzia i procesu skrawania nie została wystarczająco rozwiązana i jest nadal aktualna. Przedsiębiorstwa oczekują prostych układów pomiarowych, nie wymagających przesadnej ingerencji w samą budowę obrabiarki oraz by można było je przenosić na inne urządzenia. Czynniki takie jak złożoność procesów produkcyjnych, automatyzacja i robotyzacja procesów wytwórczych, popularne stosowanie elastycznych systemów produkcji, wzrastające wymagania dotyczące dokładności elementów dodatkowo powodują konieczność wdrażania i stosowania technologii umożliwiających skuteczne monitorowanie procesu obróbki. [2]

Rynki obrabiarek oraz narzędzi skrawających w oczywisty sposób wzajemnie się uzupełniają i stymulują do rozwoju innowacyjnych rozwiązań konstrukcyjnych oraz technologicznych. Popyt na narzędzia jest zatem ściśle związany z sytuacją w przemyśle obrabiarkowym, ta zaś zależy od kondycji wielu segmentów przemysłu przetwórczego, w szczególności branż wytwarzających maszyny i urządzenia, wyroby z metalu, samochody osobowe i ciężarowe oraz inne środki transportu, które w szerokim zakresie wykorzystują obróbkę skrawaniem. Ze statystyk GUS wynika, że od 2013 r. w tych branżach, jak i całym przetwórstwie przemysłowym, przeważa dobra koniunktura, na co wskazuje wysoka dynamika produkcji sprzedanej. Zapotrzebowanie na maszyny i urządzenia jest ściśle związane z aktywnością inwestycyjną wielu działów przemysłu, a także górnictwa, budownictwa i energetyki. Stwarza to korzystne warunki rynkowe dla firm oferujących obrabiarki oraz związane z nimi oprzyrządowanie, a także świadczących specjalistyczne usługi z zakresu napraw, remontów i modernizacji maszyn oraz regeneracji narzędzi wykorzystywanych w procesach obróbkowych. [2]

Nowoczesne narzędzia skrawające wymagają jednakże kompleksowej i bardzo dokładnej kontroli z trzech powodów. Pierwszym są zmiany konstrukcyjne w samej budowie narzędzi (m.in. bezpośrednie doprowadzenie chłodziwa do obszaru skrawanego np. MQL), co często prowadzi do „osłabienia" struktury narzędzia. Drugim powód jest następstwem pierwszego – nowe rozwiązania konstrukcyjne wpływają bezpośrednio na wzrost ceny narzędzi (nowe projekty, materiały itp.) Ostatnim aspektem jest przeprowadzanie testów narzędzi. Niewiele informacji można uzyskać na ten temat, w jaki sposób producenci narzędzi dokonują ich testów, jednakże niepodważalnym faktem jest, że najlepszym „testerem" narzędzi są bezpośrednio przedsiębiorstwa produkcyjne, zwłaszcza w sektorze motoryzacyjnym, gdzie obróbka skrawaniem jest techniką dominującą. W celu spełnienia tych wymagań niezbędne są przyrządy, które – oprócz wysokiej dokładności – oferują prostą obsługę oraz duże możliwości wykonywania pomiarów.

2. Digital Way WattPilote – zasada działania

Stosowanie systemów monitorowania narzędzi staje się powoli codzienną praktyką w przedsiębiorstwach produkcyjnych dążących do ciągłej poprawy i optymalizacji własnych procesów wytwórczych. System firmy Digital Way - WattPillote oferuje liczne możliwości prowadzenia monitoringu obróbki skrawaniem takich jak wiercenie, gwintowanie, rozwiercanie, wytaczanie, frezowanie, nawet w najtrudniejszych przypadkach. W poprzednim wydaniu tego zeszytu specjalnego (Bielsko-Biała 2015) w artykule pt. *„Zastosowanie zaawansowanego systemu kontroli narzędzi z punktu widzenia optymalizacji procesu produkcyjnego"* opisany został potencjał i zastosowanie samego systemu. Na poniższym rysunku (rys.1) zaprezentowano schemat działania systemu. [3,4]



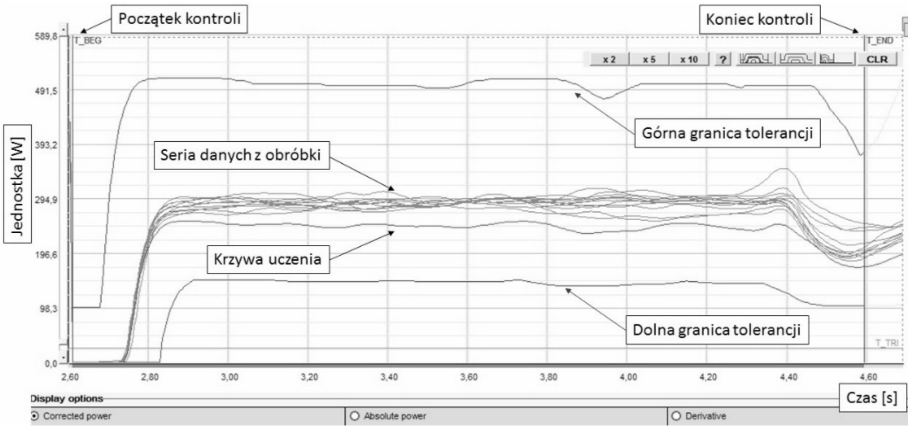
Rysunek 1. Ogólny schemat działania systemu Digital Way

Dokładność systemu Digital Way wywodzi się z faktu zbierania i przetwarzania własnych danych. Urządzenie posiada unikalny opatentowany system pomiarowy oraz własny algorytm obliczeniowy. Część pomiarowa jest połączona szeregowo z silnikiem wrzeciona, podczas gdy część przetwarzająca komunikuje się ze sterowaniem numerycznym (NC) i z programowalnym sterownikiem (PLC). Przy pomocy dedykowanego oprogramowania Digital Way WattPilote Visu-CN-C wizualizuje krzywe obróbki, stopień zużycia narzędzia, krzywe alarmów, a także umożliwia zmianę parametrów kontrolnych [4]. Dodatkowo istnieje możliwość prowadzenia długofalowej analizy danych, pod warunkiem podłączenia do systemu zewnętrznego komputera, który będzie przechowywał dane z obróbki. W celu monitorowania konkretnego procesu przy użyciu systemu Digital Way konieczne jest zdefiniowanie kilku wymienionych poniżej funkcji bazowych (rys.2):

- początku i końca kontroli na poziomie programu obróbczego,

- krzywej uczenia; czyli zakomunikowanie do systemu jak wygląda proces optymalny,
- początku i końca kontroli w aplikacji WP Visu-C,
- górnego zakresu tolerancji; ustalony procentowo dopuszczalny górny poziom obróbki względem krzywej uczenia (optymalnego przebiegu),
- dolnego zakresu tolerancji; ustalony procentowo dopuszczalny dolny poziom obróbki względem krzywej uczenia (optymalnego przebiegu).

Kompleksowe oprogramowanie systemu DW sprowadza się do konieczności przeprowadzenia gruntownych studiów nad procesem i zastosowaniem wielu zaawansowanych parametrów oraz funkcji dodatkowych. [3]



Rysunek 2. Wizualizacja procesu obróbki wygenerowana za pomocą systemu

Zebrane dane na komputerze, za pomocą dedykowanej aplikacji WP_Visu_C mogą być wizualizowane w postaci krzywych. Takie wykorzystanie możliwości systemu pozwala na uzyskanie obrazu przebiegu procesu, przeprowadzanie symulacji zmian parametrów (parametrów procesu w postaci posuwu, obrotów, czy też ustawień samego systemu; granic tolerancji, początku lub końca kontroli itp.) oraz obserwowanie rezultatów, które w następstwie można zastosować bezpośrednio na maszynie, minimalizując w ten sposób ryzyko – braki lub postoje.

Spośród licznych zalet systemu firmy Digital Way, jako najważniejsze należy wymienić:

- zapewnienie jakości procesu skrawania na podstawie precyzyjnej jego kontroli (częstotliwość próbkowania sygnału 40kHz, dokładność pomiaru 0,01% przy znakomitej dynamice),
- redukcja kosztów wytwarzania, poprzez eliminowanie możliwości produkcji wadliwych wyrobów, dzięki wczesnemu wykrywaniu ewentualnych anomalii,
- optymalizacja gospodarki narzędziowej - wzrost świadomości na temat czynników kształtujących pracę narzędzi w procesie i umożliwienie odpowiedniego reagowania np. poprzez parametryzacje narzędzi na

podstawie rzeczowej (empirycznej) analizy wykonanej w oparciu o zebrane dane, czy zmianę parametrów samego procesu,

- ochrona maszyny przed uszkodzeniem i nadmiernym eksploatowaniem.

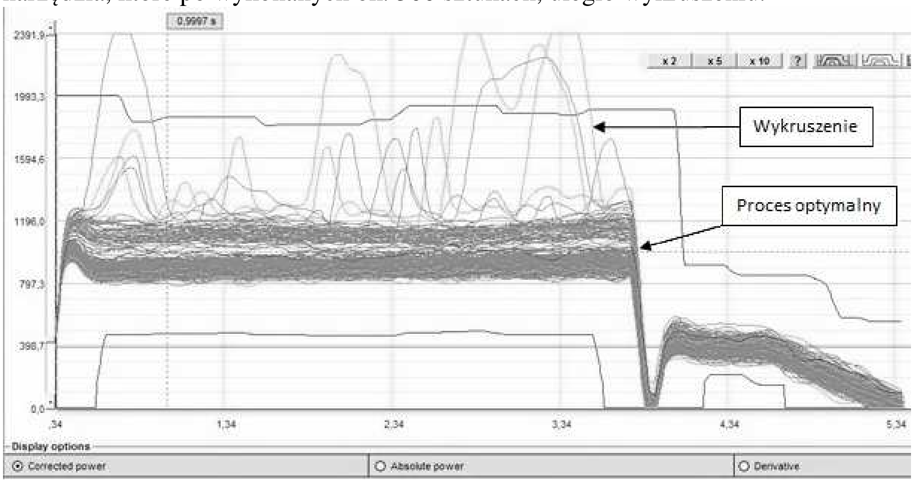
Stosowanie tego rodzaju systemów w praktyce może prowadzić do wzrostu wymagań stawianych producentom narzędzi na podstawie rosnącej świadomości technologów i inżynierów w zakresie zaawansowanych technik monitoringu wewnątrzprocesowego. Prowadzenie długofalowych analiz będzie wtedy punktem początkowym do stwierdzenia nieprawidłowości we własnym procesie ze względu na wady narzędziowe (przy wykluczonym udziale wad materiałowych) oraz sygnałem do konieczności rozpoczęcia prowadzenia wspólnych projektów badawczo-rozwojowych z dostawcami narzędzi.

3. Empiryczne podejście do parametryzacji procesu skrawania

Ze względu na szerokie spektrum możliwości prowadzenia badań pomiarowych za pomocą systemu Digital Way, zostały wybrane 4 przykładowe wykonane analizy.

3.1. Osiągnięcie żywotności narzędzia

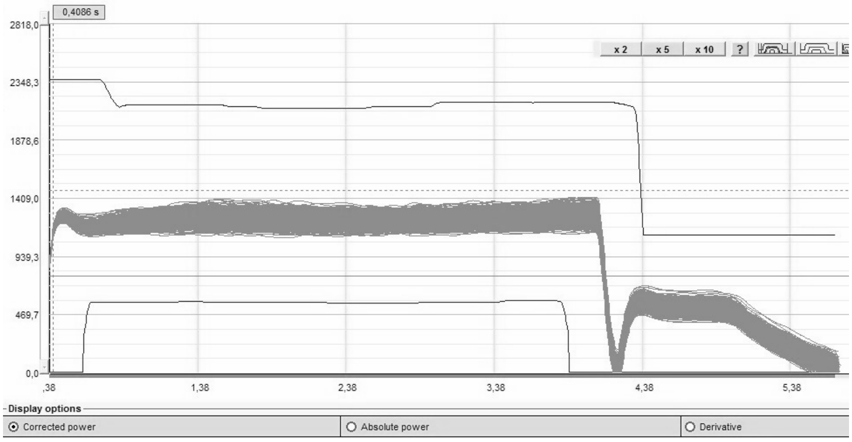
Pierwsza analiza dotyczy próby usystematyzowania osiąganej żywotności przez narzędzie (wiertło do głębokiego wiercenia). Długofalowa analiza danych skoncentrowana na tym jednym narzędziu w danym procesie produkcyjnym wykazała bardzo niestabilną pracę. W efekcie przy założonej (deklarowanej przez dostawcę) żywotności narzędzia na poziomie 1000szt., spora część nie wykonywała nawet połowy zadanej wielkości. Na rysunku poniżej (rys.3) został przedstawiony przykład narzędzia, które po wykonanych ok. 300 sztukach, uległo wykruszeniu.



Rysunek 3. Wizualizacja ok. 300 krzywych obróbki skrawaniem (głębokie wiercenie) – ze znamionami niestabilności procesu

W oparciu o wspólnie prowadzony projekt, mający na celu osiągnięcie zakładanego poziomu żywotności narzędzia na poziomie 1000 sztuk, podjęto działania związane

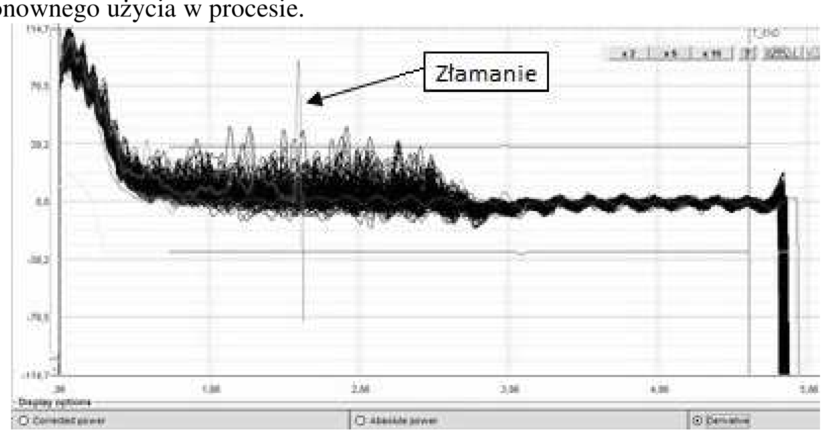
z weryfikacją i modyfikacją geometrii narzędzia w oparciu o zebrane i zwizualizowane dane z przebiegu pracy narzędzi z okresu kilku miesięcy.
Przedstawiony poniżej wykres (rys.4) tego samego procesu skrawania, wykonany na bazie danych z 1000 obróbek jednym narzędziem, jest efektem wypracowanej koncepcji nowej geometrii narzędzia, które wykazało w fazie dalszego użytkowania (testowania), iż zastosowane zmiany odpowiadają wymaganiom klienta oraz osiągają żywotność deklarowaną przez producenta.



Rysunek 4. Wizualizacja 1000 krzywych obróbki (głębokie wiercenie) – proces stabilny

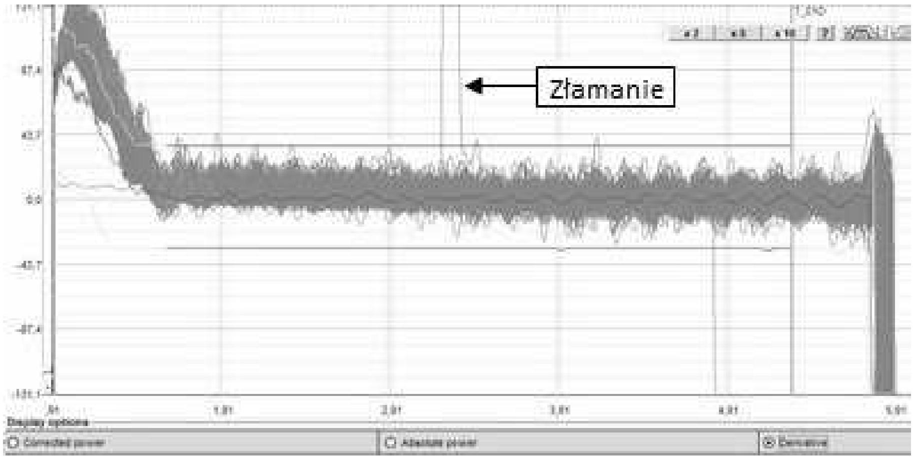
3.2 Wpływ regeneracji na jakość narzędzi

Kolejna analiza jest związana z aspektami ekonomicznymi, tj. poddawanie narzędzi regeneracji. Znacznie bardziej opłacalne (mniej kosztowne) jest zakończenie obróbki danym narzędziem odpowiednio wcześniej, aby nie doprowadzić do jego nadmiernego zużycia, wykruszenia czy złamania (rys.5), w celu jego regeneracji i ponownego użycia w procesie.



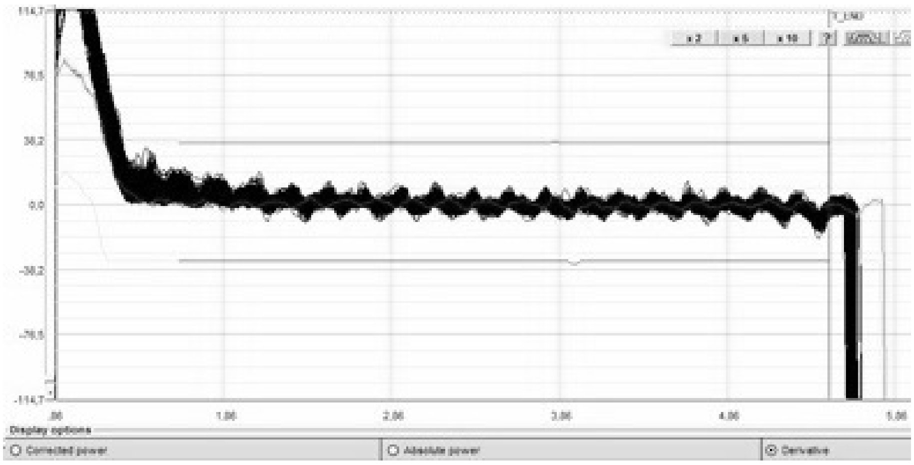
Rysunek 5. Gwintownik regenerowany – syndromy nieprawidłowego ostrzenia, zbyt duża liczba krzywych wychodzących poza założoną górną granicę tolerancji

Koszt regeneracji narzędzia (czyli przywrócenia mu oryginalnej geometrii) często bywa kilkukrotnie niższy, niż koszt nowego narzędzia. Zdarza się jednak i tak, że narzędzia po regeneracji przestają nadawać się do dalszej pracy znacznie wcześniej, niż wstępnie zakładano (rys.6).



Rysunek 6. Gwintownik regenerowany – syndromy nieprawidłowego ostrzenia, mieszczące się w granicach tolerancji

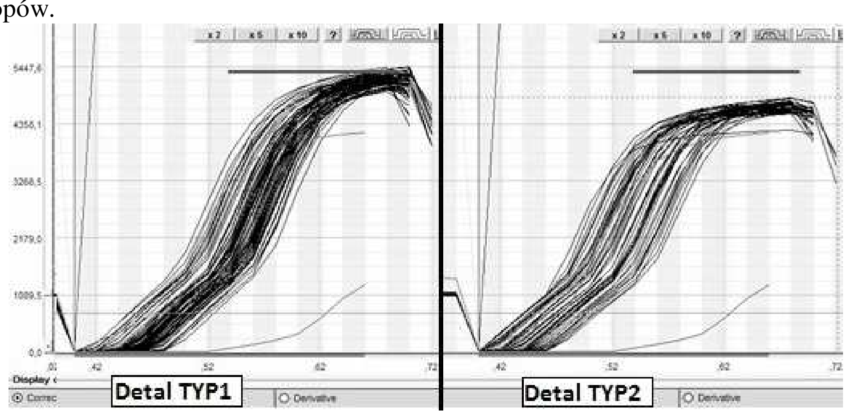
Na podstawie tego przypadku zawężono granice tolerancji, gdyż w efekcie i tak doszło do złamania narzędzia. Rozwiązanie tego typu problemu nie jest proste. Trudność polega na zakończeniu pracy nowego lub regenerowanego narzędzia odpowiednio wcześnie, aby jak najdłużej mogło być poddawane regeneracji oraz by ta miała sens (rys.7) – im zużycie narzędzia jest większe, tym jego regeneracja przyniesie słabszy efekt.



Rysunek 7. Gwintownik nowy – wizualizacja przebiegu optymalnego

3.3. Wpływ struktury materiału na jego obrabialność

W praktyce produkcyjnej często zdarza się, że ze względu na optymalizację charakterystyk wyrobu finalnego, zachodzi konieczność wprowadzenia zmian technologicznych oraz zmian składu materiału obrabianego. Na rysunku 8 przedstawiono obróbkę 2 komponentów wykonanych o różnych twardościach stopów.



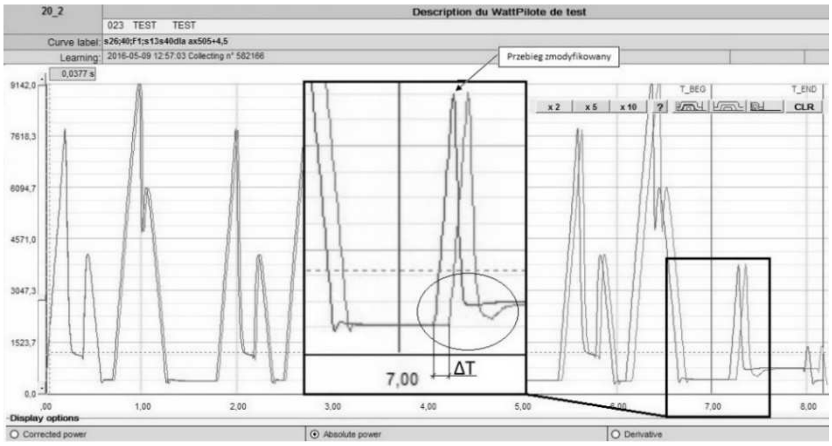
Rysunek 8. Testy obrabialności dwóch detali wykonanych z materiałów o różnym składzie

Na podstawie danych zebranych za pomocą systemu WattPilote stwierdzone zostało, iż detal „typ2" wykonany ze stopu o większej twardości, wykazuje lepsze właściwości obróbcze, przy mniejszym obciążeniu układu maszyna-narzędzie. Pozwala to przypuszczać, że w dłuższej perspektywie czasu, wydłuży się żywotność narzędzia, aczkolwiek proces ten wymaga dalszej obserwacji i analizy.

3.4. Parametryzacja procesu obróbki skrawaniem

Ostatnim przykładem możliwych do przeprowadzenia analiz za pomocą systemu firmy Digital Way są testy parametryzacji procesu obróbki skrawaniem. Polegają one na równoczesnych zmianach parametrów procesu (obroty, posuw), przy jednoczesnej kontroli oporu skrawania, wyrażonych w wartości mocy w zadanym przedziale czasu.

Na rysunku 9 została przedstawiona wizualizacja takiego procesu zmian parametrów. W następstwie przeprowadzonych zmian parametrów procesu gwintowania doszło do optymalizacji globalnego czasu obróbki detalu (ΔT). Tego typu mikroskopowe podejście do procesu obróbki pozwala w racjonalny sposób zarządzać czasem cyklu, w oparciu o dane empiryczne.



Rysunek 9. Gwintowanie - wpływ zmiany parametrów posuwu i obrotów na czas cyklu

4. Podsumowanie

Systematyczne, długofalowe analizy prowadzone dzięki monitorowaniu zużycia narzędzi, ułatwiają podejmowanie decyzji związanych z ich zakupem i parametryzacją. Opisane rozwiązania umożliwiają również prowadzenie badań nad jakością narzędzi oferowanych przez różnych producentów, dzięki czemu może zostać osiągnięty zrównoważony poziom zarządzania w zakresie kosztów własnej gospodarki narzędziowej. Zważywszy na ciągły rozwój w sektorze przemysłu motoryzacyjnego, wszelkie informacje i innowacyjne rozwiązania pozwalające zwiększyć efektywność prowadzonej działalności produkcyjnej, tworzą łańcuch wartości dodanej, znacząco zwiększający szeroko pojętą konkurencyjność przedsiębiorstwa na dynamicznie zmieniającym się rynku globalnym.

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Opiekun naukowy: Jacek RYSIŃSKI[2]

PROJEKT I WYKONANIE HEKSAKOPTERA

Streszczenie: Artykuł zawiera opis przebiegu projektowania drona przy wykorzystaniu oprogramowania Autodest Inventor. Dodatkowo został opisany przebieg badań silnika bezszczotkowego przy współpracy z różnymi śmigłami.

Słowa kluczowe: projekt, dron, model CAD, silnik bezszczotkowy, test

DESIGN AND IMPLEMENTATION OF HEXACOPTER

Summary: The article includes description of the drone design by using Autodesk Inventor software . Additionally includes a description of testing of the brushless motor in cooperation with different propellers.

Keywords: project, drone, CAD model, brushless motor, testing

1. Wstęp

Jeszcze parę lat temu ujęcia z lotu ptaka były zarezerwowane dla nielicznych, majętnych osób. W dzisiejszych czasach można zaobserwować znaczny wzrost zainteresowania bezzałogowymi statkami powietrznymi, powszechnie zwanymi dronami, które są wykorzystywane do przeróżnych celów. Rozwój technologii oraz spadek cen poszczególnych elementów konstrukcji dronów spowodował, że od pewnego czasu każdy amator ma dostęp do szerokiego wachlarza urządzeń zastępujących kosztowne loty helikopterem lub samolotem.
Można by mnożyć podziały dronów ze względu na ich specyfikację czy przeznaczenie. Można wyróżnić drony wojskowe, akrobatyczne, wyścigowe, transportowe. Wyróżnia się także drony typowo filmowe - operatorskie, które charakteryzują się ponadprzeciętną stabilnością lotu i łatwością pilotażu. Rozwój technologii pozwolił także wyróżnić bezzałogowe statki powietrzne wyposażone

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w niezbędne jednostki przetwarzania danych, czujniki, automatyczne sterowanie, systemy łączności, które są zdolne do lotu bez ingerencji człowieka jako pilota.

Ze względu na coraz większe zainteresowanie latającymi maszynami coraz częściej porusza się kwestię bezpieczeństwa. Bezzałogowe statki powietrzne są wbrew obiegowym opiniom bardzo skomplikowanymi urządzeniami, z tego powodu należy zawsze stosować do nich zasadę ograniczonego zaufania i nie przeceniać jej możliwości. Wszystkie bezzałogowe statki powietrzne podlegają prawu ciążenia, które może doprowadzić do katastrofy niezależnie od ceny i zaawansowania technicznego maszyny. Dlatego też należy wszystkie elementy platformy latającej kontrolować przed lotem. Każdy przetarty przewód, wypięta częściowo wtyczka czy niedokręcona śruba zwiększa prawdopodobieństwa niekontrolowanego upadku bez kontroli pilota.

2. Konstrukcja

2.1. Rama

Rama stanowi główny element nośny, na którym umieszczane są pozostałe elementy konstrukcji. Rama zazwyczaj składa się z takich elementów jak:

- Płyta centralna – głównym zadaniem płyty centralnej jest zespolenie ze sobą wszystkich ramion. Na płycie centralnej często umieszcza się także układ sterowania oraz zespół baterii zasilających. Płyta centralna najczęściej złożona jest z dwóch części (górnej oraz dolnej) i wykonywana jest laminatu szklanego lub włókna węglowego. Przy projektowaniu płyty centralnej warto przemyśleć rozstaw otworów montażowych, rozmieszczenie regulatorów, baterii oraz prowadzenie kabli.
- Ramiona – mogą być wykonane z różnych materiałów oraz mogą mieć różne kształty. Montowane są do płyty centralnej na sztywno lub ruchomo, ruchoma konstrukcja pozwala zmniejszyć wymiary modelu w trakcie jego transportu.
- Łoża silników - są instalowane bezpośrednio na ramionach za pomocą śrub, kleju lub za pomocą opasek zaciskowych. Często stosowane są także, tzw. „boom bloki”, dzięki którym można częściowo wytłumić drgania.
- Podwozie – konstruowane jest najczęściej z tego samego materiału co ramiona. Jest stosunkowo ważnym elementem konstrukcji, ponieważ w znacznym stopniu ułatwia osadzenie drona na ziemi.
- Kopułka – stanowi element zabezpieczający elektronikę przed warunkami zewnętrznymi takimi jak słońce, wiatr, trawa, wilgoć czy nawet piasek.
- Półka na baterie – jest to miejsce gdzie montowane są baterie zasilające wszystkie podzespoły elektroniczne.
- Element do montażu kamery lub aparatu.

Dobór odpowiedniej ramy wbrew pozorom nie jest wcale łatwy. Ważnym aspektem konstrukcji jest jej waga i wytrzymałość [1]. Im mniej waży model tym lepsze osiągi można uzyskać, a także pozwala na redukcję kosztów całego modelu. Jako ramiona ramy zostały zastosowane rury z włókna węglowego. Natomiast łoża silników oraz płyta centralna zostały zaprojektowane w oprogramowaniu CAD i wydrukowane w technologii 3D [2].

2.1.1. Klasyfikacja ram

Ze względu na liczbę ramion:

a) Bicopter – dwa silniki,
b) Tricopter – trzy silniki,
c) Quadrocopter – cztery silniki,
d) Hexacopter – sześć silników,
e) Octocopter – osiem silników.

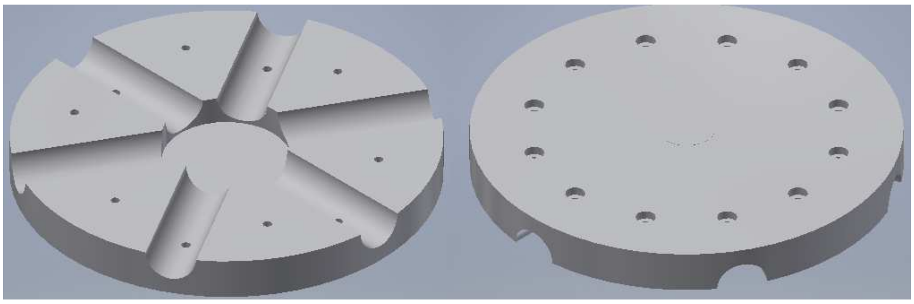
Ze względu na układ śmigieł w stosunku do kierunku lotu:

a) + - jedno śmigło jest wiodące (przy co najmniej 4 śmigłach),
b) X – najczęstsza konstrukcja, dwa śmigła są wiodące (przy parzystej liczbie śmigieł),
c) Y – trzy ramiona ułożone w znak Y, jedno lub dwa ramiona mogą być wiodące,
d) V –bardzo rzadki układ, gdzie dwa śmigła prowadzą na wyciągniętych ramionach,
e) H – bardzo rzadki układ, gdzie konstrukcja opiera się na kształcie litery H, z dwoma śmigłami wiodącymi.

2.1.2. Projekt CAD

<u>Płyta centralna</u>

Płyta centralna została podzielona na dwie części, górną i dolną, obie części płyty są skonstruowane identycznie. Dwie części płyty są ze sobą połączone za pomocą dwunastu śrub M3, z pośród których sześć z nich zabezpiecza ramiona przed obrotem. Ramiona wkładane są w specjalnie przygotowane sloty. W płycie centralnej zostały przewidziane pogłębienia walcowe pozwalające ukryć łby śrub oraz nakrętki.



Rysunek 1. Płyta cenrtalna

<u>Ramiona</u>

Ramiona konstrukcji zostały wykonane z rur z włókna węglowego, zastosowanie takiego materiału pozwoliło na redukcję masy konstrukcji.

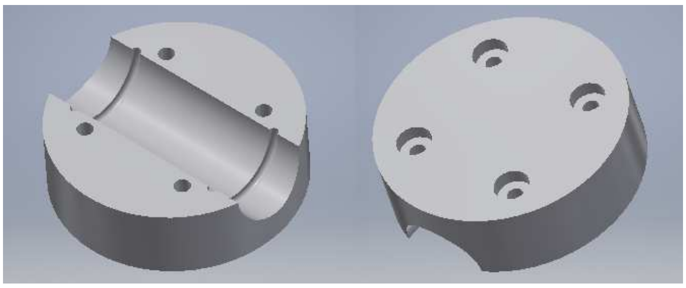
Rysunek 2. Ramie

Na każdym ramieniu został nawiercony otwór, dzięki czemu możliwy jest montaż śruby zabezpieczającej przed obrotem ramienia.

Rysunek 3. Montaż ramion na głównej podstawie.

Łoża silników

Łoże silnika składa się z dwóch identycznych części. Obie części łączone są ze sobą za pomocą czterech śrub M3. W konstrukcji łoża zostały przewidziane pogłębienia walcowe pod łby śrub oraz nakrętki. Zostały przewidziane także wcięcia pod uszczelki umożliwiające stabilniejszy montaż na ramieniu oraz niwelację niedokładności wynikających z technologii wydruku 3D. Rysunek wykonawczy łoża silników został umieszczony w załączniku nr 3.



Rysunek 4. Łoża silników

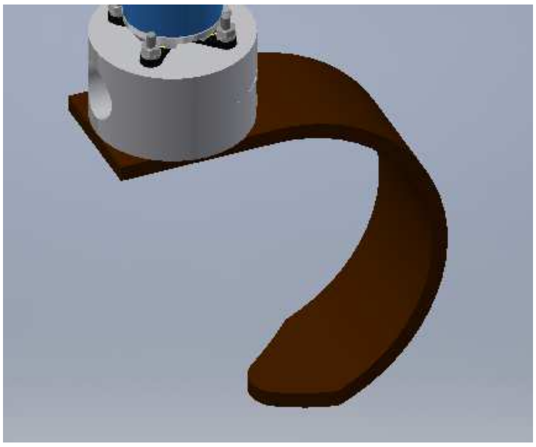
Rysunek 5. Mocowanie silnika na łożu.

<u>Podwozie</u>

Prototypowe podwozie zostało skonstruowane, podobnie jak ramiona, z rur z włókna węglowego. Wszystkie elementy podwozia zostały scalone za pomocą kleju na gorąco oraz taśmy. Takie połączenie miało spowodować szybkie rozłączenie elementów w przypadku ewentualnego upadku i amortyzację uderzenia, dzięki czemu pozostałe ważniejsze elementy konstrukcji miały pozostać nienaruszone. Podwozie to okazało się nieużyteczne, ponieważ rozpadało się pod ciężarem konstrukcji. Kolejne podwozie zostało wykonane z rury PCV. Składało się ono z sześciu elementów, z których każdy zamocowany został do łoża silnika. Podwozie to okazało się lepszym rozwiązaniem, ponieważ w porównaniu z prototypowym rozwiązaniem ułatwiało kontrole drona podczas prób wznoszenia. Nowe rozwiązanie stabilizowało dorna przy starcie oraz znacznie lepiej amortyzowało drona podczas lądowania.

Rysunek 6. Model prototypu podwozia

Rysunek 7. Prototyp podwozia



Rysunek 8. Podwozie

Rysunek 9. Montaż podwozia

2.2. Bezszczotkowy silnik prądu stałego

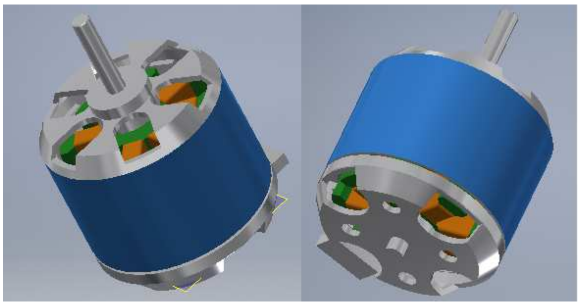
Jako napęd został wykorzystany silnik bezszczotkowy firmy EMAX o oznaczeniu BL2215/20. Silnik ten charakteryzuje się bardzo dobrymi parametrami w stosunku do ceny.

Parametry silnika są następujące:

- liczba zasilających celi - 2-3,
- obroty/volt – 1200,
- maksymalny ciąg – 1200 g,
- maksymalna moc – 309 W,
- zalecana średnica śmigła - 9*10,
- masa silnika – 59 g,
- średnica silnika – 28.5 mm,
- średnica wału – 3 mm,
- maksymalny pobór prądu – 24.5 A.

Rysunek 10. Silnik EMAX BL2215/20 [www.banggood.com]

Każdy z silników wyposażony jest dodatkowo w krzyż mocujący, co w dużym stopniu upraszcza montaż silnika na łożach. Należy okresowo kontrolować śruby mocujące krzyż z silnikiem, ponieważ drgania wywołane przez silnik mogą powodować ich wykręcanie.



Rysunek 11. Model silnika EMAX BL2215/20

2.3. Regulator prędkości ESC

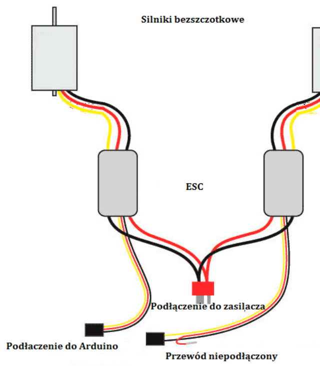
Elektryczne regulatory obrotów dla silników bezszczotkowych to urządzenia regulujące pracę trójfazowych silników elektrycznych. Konwertują sygnał wejściowy odpowiednio zwiększając lub zmniejszając prędkość obrotową silnika. Praktycznie wszystkie nowe regulatory posiadają w sobie mikroprocesory, które dają ogromne możliwości techniczne przy bardzo małych rozmiarach tych elementów.

Rysunek 12. Regulator ESC Redox

Regulatory ESC przed użyciem należy zaprogramować. Regulator Redox umożliwia zaprogramowanie m.in. następujących funkcji :

- Hamulec: Włączony/Wyłączony,
- Sposób odcięcia przy niskim napięciu,
- Kąt wyprzedzenia,
- Krzywa startu,
- Kierunek pracy silnika.

Regulator ESC jest sterowany za pomocą sygnału PPM (Pusle Position Modeulation) czyli sygnału modulującego oddziałującego na fazę impulsu, tj. na jego położenie w czasie. Wszystkie regulatory elektroniczne działają na podobnej zasadzie. Otóż układy logiczne (sterujące), generują impulsy o odpowiedniej częstotliwości. Przerwy między impulsami przeważnie są stałe. W zależności od położenia impulsów w czasie silnik zwalnia lub przyśpiesza.
Podłączenie regulatorów:



Rysunek 13. Schemat podłączenia silników z regulatorami

2.4. Śmigła

Oznaczenia kierunków obrotu zostały przyjęte już na początku historii lotnictwa, wtedy nie istniały jeszcze śmigłowce ani wielowirnikowce. Ustalono wówczas zasadę opisywania wszystkich części samolotu z pozycji pilota znajdującego się wewnątrz kabiny samolotu. Śmigło prawe (R, Regular lub ciągnące) kręci się w prawo (zgodnie z kierunkiem ruchu wskazówek zegara) patrząc z pozycji pilota, natomiast w lewo patrząc od przodu samolotu. Śmigła lewe pojawiły się razem z maszynami wielowirnikowymi, zostały skonstruowane aby skompensować działanie sił odśmigłowych. Maszyny wielowirnikowe wyposażone w śmigła obracające się w różne strony były stabilniejsze podczas lotu. Śmigła lewe (P, Pusher, Pchające), czyli prawe patrząc z przodu samolotu.

Powyższe oznaczenia wprowadzają jednak pewne problemy dla konstruktorów bezzałogowych maszyn wielowirnikowych, ponieważ w przypadku tych maszyn nie wyróżnia się kabiny pilota. Powstał wówczas nowy nurt oznaczania śmigieł, który mówi aby oznaczać kierunki obrotu śmigieł patrząc od góry modelu. Wówczas śmigło lewe stało się prawym CW (Clockwise – zgodnie z wskazówkami zegara) a śmigło prawe stało się lewym CCW (CounterClockwise – przeciwnie do wskazówek zegara)

Podsumowując:

Śmigło normalnie prawe

- dla modelarza lotniczego – R, Regular lub ciągnące,
- dla pilota dronów – oznaczenie CCW (jest to śmigło lewe).

Śmigło normalnie lewe

- dla modelarza lotniczego – P, Pusher, Pchające,
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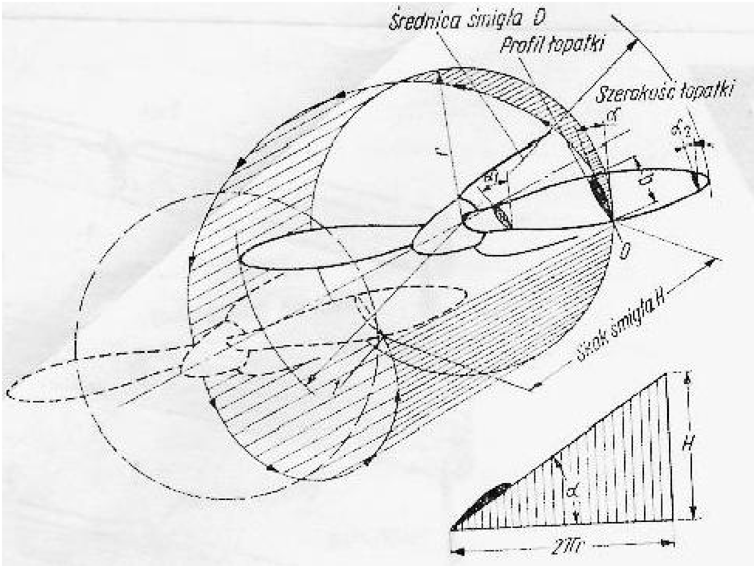
Geometria śmigła

Geometria śmigła wpływa na jego parametry pracy. Każde ze śmigieł posiada dwa główne parametry:

- Średnica śmigła D – jest to średnica okręgu jakie zataczają końce łopat śmigła.
- Skok śmigła H – jest to odległość jaką pokonałoby śmigło gdyby mogło się wkręcać w powietrze jak śruba w nakrętkę. Skok rzeczywisty śmigła zależy od stosunku prędkości lotu do prędkości obrotowej śmigła. W momencie, gdy nie ma ciągu śmigła, bo jest bardzo duża prędkość (np. nurkowanie) albo nie ma posuwu, bo napęd stoi w miejscu (np. początek startu), nie ma dużej sprawności śmigła, bo przy starcie powinno mieć mały kąt natarcia zaś w miarę nabierania prędkości, powinien się on zwiększać, żeby siedział w „gwincie”. Dlatego też śmigło o stałym skoku osiąga maksimum sprawności przy określonej prędkości lotu, tzn. jest sprawne w wąskim przedziale prędkości. [3]



Rysunek 14. Geometria śmigła [abc-rc.pl]

Średnica i skok śmigła tworzą tzw. cechę śmigła. Jeżeli śmigło posiada cechę 8x4, oznacza to, że ma średnicę 8 cali i skok 4 cale.

2.5. Akumulator

Akumulator Li-Po (zwany również lipolem czy pakietem) to litowo-polimerowy rodzaj akumulatora z wypełnieniem stałymi polimerami (w zabezpieczeniu przed wyciekiem). Pakiety stosowane do zasilania wielowirnikowców charakteryzuje bardzo duża pojemność i wydajność prądowa. Składają się one z cel o napięciu znamionowym 3,7V/cela. Maksymalne napięcie celi (w pełni naładowany pakiet) to 4.2V, a maksymalne dopuszczalne rozładowanie celi to 3.3V.

Terminologia:

- Ogniwo to pojedynczy akumulatorek, posiadający dwa wyprowadzenia. Popularną nazwą ogniwa jest cela od angielskiego „cell" (ogniwo).
- Pakiet jest to akumulator, który składa się z co najmniej dwóch ogniw. Najczęściej spotykane są akumulatory 2- lub 3-ogniwowe, choć można znaleźć także nawet 10-ogniwowe. Pakiety często wyposażone są w dwie wtyczki, jedna to wtyczka główna służąca do podłączenia urządzeń, a druga dodatkowa to wtyczka balansera, która zawiera wyprowadzenia wszystkich ogniw.
- liczba ogniw – oznaczana literą S (w przypadku szeregowo połączenia ogniw) bądź P (w przypadku równoległego połączenia ogniw). Przykład:
  3S – pakiet złożony z trzech cel połączonych szeregowo,
  1S – pojedyncze ogniwo,
  2S2P – pakiet złożony z 2 ogniw połączonych szeregowo i dwóch ogniw połączonych równolegle.

- Wydajność prądowa – oznaczana jest literą C. Określa maksymalne natężenia prądu, który można pobierać z akumulatora. Wydajność prądowa nie jest podawana w amperach. Jest to parametr, który pozwala wyznaczyć wydajność pakietu w amperach. Typowe wartości to 10C, 15C, 20C itd. (wielokrotności 5).
- Maksymalny prąd ładowania – oznaczany jest literą C. Informuje nas o maksymalnym prądzie, jakim można ładować akumulator. Przekroczenie tej wartości może uszkodzić ogniwa. Zazwyczaj jest to 1C, 2C.
- Pojemność – podawana w mAh (miliamperogodzinach), jest to wartość, która określa przez jaki czas można pobierać prąd o danym natężeniu.

Wyznaczanie napięć pakietu:
- napięcie znamionowe pakietu to 3S x 3.7V = 11.1V,
- napięcie maksymalne to 3 x 4.2V = 12.6V,
- minimalne dopuszczalne napięcie to 3 x 3.3V = 9.9V.

Wydajność prądowa pakietów:
Akumulatory Li-Po znane są dużej wydajności prądowej. Przy zakupie akumulatora nie można jednak założyć, że dany akumulator sprawdzi się w naszych warunkach. Wydajność akumulatora trzeba dobierać indywidualnie dla każdego przypadku, co pozwala na obniżenie kosztów, ceny, wagi oraz na bezpieczną pracę pakietu i zasilanego urządzenia.

Przykład:

Pakiet nr 1: 3000mAh 4S 20C

$$I_p = C_p \cdot x = 3Ah \cdot 20C = 60A \quad (1)$$

Pakiet nr 2: 5000mAh 3S 30C

$$I_p = C_p \cdot x = 5Ah \cdot 30C = 150A \quad (2)$$

Pakiet nr 3: 4000mah 4S 30C

$$I_p = C_p \cdot x = 4Ah \cdot 30C = 120A \quad (3)$$

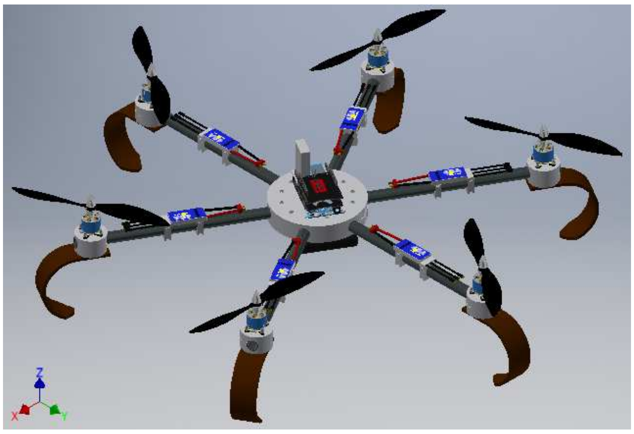
Przy doborze akumulatora do wielowirnikowca, bierze się pod uwagę jego wydajność prądową (zawsze musi być większa o minimum 20% od maksymalnego poboru prądu wielowirnikowca) oraz liczbę cel (liczba cel nie może być większa niż zalecana przez producenta silników i regulatorów ESC). [4]

3. Zestawienie części

Tabela 1. Spis elementów

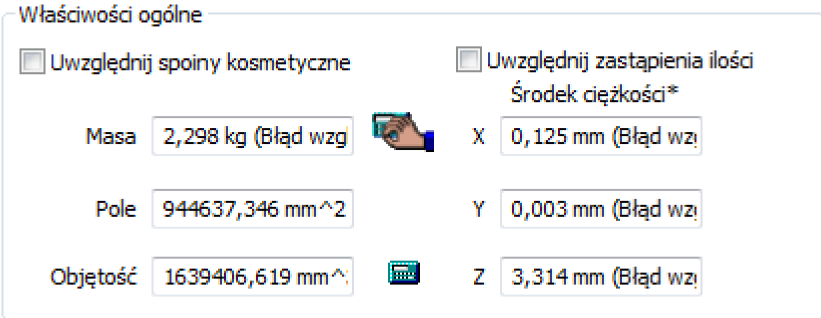
Lp.	Nazwa	Waga [g]	Liczba [szt.]	Waga całkowita [g]
1	Płyta centralna	240	1	240
2	Łoże silnika	26	6	156
3	Ramie	29	6	174

4	Podwozie	8	6	48
5	Regulator	39	6	234
6	Śmigło	16	6	96
7	Piasta	4	6	24
8	Bateria	330	2	660
9	Silnik	65	6	390
10	Układ Razor IMU	13	1	13
11	Podstawa pod układ Razor IMU	15	1	15
12	GPS	13	1	13
13	Podstawa pod GPS i odbiornik	8	1	8
14	Czytnik kart	15	1	15
15	Arduino Due	36	1	36
16	Odbiornik RC	25	1	25
17	Kopułka	25	1	25
18	Śruba M3 + nakrętka + podkładka	3,5	36	126
			SUMA	2298 g



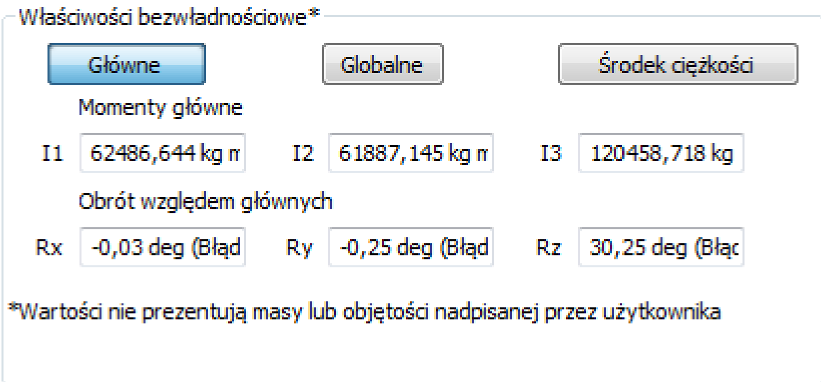
Rysunek 15. Model CAD drona

Autodesk Inventor automatycznie wylicza podstawowe parametry konstrukcji. Poniżej przedstawione są właściwości ogólne konstrukcji oraz masowe momenty bezwładności. W oknie Właściwości ogólne możemy sprawdzić masę konstrukcji oraz położenie jej środka ciężkości. Masa modelu oraz obiektu rzeczywistego może się nieco różnić, ponieważ model nie zawiera prowadzenia przewodów. Jak widzimy środek ciężkości nie leży w puncie zerowym na osi x i y, wynika to z nierównomiernego rozmieszczenia zespołu sterującego. Rzeczywisty środek ciężkości może znajdować się w innym miejscu, ponieważ będzie uwzględniał prowadzenie przewodów oraz odchyłki związane z montażem poszczególnych podzespołów.



Rysunek 16. Właściwości ogólne konstrukcji

Okno właściwości bezwładnościowych umożliwia sprawdzenie głównych momentów bezwładnościowych, które wykorzystywane są przez regulator LQR.



Rysunek 17. Właściwości bezwładnościowe konstrukcji

4. Badania paramentów pracy silnika

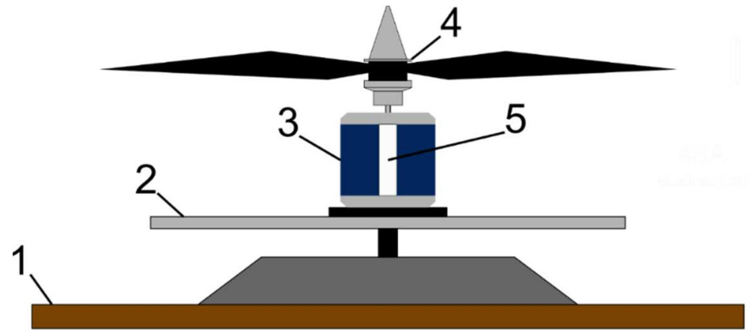
Badania parametrów pracy silnika zostały przeprowadzone przy wykorzystaniu silnika EMAX BL2215/20 oraz czterech różnych śmigieł:

- śmigała 10x4.5 (producent nieznany),
- śmigła 10x6 (producent APC),
- śmigła 10x5 (producent APC),
- śmigła 9x6 (producent APC).

Śmigła 10x4.5, które wykorzystywane są w konstrukcji drona nie posiadają oznaczenia producenta, natomiast pozostałe trzy śmigła są wyprodukowane przez tego samego. Celem badania jest wyznaczanie, z którym rodzajem śmigieł wybrany silnik będzie wykazywał najlepsze właściwości.
Wszystkie badania zostały przeprowadzone na tym samym silniku, przy wykorzystaniu tego samego akumulatora oraz w tych samych warunkach.

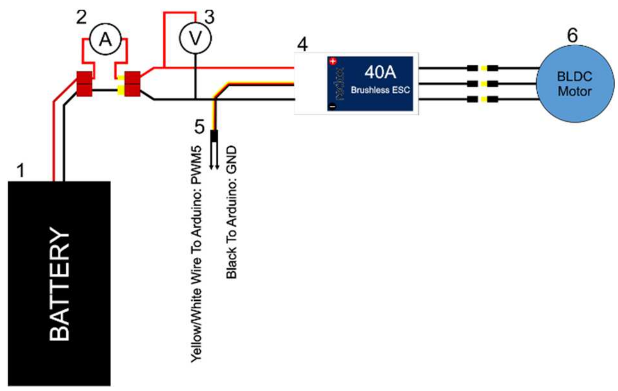
4.1. Stanowisko pomiarowe

Stanowisko pomiarowe zostało zbudowane wykorzystując wagę elektroniczną, z której został wykręcony stół pomiarowy. W miejsce starego szklanego stołu pomiarowego został wkręcony nowy, specjalnie przygotowany drewniany stół, do którego w prosty sposób można było zamocować silnik za pomocą wkrętów oraz krzyża mocującego. Po wymianie stołu pomiarowego należało wycechować wagę, do tego celu użyto odważnika o masie 500g. Czynność została powtórzona kilkukrotnie, dzięki czemu została sprawdzona powtarzalność pomiaru. Cechowanie wagi wykazało, że wymiana stołu pomiarowego nie miała wpływu na pomiar. Śmigło napędzane przez silnik wytwarzało siłę ciągu, której wartość można było obserwować na wyświetlaczu wagi. Na silnik został naklejony odblaskowy pasek, dzięki któremu możliwy był pomiar prędkości obrotowej silnika za pomocą tachometru laserowego DT-2234C. Pomiar temperatury regulatora prędkości oraz temperatury silnika wykonywany był za pomocą bezdotykowego termometru Microlife NC150.



Rysunek 18. Schemat stanowiska pomiarowego. 1-podstawa, 2- waga, 3- silnik BL2520, 4- śmigło z piastą, 5- odblaskowy pasek do pomiaru prędkości

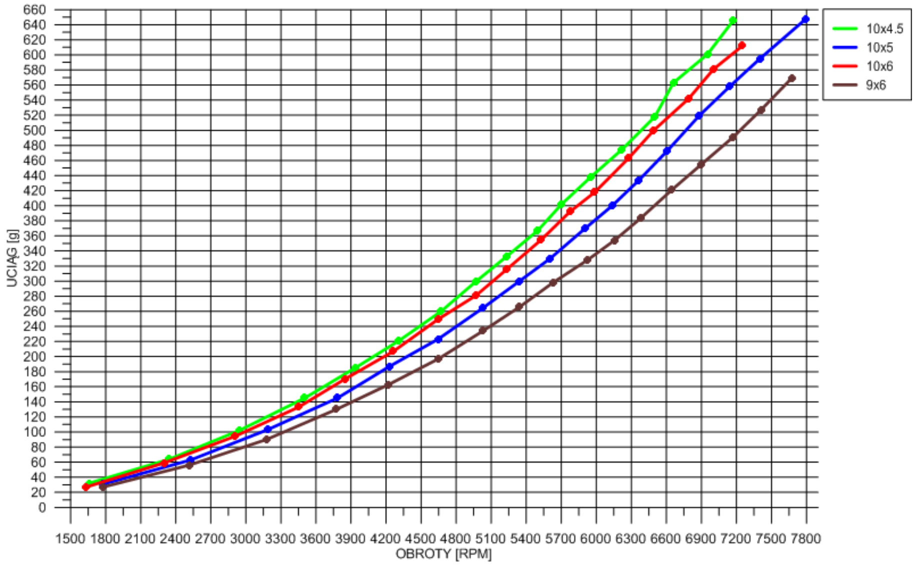
W czasie pomiarów rejestrowane było także napięcie na akumulatorze oraz prąd jaki pobierany jest przez silnik, aby możliwy był pomiar obu wspomnianych wielkości układ pomiarowy należało połączyć zgodnie ze schematem na rysunku 19.



Rysunek 19. Schemat połączenia. 1- bateria 3300 mAh, 2- amperomierz, 3- woltomierz, 4- regulator ESC, silnik BL2520, złącze BEC regulatora

4.2. Analiza wykonanych pomiarów

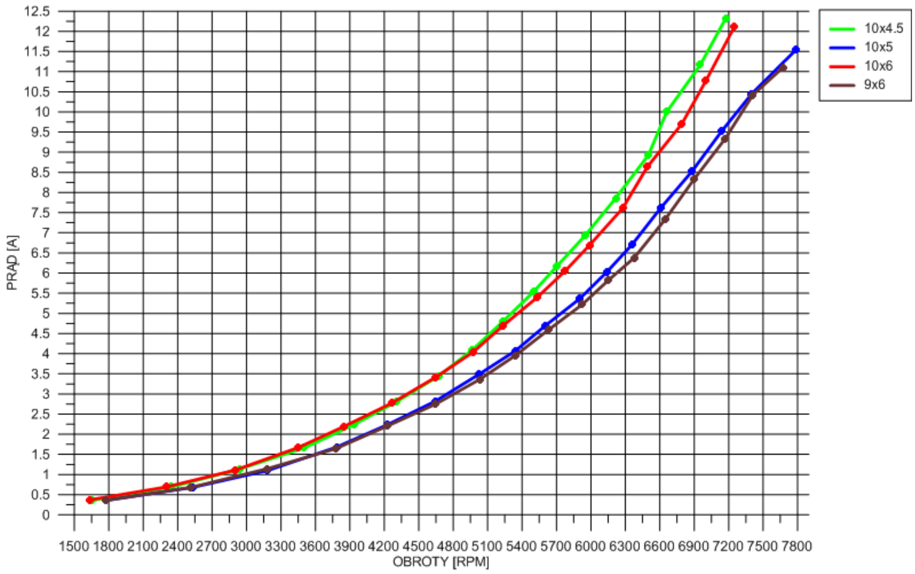
Rysunek 20 przedstawia zależność uciągu od prędkości obrotowej dla czterech różnych śmigieł, natomiast na rysunku 21 została przedstawiona zależność poboru prądu od prędkości obrotowej.



Rysunek 20. Zależność uciągu śmigieł od prędkości obrotowej

Na podstawie poniższych wykresów można wstępie zdecydować jakie śmigło najbardziej nadaję się do współpracy z zastosowanym silnikiem. Jak można zauważyć śmigło 10x4.5 osiąga większy uciąg przy niskich prędkościach, niewiele mniejszy uciąg wykazuje śmigło 10x6, następnie 10x5 i na końcu śmigło 9x6. Na pierwszy rzut oka wydaję się że najlepiej zastosować śmigło 10x4.5, ponieważ przy niskich prędkościach generuje większy uciąg niż pozostałe śmigła, lecz należy także przeanalizować przebieg pobory prądu w odniesieniu do prędkości obrotowej.

Jak można zauważyć na rysunku 21 silnik wyposażony w śmigło 10x4.5 pobiera najwięcej prądu podczas pracy, lecz wartość poboru prądu jest bardzo podobna jak przy zastosowaniu śmigła 10x6 (dla prędkości obrotowej do 5000 obr/min można przyjąć, że pobór prądu jest identyczny). Silnik wyposażony w śmigła 10x5 lub 10x6 pobiera mniej prądu, co potwierdza, że im większa siła ciągu tym większy pobór prądu. Aby właściwie sklasyfikować śmigła należy porównać ich prędkość obrotową i pobór prądu silnika przy określonym uciągu.



Rysunek 21. Zależność poboru prądu od prędkości obrotowej

Waga rzeczywistego obiektu bez dodatkowego oprzyrządowania wynosi ponad 2,4 kg, dlatego aby dron mógł się wznieść każdy z silników powinien wygenerować co najmniej 400G.

Tabela 2. Prędkość obrotowa i pobór prądu silnika przy uciągu 400G

Śmigło	Prędkość obrotowa [obr/min]	Prąd [A]
10x4.5	ok. 5700	ok. 6,21
10x6	ok. 5850	ok. 6,24
10x5	ok. 6150	ok. 6,00
9x6	ok. 6500	ok. 6,75

Tabela 3. Prędkość obrotowa i pobór prądu silnika przy uciągu 450G

Śmigło	Prędkość obrotowa [obr/min]	Prąd [A]
10x4.5	ok. 6170	ok. 7,75
10x6	ok. 6300	ok. 7,75
10x5	ok. 6600	ok. 7,70
9x6	ok. 7030	ok. 8,80

Tabela 4. Prędkość obrotowa i pobór prądu silnika przy uciągu 500G.

Śmigło	Prędkość obrotowa [obr/min]	Prąd [A]
10x4.5	ok. 6370	ok. 8,50
10x6	ok. 6470	ok. 8,75
10x5	ok. 6750	ok. 8,25
9x6	ok. 7210	ok. 9,75

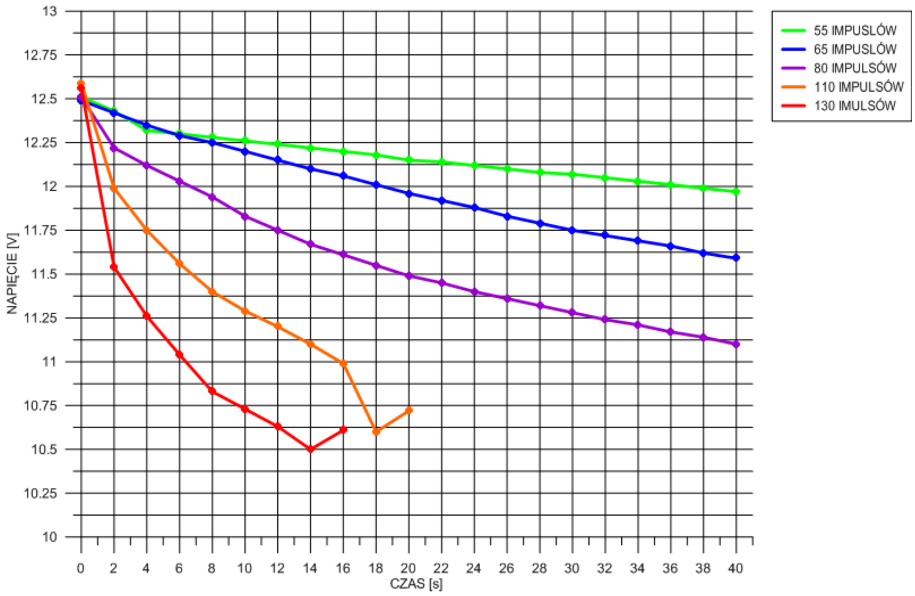
Jak widać z powyższych tabel pobór prądu przy zastosowaniu śmigieł 10x4.5, 10x6 oraz 10x5 dla różnych uciągów plasuje się na podobnym poziomie. Śmigło 9x6 w tej klasyfikacji wypada najgorzej, z pośród pozostałych trzech śmigieł nieznacznie lepiej wypada śmigło 10x5.

Podczas doboru śmigła należy także zwrócić uwagę na prędkość obrotową śmigła oraz jego skok. Skok śmigła jest to odległość jaką pokonałoby śmigło podczas jednego obrotu jakby umiało się „wkręcić" w powietrze. Na tej podstawie wiemy, że dla określonej prędkości obrotowej silnika stosują śmigło o skoku 6 będziemy osiągali większe prędkości drona, niż w przypadku zastosowania śmigła o skoku 4.5. Podczas konstruowania należy podjąć decyzję jakie prędkości chcemy osiągać podczas lotu, dla modeli wyścigowych zaleca się stosowanie śmigieł o dużych skokach, natomiast np. dla testowych modeli warto zastosować śmigła o mniejszym skoku.

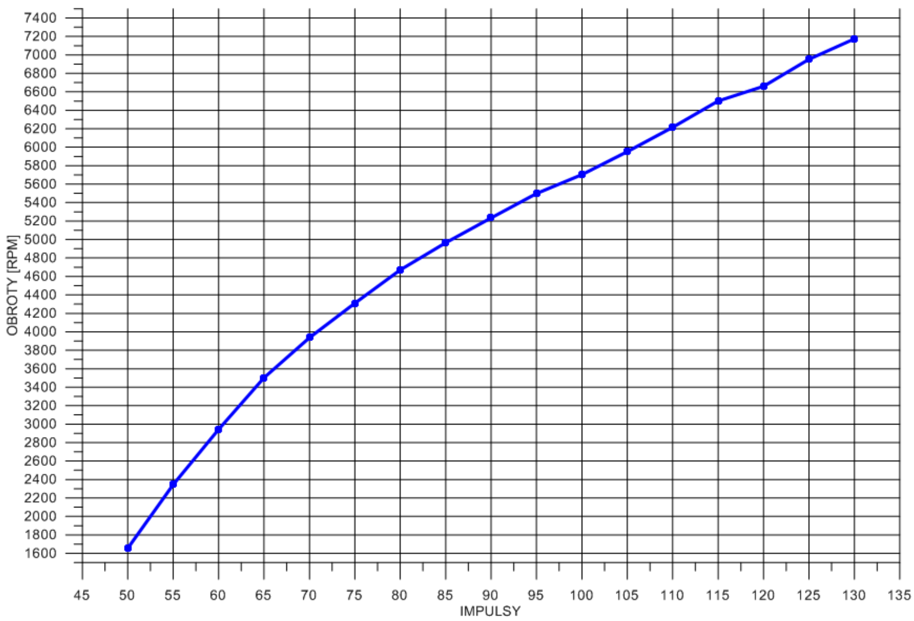
Podczas konstruowania drona zostało wybrane śmigło 10x4.5, dla którego zostały przeprowadzone rozszerzone badania. Na rysunkach poniżej zostało przedstawione napięcie, prąd oraz uciąg w funkcji czasu.

Na rysunku 22 zostało przedstawione napięcie na akumulatorze w funkcji czasu dla różnej liczby impulsów sterujących. Jak widać im większa liczba impulsów sterujących tym szybciej następuje rozładowanie akumulatora. Dla 110 i 130 impulsów na końcach przebiegów można zauważyć nagły wzrost napięcia, co jest spowodowane wykryciem przez regulator napięcia niższego od bezpiecznego poziomu. Po spadku napięcia poniżej bezpiecznego poziomu regulator obniża prędkość obrotową silnika i blokuje możliwość jej zwiększenia. Z rysunku 20 wynika, że aby można było sterować dronem pojedynczy silnik musi osiągać prędkość obrotową powyżej 5700 RPM, ponieważ powyżej tej prędkości zostanie wygenerowana siła pozwalająca unieść drona.

Z rysunku 23 wynika, że w celu wygenerowania takiej siły należy zadawać powyżej 100 impulsów, można przyjąć średnie sterowanie na poziomie 110 impulsów. Analizując wykres przebiegu napięcia na akumulatorze w funkcji czasu widzimy, że pojedynczy silnik działający na pojedynczym akumulatorze rozładuje się po ok. 18 minutach. Wykorzystując powyższe informacje możemy wyliczyć, że dron wyposażony w 6 silników zasilanych dwoma akumulatorami przy średnim sterowaniu na poziomie 110 impulsów będzie wstanie latać maksymalnie 6 minut.

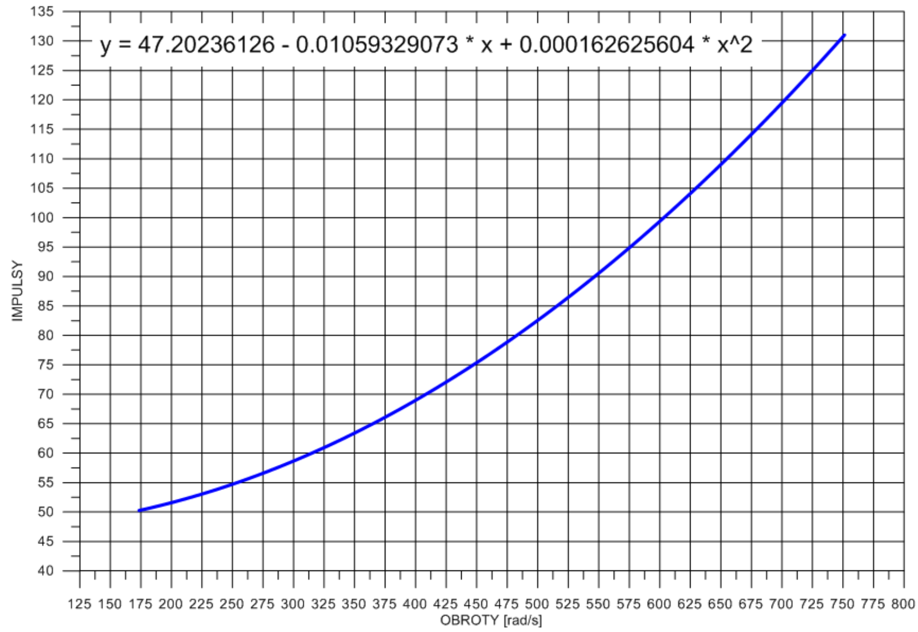


Rysunek 22. Napięcie na akumulatorze w funkcji czasu



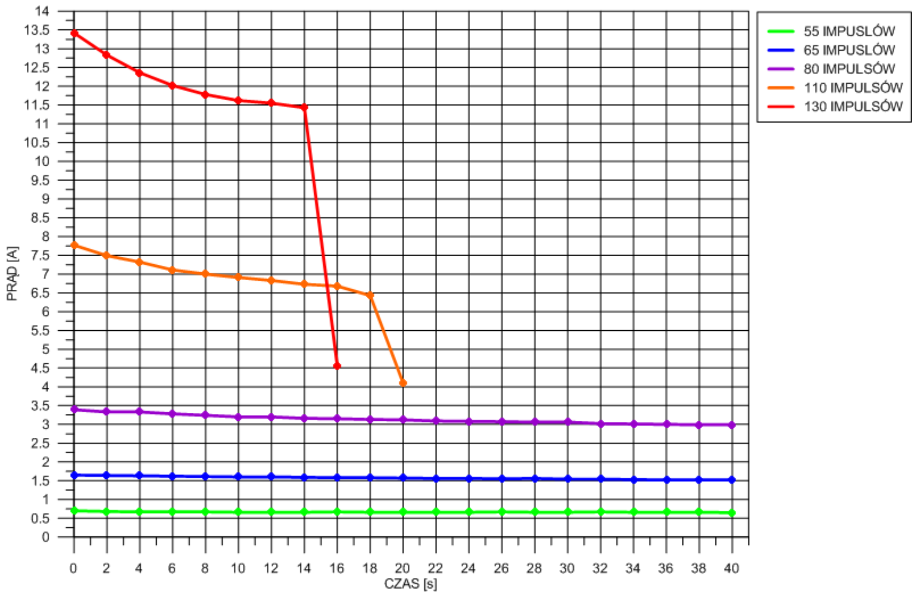
Rysunek 23. Zależność prędkości obrotowej od zadawanych impulsów

Aby zależność przedstawiona na rysunku 23 mogła być wykorzystywana przez regulator LQR należy ją przedstawić jako zależność impulsów od prędkości obrotowej, przy czym prędkość obrotowa musi być wyrażona w rad/s. Regulator LQR na podstawie zebranych informacji analizuje z jakimi prędkościami powinny obracać się silniki, następnie korzystając z wyznaczonej funkcji dobiera wartość impulsów sterujących. Zależność impulsów sterujących od prędkości obrotowej oraz wzór wyznaczonej funkcji zostały przedstawione na rysunku 24.



Rysunek 24. Zależność liczby impulsów sterujących od prędkości obrotowej

Wszystkie pomiary zostały wykonane praktycznie w tych samych warunkach, rzeczywiste przebiegi wszystkich parametrów dla obiektu rzeczywistego mogą się różnić. W rzeczywistości każdy z silników w trakcie lotu może być obciążony w różnym stopniu, obciążenie to może zależeć m.in. od warunków atmosferycznych (wiatr), od nierównomiernego rozłożenia komponentów konstrukcji, czy też rodzaju lotu (lot szybki, lot wolny, nagłe ruchy, zawis w powietrzu). Powyższe badanie pokazują, że niezależnie od warunków w trakcie lotu należy obserwować wszystkie parametry silnika i regulatora, tak aby w jak największym stopniu wyeliminować uszkodzenia podzespołów.



Rysunek 25. Pobór prądu w funkcji czasu

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WALIDACJA DOŚWIADCZALNA MODELU MES KOMPOZYTU WARSTWOWEGO WZMOCNIONEGO TKANINĄ

Streszczenie: W artykule przedstawiono modele dyskretne płaskich próbek kompozytu warstwowego wzmocnionego tkaniną z włókien węglowych opracowane w środowisku MES. Modele uwzględniają strukturę wewnętrzną kompozytu na poziomie jego komponentów, tj. tasiemek tkaniny wzmocnienia oraz osnowy i pozwalają na symulowanie zniszczenia polegającego na rozwarstwieniu. Wyniki symulacji numerycznych zweryfikowano eksperymentalnie w testach zginania trójpunktowego i czteropunktowego.

Słowa kluczowe: kompozyt warstwowy, model MES, struktura wewnętrzna, testy zginania

EXPERIMENTAL VALIDATION OF A FINITE ELEMENT MODEL OF A WOVEN FIBER-REINFORCED COMPOS

Summary: In this paper, the finite element models of flat specimens of the woven carbon laminate composite were presented. The models take into account the internal structure of the composite at the level of its components: filament tows and resin and models can be used to simulate delamination of the composite. The results of numerical simulations were compared with the results of experiments in which the composite specimens were deformed in the three point and four point flexural tests.

Keywords: composite laminate, FEM model, internal structure, flexural tests

1. Wprowadzenie

Materiały kompozytowe z uwagi na dużą wytrzymałość mechaniczną, mały ciężar własny i odporność na korozję znajdują coraz szersze zastosowanie w różnych konstrukcjach. Szczególnym rodzajem kompozytów są laminaty, w których wzmocnieniem są warstwy tkaniny układane jedna na drugiej. Laminaty wzmocnione tkaniną z włókna węglowego wykorzystywane są np. w produkcji łopat elektrowni

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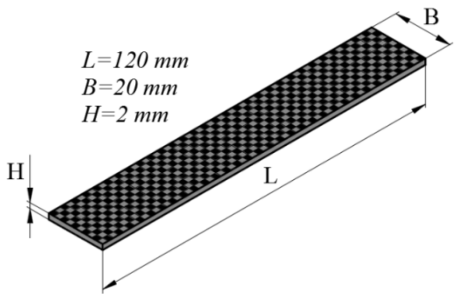
wiatrowych, w przemyśle lotniczym na kadłuby i skrzydła, w produkcji jachtów i samochodów oraz w wielu innych zastosowaniach. Dynamiczny rozwój materiałów kompozytowych determinuje konieczność nie tylko doskonalenia metod ich wytwarzania ale również technik obliczeniowych. W metodzie elementów skończonych modelowanie kompozytów warstwowych zwykle sprowadza się do zastosowania elementów powierzchniowych lub bryłowych, którym przypisuje się warstwową budowę tworząc zastępczy element skończony typu kanapkowego (*sandwich element*) [6]. Każdej warstwie przypisuje się grubość, orientację ułożenia wzmocnienia i stałe materiałowe. W ten sposób można modelować kompozyty jednokierunkowe, zbrojone dwukierunkowo (ortogonalne) lub anizotropowe. Tego typu modele w rzeczywistości są jednofazowe. Zastępcze charakterystyki materiałowe jednofazowego modelu kompozytu otrzymuje się w standardowych testach rozciągania lub zginania. Stałe inżynierskie określa się nie wnikając w to, jaka jest struktura wewnętrzna kompozytu.

Modele MES kompozytu uwzględniające strukturę wzmocnienia w postaci tkaniny z tasiemek (*rovingu*) z włókien są również tworzone z elementów bryłowych, tak aby odwzorować odrębność faz wzmocnienia i osnowy oraz charakter przeplotu tasiemek w tkaninie [4]. Wymaga to jednak dokładnego przygotowania sparametryzowanego przestrzennego modelu geometrycznego kompozytu i prowadzi do modelu MES o bardzo dużej liczbie stopni swobody (*mikroskalowego modelu MES*), który okazuje się nieprzydatny w obliczeniach inżynierskich rzeczywistych konstrukcji kompozytowych.

W niniejszej pracy zaproponowano model MES kompozytu warstwowego o średniej skali złożoności (*mezoskalowy model MES*), który w uproszczony sposób odwzorowuje strukturę wzmocnienia i niejednorodność faz komponentów. Model zachowuje przy tym udziały objętościowe komponentów w kompozycie i jest zadowalająco efektywny numeryczne w obliczeniach inżynierskich.

2. Próbka badanego kompozytu

Kompozyt to materiał, który powstaje w wyniku trwałego połączenia co najmniej dwóch komponentów o różnych właściwościach mechanicznych z zachowaniem wyraźnej granicy rozdziału. Te komponenty to osnowa (matryca), która nadaje odpowiednią spójność, elastyczność i twardość oraz komponent konstrukcyjny (wzmocnienie) zapewniający pożądane właściwości mechaniczne. Na potrzeby niniejszej pracy wykonano płytę kompozytową z ośmiu warstw tkaniny o splocie płóciennym z tasiemek z włókna węglowego i żywicy epoksydowej. W tym celu wykorzystano foremnik, w którym podczas laminowania układano kolejne warstwy tkaniny w specjalnej ramce. Warstwy podczas laminowania dociskano sztywną pokrywą ramki, usuwając w ten sposób nadmiar żywicy i powietrza, przez co przestrzeń między poszczególnymi włóknami tasiemek uległa wypełnieniu. Z przygotowanej płyty kompozytowej zostały następnie wycięte próbki o wymiarach $120\times20\times2\ mm$ (rys.1).



Rysunek 1. Wymiary próbek kompozytu warstwowego

Udziały objętościowe komponentów określono na podstawie analizy wagowej próbek i tkaniny węglowej. Według kart technologicznych producentów gęstość zastosowanej tkaniny węglowej wynosi *1,78 g/cm³*, a żywicy epoksydowej *1,17 g/cm³*. Analiza wagowa dziesięciu próbek wykazała, że tkanina stanowi *58,5±0,6 %* masy kompozytu. Następnie również na podstawie kart technologicznych komponentów przyjęto ich stałe materiałowe tj. moduł sprężystości podłużnej *E* oraz współczynnik Poissona *v* oraz inne niezbędne w obliczeniach parametry tj. pole przekroju poprzecznego tasiemek S_t, wytrzymałość na rozciąganie *Rm* i wydłużenie przy zerwaniu *A%* dla żywicy epoksydowej. Wartości liczbowe tych stałych i parametrów podano w tabelach 1 i 2.

Tabela 1. Parametry tasiemek z włókna węglowego

Moduł sprężystości podłużnej ***E*, *GPa***	**Współczynnik Poissona *v*,** —	**Pole przekroju poprzecznego** S_t, mm²
105	0,1	0,12

Tabela 2. Parametry żywicy epoksydowej

Moduł sprężystości podłużnej ***E*, *GPa***	**Współczynnik Poissona *v*,** —	**Wytrzymałość na rozciąganie,** ***Rm*, *MPa***	**Wydłużenie przy zerwaniu,** ***A%***
3,4	0,35	84	5,4

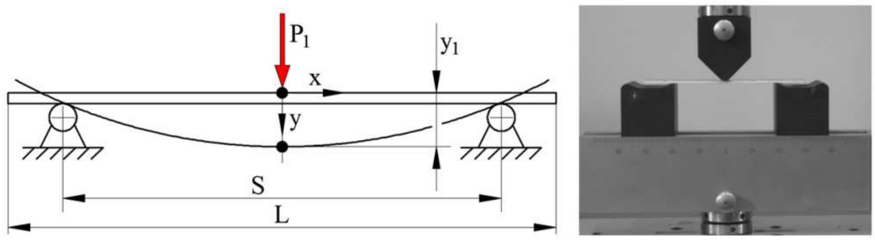
3. Badania doświadczalne płaskich próbek kompozytu warstwowego

W praktyce inżynierskiej podstawową metodą sprawdzenia poprawności modelu obliczeniowego jest eksperymentalna ocena zgodności wyników symulacji z badaniami doświadczalnymi. Z uwagi na to, iż konstrukcje kompozytowe najczęściej są konstrukcjami cienkościennymi obciążonymi zginaniem, przeprowadzono badania doświadczalne polegające na zginaniu płaskich próbek kompozytu. Warunki przeprowadzania doświadczalnego zginania trójpunktowego i czteropunktowego materiałów kompozytowych opisuje norma ASTM D7264 [1].

Została również opracowana norma ASTM D6272 [2], która zawiera wytyczne dla zginania czteropunktowego. Ta problematyka została także całościowo opracowana w podręcznikach, np. [3]. Na potrzeby badań wykorzystano pięć próbek o wymiarach jak na rys.1, które wykonano w opisany wcześniej sposób (każda składała się z ośmiu warstw tkaniny z tasiemek o splocie płóciennym i żywicy epoksydowej). Wszystkie próby zginania zostały zrealizowane na uniwersalnej maszynie wytrzymałościowej *Inspekt Table Blue 5*. W przypadku zginania trójpunktowego jak i czteropunktowego zaleca się aby stosunek rozstawu podpór do grubości próbek kompozytu wynosił 16:1, 20:1, 32:1, 40:1 lub 60:1. Wykorzystując oprogramowanie maszyny wytrzymałościowej zdefiniowano warunek zatrzymania trawersy maszyny podczas realizacji próby tak aby zatrzymanie próby następowało w chwili, gdy obciążenie działające na próbkę osiągnie wartość *200 N* dla zginania trójpunktowego i *400 N* dla czteropunktowego. Wtedy boczne powierzchnie próbek były skanowane za pomocą optycznego skanera *3D - EviXscan 3D Loupe+*. Odpowiednio przetworzone wyniki skanowania posłużyły do wyznaczenia linii ugięcia próbek.

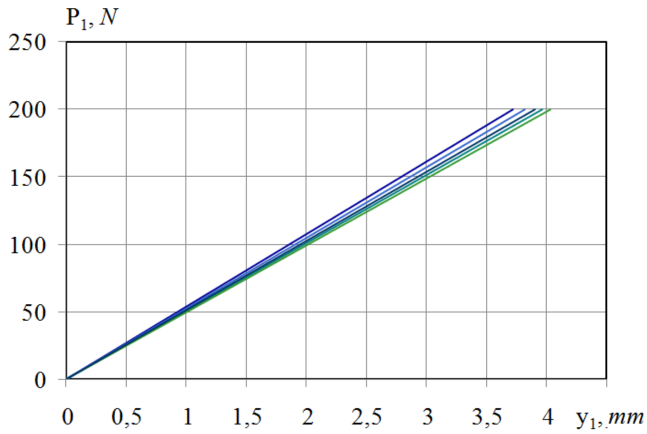
3.1. Zginanie trójpunktowe kompozytu

W zginaniu trójpunktowym (rys.2) zadawano przemieszczenie y w połowie rozpiętości próbki, które odpowiadało strzałce ugięcia y_1 a mierzono odpowiadającą mu siłę P_1. Zgodnie z zaleceniami, dla próbek o grubości $H=2$ *mm* rozstaw podpór ustawiono na wartość $S=80$ *mm*, przez co stosunek tych wymiarów wynosił 40:1. Przyjęty sposób podparcia powodował, że w zginanych próbkach kompozytu warstwowego występowały pomijalnie małe siły ścinające.

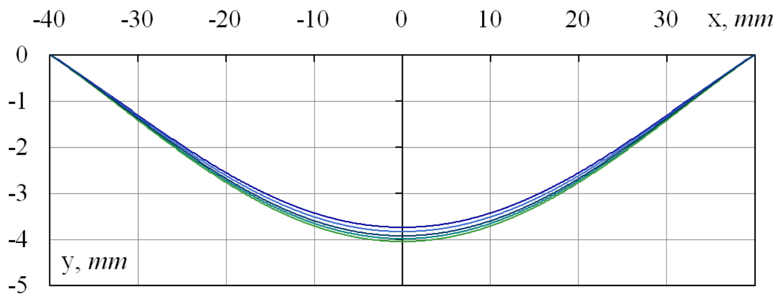


Rysunek 2. Schemat i fotografia stanowiska do badań wytrzymałości kompozytów w warunkach testu trójpunktowego zginania

Pomiary zrealizowano dla pięciu próbek w zakresie odkształceń sprężystych przy szybkości przesuwu trawersy maszyny wytrzymałościowej równej *1 mm/min*. Na wykresie na rys.3 przedstawiono otrzymane charakterystyki $P_1(y_1)$. Skanowanie wygiętych próbek dla tej samej siły $P_1=200$ *N* pozwoliło na wyznaczenie linii ugięcia próbek (rys.4).



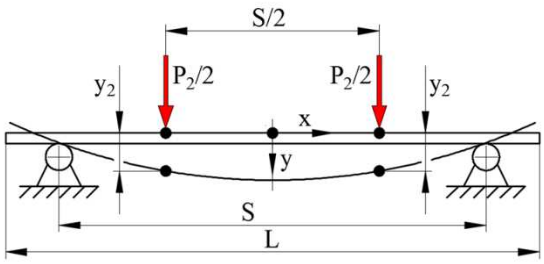
Rysunek 3. Charakterystyki zginania trójpunktowego dla pięciu próbek kompozytu

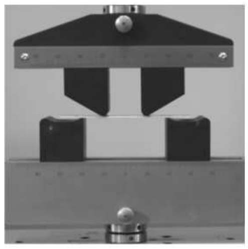


Rysunek 4. Linie ugięcia pięciu próbek w teście zginania trójpunktowego dla siły P_1 = 200 N uzyskane metodą skanowania 3D

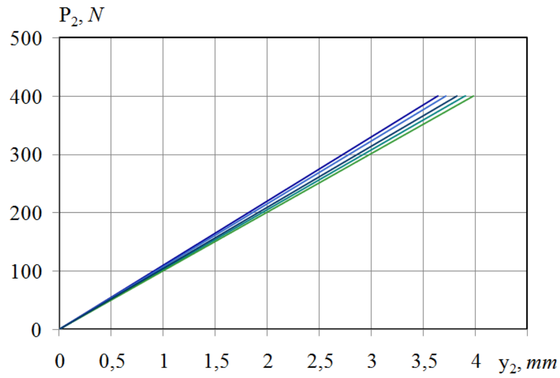
3.2. Zginanie czteropunktowe kompozytu

W zginaniu czteropunktowym (rys.5) siła P_2 była przenoszona na próbki za pomocą dwóch stempli o rozstawie *S/2=40 mm*. Wielkością zadawaną w badaniu było przemieszczenie trawersy maszyny wytrzymałościowej y_2, które odpowiadało ugięciu próbek w miejscu przyłożenia obciążenia. Cechą czteropunktowego zginania jest występowanie przedziału wolnego od sił ścinających między miejscami przyłożenia obciążenia. Podpory rozstawiono również w odległości *S=80 mm*, z tego samego powodu co w przypadku zginania trójpunktowego. Pomiary zrealizowano dla próbek, które wcześniej zostały przebadane w teście zginania trójpunktowego. Prędkość przemieszczania trawersy maszyny wytrzymałościowej ustawiono na wartość *1 mm/min*. Na podstawie wykonanych pomiarów otrzymano charakterystyki $P_2(y_2)$ próbek kompozytu pokazane na rys.6. Skanowanie 3D umożliwiło wykreślenie linii ugięcia próbek dla obciążenia P_2=*400 N* (rys.7).

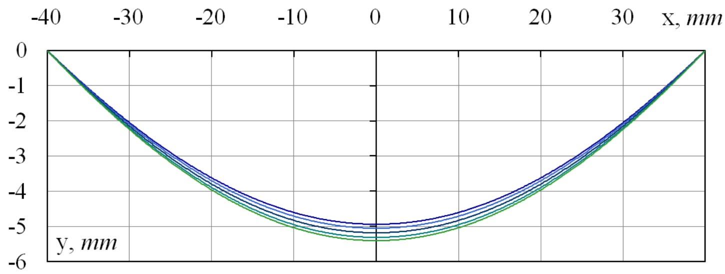




Rysunek 5. Schemat i fotografia stanowiska do badań wytrzymałości w warunkach testu czteropunktowego zginania



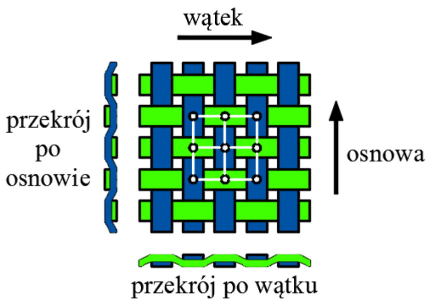
Rysunek 6. Charakterystyki zginania czteropunktowego dla pięciu próbek kompozytu



Rysunek 7. Linie ugięcia pięciu próbek w teście zginania czteropunktowego dla siły P_2 = 400 N uzyskane metodą skanowania 3D

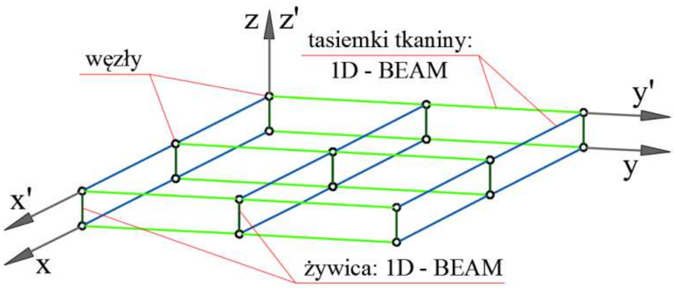
4. Modele MES kompozytu warstwowego

W dalszej części pracy przedstawiono dwa modele numeryczne kompozytu, które przygotowano w programie *Ansys Mechanical*. Każdy model odwzorowywał strukturę wewnętrzną kompozytu i uwzględniał udziały objętościowe komponentów przy określaniu parametrów przekrojowych elementów skończonych. Pierwszy etap budowy modeli polegał na zdefiniowaniu pojedynczej, tzw. elementarnej komórki tkaniny[3]. Złożona jest ona z dwóch tasiemek wątku oraz dwóch tasiemek osnowy[4]. Schemat tkaniny o splocie płóciennym z czterema komórkami elementarnymi przedstawiono na rysunku 8.



Rysunek 8. Schemat tkaniny z tasiemkami o splocie płóciennym z zaznaczonymi komórkami elementarnymi

W modelowaniu kompozytu wykorzystano elementy skończone typu belkowego -1D *Beam* i powierzchniowego - 2D *Shell*. Na wstępie opracowano strukturę, którą określono jako model A. Zdefiniowanie pojedynczej warstwy kompozytu wymagało utworzenia jednej warstwy węzłów – ponieważ tkanina została sprowadzona do płaszczyzny. Węzły wyznaczały miejsca przeplotu tasiemek, tasiemki między węzłami zamodelowano elementami belkowymi. Kolejne warstwy tkaniny były ze sobą łączone za pomocą pionowych elementów belkowych modelujących żywicę. Budowę modelu kompozytu z komórką elementarną wg schematu modelu A dla czterech sąsiadujących komórek elementarnych i dwóch warstw tkaniny w płaszczyznach XYZ i X'Y'Z' pokazano na rysunku 9.

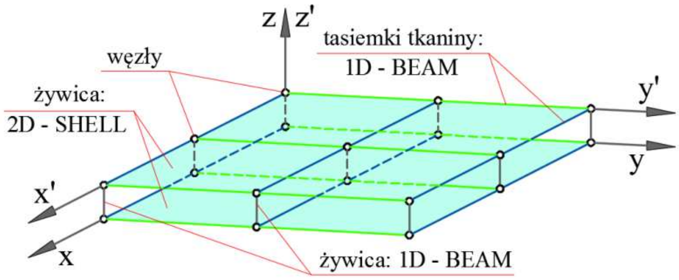


Rysunek 9. Schemat czterech komórek elementarnych kompozytu dla dwóch warstw tkaniny wg modelu A

[3] W literaturze angielskojęzycznej używa się określenia *RUC: repetitive unit cell.*

[4] *osnowa* - termin ten posiada dwa znaczenia: w dziedzinie materiałów kompozytowych oznacza materiał wypełniający przestrzeń między wzmocnieniem kompozytu (lepiszcze), we włókiennictwie jeden z dwóch układów przędz (tasiemek) tworzących tkaninę. Tutaj został użyty w tym drugim znaczeniu.

Model z rysunku 9 został następnie zmodyfikowany do postaci oznaczonej jako model B, w której żywicę zamodelowano za pomocą elementów belkowych łączących kolejne warstwy wzmocnienia oraz elementów powierzchniowych modelujących przestrzeń między tasiemkami komórki elementarnej w płaszczyźnie XY (lub X'Y') (rys.10).

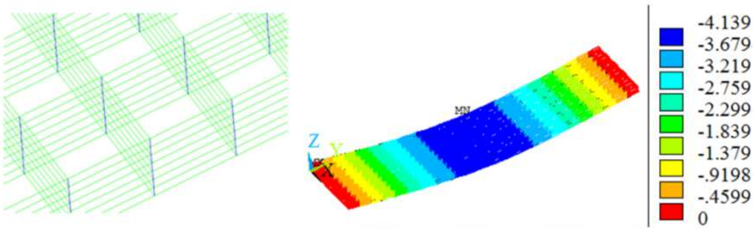


Rysunek 10. Schemat czterech komórek elementarnych kompozytu dla dwóch warstw tkaniny wg modelu B

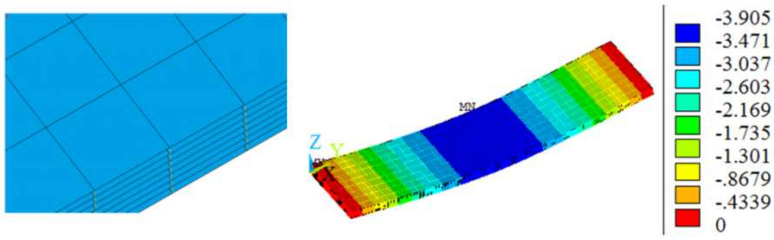
Walidacji modeli dokonano na podstawie wyników przeprowadzonych badań doświadczalnych i otrzymanych w próbach zginania trój i czteropunktowego charakterystyk. W celu automatyzowania tworzenia modeli MES próbek kompozytowych opracowano specjalny program w języku poleceń APDL będącym wewnętrznym językiem systemu Ansys. Program pełnił funkcję generatora węzłów i elementów skończonych wg definicji komórek elementarnych z rys. 9 i 10. Wygenerowanie modelu próbki wymagało podania jej długości i szerokości, liczby warstw oraz wymiarów pojedynczej komórki elementarnej. Dodatkową zaletą programu jest możliwość generowania modeli o zmiennej grubości warstw. W pierwszym etapie program rozmieszcza węzły ponumerowane zgodnie z przyjętym dla próbki ortokartezjańskim układem współrzędnych. Następnie węzły łączone są elementami belkowymi i powierzchniowymi o odpowiednich parametrach przekrojowych. Program przypisuje do elementów zdefiniowanie wcześniej parametry materiałowe i przekrojowe.

5. Wyniki analiz numerycznych

Opracowane modele MES zostały poddane analizom. Obliczenia przeprowadzono zgodnie z przedstawionymi w punkcie trzecim warunkami testów zginania. Na rysunku 11 przedstawiono schemat siatki węzłów i elementów skończonych modelu próbki, w którym zastosowano model A komórki elementarnej kompozytu oraz wypadkowe przemieszczenia węzłów próbki podczas zginania trójpunktowego. Rysunek 12 przedstawia podobny schemat i przemieszczenia węzłowe dla modelu próbki kompozytu, w którym wykorzystano model B komórki elementarnej.



Rysunek 11. Struktura modelu A oraz przemieszczenia węzłów modelu próbki w mm



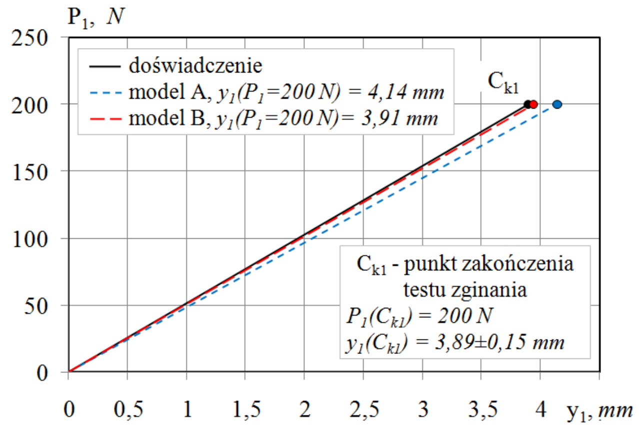
Rysunek 12. Struktura modelu B oraz przemieszczenia węzłów modelu próbki w mm

Porównanie wyników obliczeń z wynikami pomiarów dla prób zginania próbek kompozytu pokazano na kolejnych wykresach na rys.13 do 16. Rysunek 13 przedstawia porównanie charakterystyk sztywności modeli próbki kompozytu, w których komórka elementarna ma strukturę wg modeli A i B z uśrednioną dla pięciu prób charakterystyką wyznaczoną doświadczalnie według testu zginania trójpunktowego. Analogiczne porównanie dla zginania czteropunktowego pokazano na rysunku 14. Z porównań na rysunkach 13 i 14 widać, że dla obu modeli próbki (z komórką elementarną wg struktury modelu A i B) wyniki obliczeń są bardzo bliskie wartościom zmierzonym. Błędy względne ugięć obliczonych dla przemieszczeń y_1 (rys.2) i y_2 (rys.5) podano w tabeli 3.

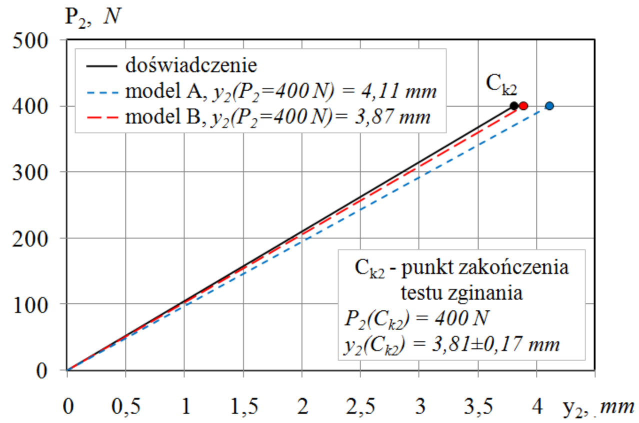
Tabela 3. Porównanie wyników doświadczalnych i obliczeniowych

rodzaj zginania	eksperyment	komórka elementarna model A		komórka elementarna model B	
	ugięcie mm	ugięcie mm	błąd względny %	ugięcie mm	błąd względny %
3-punktowe (y_1)	3,89	4,14	6,43	3,91	0,51
4-punktowe (y_2)	3,81	4,11	7,87	3,87	1,57

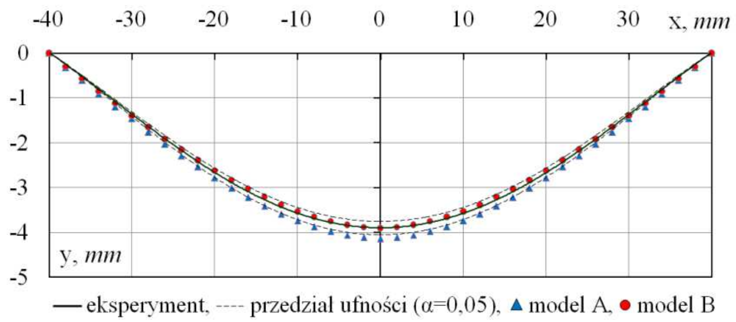
Drugi sposób walidacji poprawności modeli kompozytu polegał na porównaniu linii ugięcia próbek z badań doświadczalnych i obliczeń numerycznych. W pierwszej kolejności wyznaczono uśrednioną linię ugięcia dla wszystkich próbek z testu zginania trójpunktowego (rys.15). Na tym samym wykresie przedstawiono linie ugięcia otrzymane w wyniku symulacji numerycznych dwóch modeli MES. Podobnie porównano linie ugięcia dla zginania czteropunktowego (rys.16). W obu przypadkach model kompozytu z komórką elementarną wg modelu B dokładniej odwzorowywał wyniki pomiarów. Linia ugięcia tego modelu znalazła się w pasie wyznaczonym przez przedział ufności (dla poziomu istotności α=0,05) uśrednionej dla pięciu prób linii ugięcia wyznaczonej doświadczalnie. Natomiast linia ugięcia otrzymana w wyniku symulacji modelu kompozytu z komórką elementarną wg modelu A wykraczała poza pas wyznaczony przez przedział ufności.



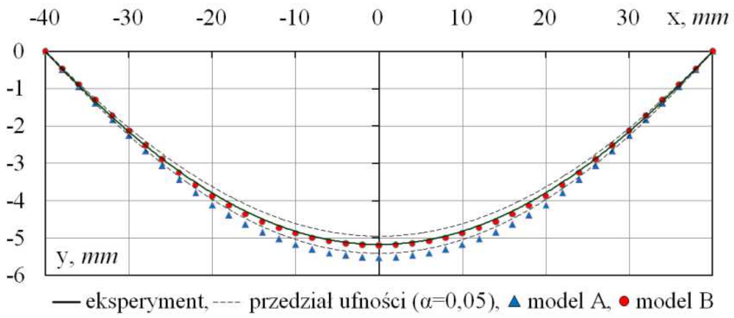
Rysunek 13. Charakterystyki dla zginania trójpunktowego - porównanie wyników



Rysunek 14. Charakterystyki dla zginania czteropunktowego - porównanie wyników



Rysunek 15. Linie ugięcia dla zginania trójpunktowego - porównanie wyników



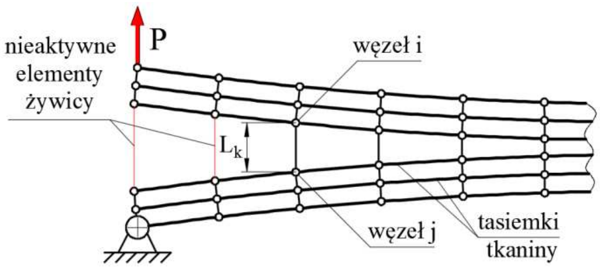
Rysunek 16. Linie ugięcia dla zginania czteropunktowego - porównanie wyników

6. Podsumowanie i kierunek dalszych badań

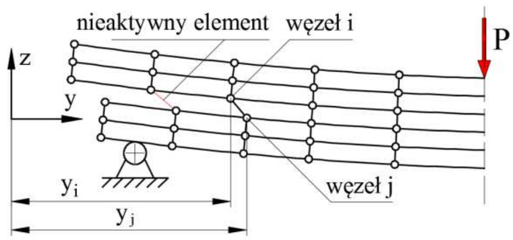
W niniejszym artykule zaprezentowano oryginalne modele MES kompozytu warstwowego, które uwzględniały strukturę kompozytu przy zachowaniu udziałów objętościowych faz wzmocnienia i osnowy. Model B komórki elementarnej najlepiej odwzorowywał kształt zginanych podczas eksperymentu próbek. Poprawność wyników obliczeń zachęca do zastosowania przedstawionego sposobu modelowania kompozytów do numerycznej symulacji rozwarstwiania, które jest najczęściej występującym rodzajem uszkodzenia tych materiałów. Propagacja pęknięcia w modelu może być realizowana poprzez dezaktywowanie odpowiednich elementów skończonych modelu. Jest to programowo realizowane przez mnożenie macierzy sztywności elementu przez współczynnik redukcji, którego domyślna wartość w programie Ansys wynosi 1.0E-6 (metoda nazywa się *Death & Birth Element*). Takie postępowanie wymaga zdefiniowania odpowiednich kryteriów, po spełnieniu których element skończony modelujący żywicę zostanie wyselekcjonowany i dezaktywowany. Z uwagi na rodzaj obciążenia wyróżnia się trzy niezależne schematy pękania (rozwarstwiania) [5]. I tak:

1. Pękanie następuje wyniku przekroczenia w osnowie dopuszczalnych naprężeń normalnych (*mode I - opening mode*), powierzchnie pęknięcia rozchylają się a propagacja pęknięcia następuje w kierunku prostopadłym do jego frontu. W takim przypadku jako kryterium selekcji i dezaktywacji elementów skończonych modelu kompozytu proponuje się przyjęcie progowej wartości wydłużeń L_k w elementach modelujących żywicę (rys.17). Jeśli odległość między węzłami *i*, *j* $L_{i,j} \geq L_k$, to element belkowy rozpięty między węzłami *i*, *j* zostaje usunięty.
2. Pękanie następuje w wyniku przekroczenia w osnowie dopuszczalnych naprężeń stycznych (*mode II - sliding shear*), powierzchnie pęknięcia przesuwają się po sobie a propagacja pęknięcia następuje w kierunku prostopadłym do jego frontu.
3. Pękanie następuje w wyniku przekroczenia w osnowie dopuszczalnych naprężeń stycznych (*mode III - scissoring shear*) lecz w odróżnieniu od schematu drugiego, powierzchnie szczeliny przesuwają się po sobie w kierunku równoległym do jego frontu. Dla drugiego i trzeciego schematu pękania proponuje się wspólne kryterium, podobne jak dla schematu 1. W nieobciążonym modelu węzły *i*, *j* elementów modelujących żywicę mają taką samą współrzędną *y* (rys.18).

Naprężenie styczne przekraczające wartość dopuszczalną powoduje ścięcie elementu skończonego. Jako warunek selekcji i dezaktywacji elementów proponuje się porównanie współrzędnych *y* węzłów *i*, *j* (rys.18). Jeśli $|y_i\text{-}y_j| \geq (y_i\text{-}y_j)_k$, to element belkowy rozpięty między węzłami *i*, *j* zostaje usunięty.



Rysunek 17. Schemat procesu rozwarstwiania dla rozrywania kompozytu



Rysunek 18. Schemat procesu rozwarstwiania dla ścinania osnowy

Przedstawione w artykule autorskie modele MES kompozytów warstwowych i propozycje kryteriów zniszczenia dla symulowania procesu ich rozwarstwiania będą wykorzystane w dalszych pracach związanych z tą tematyką.

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Kamil MAŚLANKA[1]

Opiekun naukowy: Jarosław JANUSZ[2]

PROJEKT I WYKONANIE ADAPTACYJNEGO STEROWNIKA LOTU DRONA NA PODSTAWIE MODALNEGO REGULATORA LQR

Streszczenie: W artykule przedstawiono wyprowadzenie równań ruchu modelu matematycznego drona. Na podstawie nieliniowego modelu zaprojektowany został niekonwencjonalny układ adaptacyjnego regulatora modalnego. Algorytm po zaimplementowaniu w sterowniku Arduino został poddany wielu testom sprawdzającym wpływ wielu parametrów na jakość regulacji.

Słowa kluczowe: sterownik lotu, dron, Arduino, regulator, algorytm

DESIGN AND IMPLEMENTATION OF ADAPTIVE FLIGHT CONTROL SYSTEM BASED ON MODAL LQR CONTROLLER

Summary: The article presents the derivation of the equations of motion of mathematical drone model. An unconventional system of adaptive modal control has been designed based on the nonlinear model. The algorithm has been implemented in Arduino controller and undergone number of tests checking the influence of many parameters on the quality of control

Keywords: flight controller, drone, Arduino, algorithm

1. Wstęp

Zainteresowanie bezzałogowymi statkami powietrznymi w dziedzinie militariów jak i w dziedzinie aplikacji cywilnych ciągle wzrasta i wiąże się z celowością ciągłego doskonalenia rozwiązań konstrukcyjnych jak i sterowania w celu uzyskania tańszych i bardziej niezawodnych maszyn latających. Multikoptery są statkami powietrznymi zbliżonymi konstrukcyjnie do standardowych helikopterów jednakże posiadają więcej niż dwa rotory – śmigła poziome. Najbardziej popularne rozwiązania zawierają 3 (tricopter), 4 (quadcopter), 6 (hexacopter), lub 8 (octacopter) rotorów, jednakże

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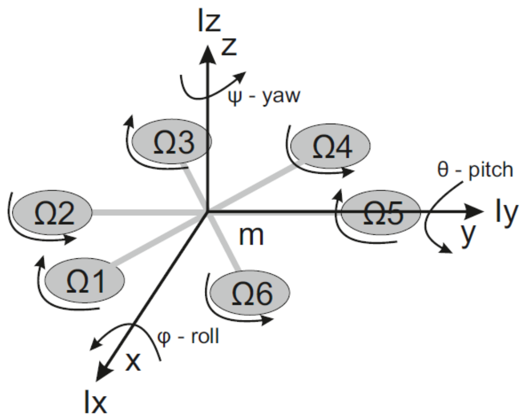
każda inna liczba jest technicznie możliwa do zrealizowania i sterowania. Rozwiązania zawierające więcej niż 4 rotory napędowe są drogie w budowie, jednakże bardziej niezawodne, gdyż odpowiednio zaprojektowany algorytm umożliwia ich lot nawet w przypadku uszkodzenia jednego z silników.

Rysunek 1. Dron sześcio-wirnikowy typu hexacopter wyposażony w kamerę i odbiornik GPS [8]

Ze względu na złożoność problemu konstrukcji i sterowania dronami wymagane jest multi-dyscyplinarne podejście do problemu. Obiekty takie bezwzględnie muszą umożliwiać swobodny zwis w powietrzu (stan lewitacji) precyzyjne sterowanie bez zbędnych oscylacji i odchyleń od zamierzonego kierunku lotu. Wszystko to jedynie przez balansowanie siłami ciągu kilku rozmieszczonych po obwodzie konstrukcji śmigieł napędowych. W ostatnich latach multikoptery stały się obiektem wielu badań prowadzącymi do poprawy sterowalności, stabilności, zmniejszenia wagi konstrukcji i zwiększenia możliwości przewożenia ładunku.

2. Model matematyczny drona [2,3]

Równania opisujące rzeczywisty model obiektu jakim jest dron są niezbędne do opracowania i dostrojenia układu stabilizacji lotu. Wyprowadzono je rozpatrując w pierwszej kolejności model rzeczywisty jako ciało sztywne w przestrzeni 3D. W takim przypadku w każdej chwili czasu siły czynne działające na obiekt równoważone są przez siły bezwładności ruchu postępowego i obrotowego jak również przez siły wzajemnego oddziaływania tych ruchów zwane siłami żyroskopowymi.



Rysunek 2. Schemat ogólny układu drona sześciowirnikowego

Poniżej przedstawiono przyjęte oznaczenia podczas wyprowadzania równań ruchu modelu oraz dane fizyczne modelu wykorzystane w późniejszych testach:
g=**9.81 m/s²** – stała grawitacji,
m=**3 kg** – masa obiektu,
C=0.3– współczynnik oporu powietrza,
Ax=**0.1 m²** – powierzchnia obiektu w płaszczyźnie Z_bY_b,
Ay=**0.1 m²** – powierzchnia obiektu w płaszczyźnie Z_bX_b,
Az=**0.5 m²** – powierzchnia obiektu w płaszczyźnie X_bY_b,
Ixx=**0.03 kgm²** – masowy moment bezwładności względem osi X_b,
Iyy=**0.02 kgm²** – masowy moment bezwładności względem osi Y_b,
Izz=**0.05 kgm²** – masowy moment bezwładności względem osi Z_b,
b=**0.00044** – współczynnik siły ciągu śmigieł,
l=**0.3 m** – długość ramienia drona liczona od osi z do osi wirnika,
d=**0.0002** – współczynnik oporu powietrza obracającego się śmigła,
ρ=**1.168 kg/m³** – gęstość powietrza,
Jr=**1.9*10⁻³ kgm²** – masowy moment bezwładności śmigła,
φ ,θ ,ψ – Roll, Pitch, Yaw – kąt pochylenia, przechylenia, zbaczania,
Ωi – prędkość obrotowa i-tego śmigła,
Fx, Fy, Fz – siły zgodnie z osiami X, Y, Z,
τx, τy, τz – momenty względem osi X, Y, Z.

Prędkości liniowe w układzie obiektu ($OX_bY_bZ_b$)

$$V^B = \begin{bmatrix} u \\ v \\ w \end{bmatrix} = \begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{z} \end{bmatrix} \tag{1}$$

Prędkości kątowe w układzie obiektu ($OX_bY_bZ_b$)

$$\omega^B = \begin{bmatrix} p \\ q \\ r \end{bmatrix} = \begin{bmatrix} \dot{\phi} \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix} \tag{2}$$

2.1. Równania ruchu ciała w przestrzeni

Równania bryły sztywnej w przestrzeni z uwzględnieniem sił żyroskopowych wyprowadzone z metody Newtona-Eulera przedstawiono w formie zapisu macierzowego:

$$\begin{bmatrix} mI_{3x3} & 0_{3x3} \\ 0_{3x3} & T_{3x3} \end{bmatrix} \begin{bmatrix} \dot{V}^B \\ \dot{\omega}^B \end{bmatrix} + \begin{bmatrix} \omega^B \times mV^B \\ \omega^B \times T\omega^B \end{bmatrix} = \begin{bmatrix} F^B \\ \tau^B \end{bmatrix} \tag{3}$$

Korzystając z zależności na mnożenie wektorowe rozwinięto równania przedstawiając je jako opisujące 6 stopni swobody w sposób jawny. Dzieląc obustronnie przez parametry fizyczne jakimi są masa i momenty bezwładności względem poszczególnych osi otrzymano równanie ruchu (6) opisujące ruch ciała sztywnego w przestrzeni:

$$\begin{bmatrix} \dot{u} \\ \dot{v} \\ \dot{w} \\ \dot{p} \\ \dot{q} \\ \dot{r} \end{bmatrix} = \begin{bmatrix} rv - qw \\ pw - ru \\ qu - pv \\ \frac{I_{yy} - I_{zz}}{I_{xx}} qr \\ \frac{I_{zz} - I_{xx}}{I_{yy}} pr \\ \frac{I_{xx} - I_{yy}}{I_{zz}} pq \end{bmatrix} + \begin{bmatrix} \frac{1}{m} F_x^B \\ \frac{1}{m} F_y^B \\ \frac{1}{m} F_z^B \\ \frac{1}{I_{xx}} \tau_x^B \\ \frac{1}{I_{yy}} \tau_y^B \\ \frac{1}{I_{zz}} \tau_z^B \end{bmatrix} \tag{4}$$

Siły i momenty działające na obiekt:
-siły napędowe,
-siła grawitacji,
-siła oporu powietrza,
-momenty żyroskopowe,
-moment bezwładności śmigieł.

2.2. Zmienne stanu

Po wyznaczeniu wszystkich sił działających na układ modelu hexacoptera przystąpiono do zapisu równań w przestrzeni stanu. W tym celu określono zmienne stanu obiektu. Naturalnym w tym wypadku było przyjęcie zmiennych określających pozycję obiektu w przestrzeni oraz ich pochodnych. Rozważano włączenie do zbioru zmiennych stanu również wartości prędkości poszczególnych śmigieł układu napędowego. Takie rozwiązanie powodowało jednak znaczne powiększenie się zapisu stanu, rozrost wymiaru macierzy i tym samym wzrost zapotrzebowania na moc obliczeniową w tracie pracy algorytmu. Zdecydowano się więc na podejście bardziej uniwersalne, w którym algorytm będzie wyznaczał zmienne sterujące w postaci sił i momentów działających na ciało o 6 stopniach swobody, a dodatkowy moduł obliczeniowy (zależny o konstrukcji drona) będzie wyznaczał konieczne do wysterowania prędkości śmigieł. W takim przypadku wartości prędkości układu napędowego wykluczono ze zmiennych stanu.

$$\begin{bmatrix} x \\ u \\ y \\ v \\ z \\ w \\ \phi \\ p \\ \theta \\ q \\ \psi \\ r \end{bmatrix} = \begin{bmatrix} \dot{x_1} \\ \dot{x_2} \\ \dot{x_3} \\ \dot{x_4} \\ \dot{x_5} \\ \dot{x_6} \\ \dot{x_7} \\ \dot{x_8} \\ \dot{x_9} \\ \dot{x_{10}} \\ \dot{x_{11}} \\ \dot{x_{12}} \end{bmatrix}$$

$$= \begin{bmatrix} x_2 \\ x_{12}x_4 - x_{10}x_6 + g\,sin(x_9) - \frac{1}{2}CA_x\rho x_2|x_2| \\ x_4 \\ x_8x_6 - x_{12}x_2 - g\,cos(x_9)\,sin(x_7) - \frac{1}{2}CA_y\rho x_4|x_4| \\ x_6 \\ x_{10}x_2 - x_8x_4 - g\,cos(x_9)\,cos(x_7) - \frac{1}{2}CA_y\rho x_6|x_6| + \frac{1}{m}(F_z) \\ x_8 \\ I_px_{10}x_{12} - \frac{1}{I_{xx}}J_rx_{10}\Omega_r + \frac{1}{I_{xx}}\Delta M_x \\ x_{10} \\ I_qx_8x_{12} - \frac{1}{I_{yy}}J_rx_8\Omega_r + \frac{1}{I_{yy}}\Delta M_y \\ x_{12} \\ I_rx_8x_{10} - \frac{1}{I_{zz}}J_r\dot{\Omega}_r + \frac{1}{I_{zz}}\Delta M_z \end{bmatrix} \tag{5}$$

2.3. Przestrzeń stanu

W kolejnym kroku z powyższych równań ruchu wyodrębniono zmienne sterujące oraz zmienne stanu oraz dokonano zapisu modelu dynamicznego w klasycznej postaci w przestrzeni stanów. Zapis taki umożliwia dokładniejszą analizę układu z wykorzystaniem narzędzi symulacyjnych takich, jak środowisko Matlab [1, 4].

$$\begin{cases} \dot{x} = Ax + Bu \\ y = Cx + Du \end{cases} \tag{6}$$

Sterowanie dronem obejmuje 4 stopnie swobody modelu dynamicznego. Pozostałe dwa stopnie swobody, a tym samym zachowanie obiektu w przestrzeni wynika ze stopni sterowalnych. Sterowane więc będą dwa kąty lotnicze *roll, pitch,* prędkość obrotu wokół osi pionowej *yaw,* oraz prędkość wznoszenia w osi pionowej bazowego układu współrzędnych modelu. Zapis pełnych równań w formie przestrzeni stanu przedstawia się następująco [1, 4].

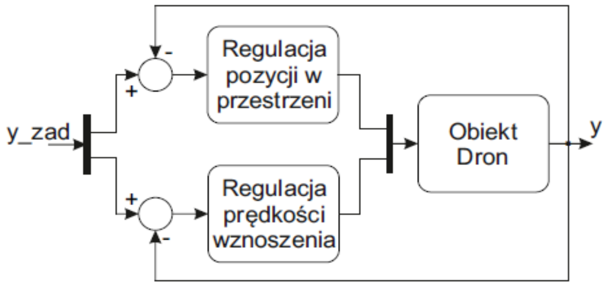
$$\begin{bmatrix} \dot{x}_6 \\ \dot{x}_7 \\ \dot{x}_8 \\ \dot{x}_9 \\ \dot{x}_{10} \\ \dot{x}_{12} \end{bmatrix} = \begin{bmatrix} -\frac{1}{2}CA_y\rho|x_6| & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -\frac{1}{I_{xx}}J_r\Omega_r & I_p x_{10} \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & I_q x_{12} - \frac{1}{I_{yy}}J_r x_8 \Omega_r & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & I_r x_8 & 0 \end{bmatrix} \begin{bmatrix} x_6 \\ x_7 \\ x_8 \\ x_9 \\ x_{10} \\ x_{12} \end{bmatrix} + \begin{bmatrix} \frac{1}{m} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & \frac{1}{I_{xx}} & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{1}{I_{yy}} & 0 \\ 0 & 0 & 0 & \frac{1}{I_{zz}} \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{bmatrix}$$

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_6 \\ x_7 \\ x_8 \\ x_9 \\ x_{10} \\ x_{12} \end{bmatrix} \tag{7}$$

3. Projekt układu sterowania

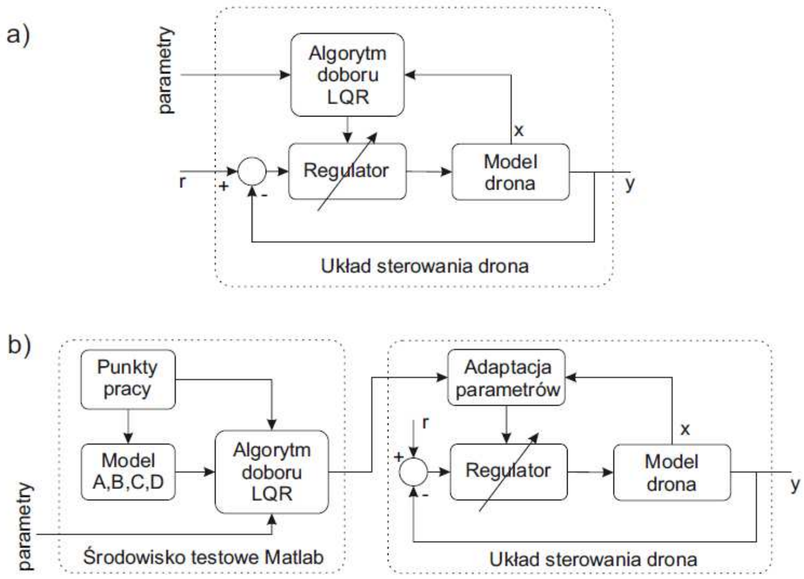
W tym rozdziale przedstawiono wszelkie aspekty związane z projektowaniem i doborem algorytmu sterującego dla modelu drona sześciowirnikowego. Etap projektowania uwzględnia wyznaczone uprzednio równania ruchu modelu, a zapis w formie macierzowej przestrzeni stanu wykorzystano przy opracowywaniu zagadnienia sterowania liniowo kwadratowego ze zdefiniowaną funkcją kosztu. W całym etapie projektowania układu sterowania posłużono się przyjętymi szacunkowymi danymi fizycznymi obiektu.

Z uwagi na fakt, że zaproponowano podział układu regulacji na dwa człony – układu regulacji pozycji w przestrzeni *Attitude* oraz układu regulacji prędkości wznoszenia *Climb Speed* –wykonano dekompozycję przestrzeni stanu na dwa podukłady analizowane osobno. Takie podejście umożliwia łatwiejsze modyfikacje układu sterowania poszczególnych parametrów lotu, bez ingerencji w pozostałe.



Rysunek 3. Schemat ideowy układu sterowania dronem w przestrzeni

Planem autora było aby układ regulacji zawierał i uwzględniał wszelkie nieliniowości układu. w tym celu należało zaprojektować układ sterowania zależny od aktualnego punktu pracy układu w danej chwili *t.* Z racji złożoności problemu oraz wielu zmiennych zdecydowano się na rozwiązanie problemu algorytmem liniowo-kwadratowym LQR z kwadratowym funkcjonałem kosztu sterowania.
Ponieważ jednak macierze stanu obiektu są funkcjami stanu i zmiennych niezależnych $A_k=f(x,\Omega_i)$ oraz $A_v=f(x,\Omega_i)$ wymagane było indywidualne podejście do problemu, odbiegające od klasycznego algorytmu LQR, który bazuje na modelach liniowych[7]. Jak się okazuje w takich wypadkach nie jest możliwe jednokrotne znalezienie parametrów regulatora dla sterowań optymalnych. Rozwiązanie to jest zmienne w zależności o wektora stanu.



Rysunek 4. Koncepcje układów sterowania rozmytego adaptacyjnego regulatora LQR

Możliwe rozwiązania zagadnienia prezentują się następująco:

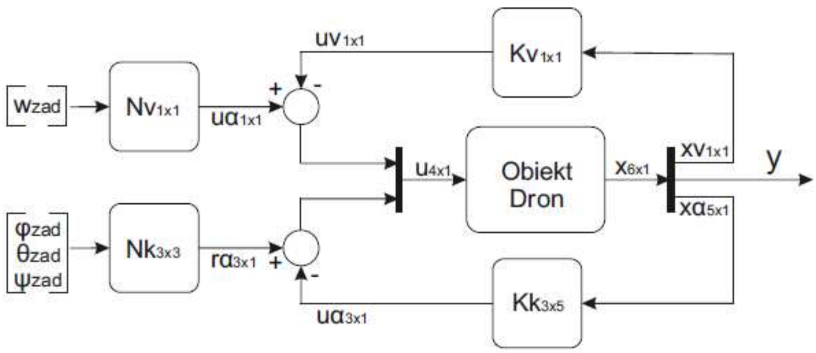
a) ciągłe rozwiązywanie problemu liniowo kwadratowego w każdej chwili t na podstawie aktualnego punktu pracy układu. W takim przypadku w każdej pętli regulacji należy rozwiązać równanie Riccatiego w postaci cyfrowej. Jedną z najbardziej wymagających obliczeniowo operacji jest wówczas znalezienie macierzy odwrotnej o wymiarach 6x6 (w przypadku analizowanego układu regulacji kąta). Z obawy przed niewystarczającą wówczas częstotliwością odświeżania algorytmu zrezygnowano z powyższego podejścia.
b) rozwiązanie problemu liniowo kwadratowego na etapie projektowania w wielu punktach pracy a następnie znalezienie powiązania wyznaczonych macierzy wzmocnień względem aktualnych parametrów punktu pracy podczas pracy algorytmu. Zdecydowano się na to podejście uważając go za mniej wymagające obliczeniowo od strony sprzętowej.

Układ adaptacyjnej regulacji modalnej liniowo kwadratowej LQR

Projekt układu regulacji modalnej stanu bazuje na opisie układu w przestrzeni stanu. w tym przypadku jeśli układ spełnia odpowiednie omówione później wymagania, kontroli podlegają wszystkie wyjściowe zmienne stanu układu a zmienną sterującą są wszystkie sygnały wejściowe do układu. Regulację modalną można w łatwy sposób zaprojektować dla układów MIMO. Ze strony celów sterowania regulacja taka jest pożądana, gdyż zapewnia pełną stabilizację obiektu. Problem takiej regulacji rozwiązany jest poprzez zastosowanie pełnej pętli sprzężenia zwrotnego od wszystkich zmiennych stanu układu, rzadziej jedynie od zmiennych wyjściowych [5]. Układ z zamkniętą pętlą sprzężenia zwrotnego od stanu opisany jest równaniami:

$$\begin{cases} \dot{x} = Ax + Bu \\ y = Cx + Du \\ u = r - kx \end{cases} \tag{8}$$

Zaproponowany wcześniej podział sterowania na dwa odrębne segmenty wymusza modyfikację schematu blokowego. Cały algorytm zostanie podzielony na dwa odrębne regulatory modalne (liniowo kwadratowe) działające niezależnie jednakże czerpiące dane ze wspólnego wektora stanu. Na poniższym schemacie przedstawiono obiekt sterowania jako model uproszczony bez ingerencji w jego strukturę wewnętrzną.



Rysunek 5. Schemat układu sterowania modalnego z podziałem na dwa osobne regulatory

Przed przystąpieniem do rozwiązania problemu liniowo kwadratowego należy zbadać obiekt pod względem sterowalności.
Problem znalezienia sterowania optymalnego w przypadku modelu o wielu stopniach swobody okazuje się trudny do rozwiązania. W tym wypadku należy określić cel regulacji, wg którego powinien pracować algorytm. Jednym z takich celów jest minimalizacja energetyczna sterowania. W tym celu wykorzystany jest regulator liniowo kwadratowy LQR. Podejście takie umożliwia wyznaczenie optymalnego wektora nastaw sprzężenia zwrotnego k tak, aby układ minimalizował całkę kosztu dla wag:

$$\mathrm{Q_k} = \begin{bmatrix} 4 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 4 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 4 \end{bmatrix} \mathrm{R_k} = \begin{bmatrix} 25 & 0 & 0 \\ 0 & 25 & 0 \\ 0 & 0 & 25 \end{bmatrix} \tag{9}$$

W przypadku przyjęcia zerowego punktu pracy – co odpowiada modelowi po linearyzacji – przebieg obliczeń w środowisku Matlab oraz wyniki przedstawiono poniżej.

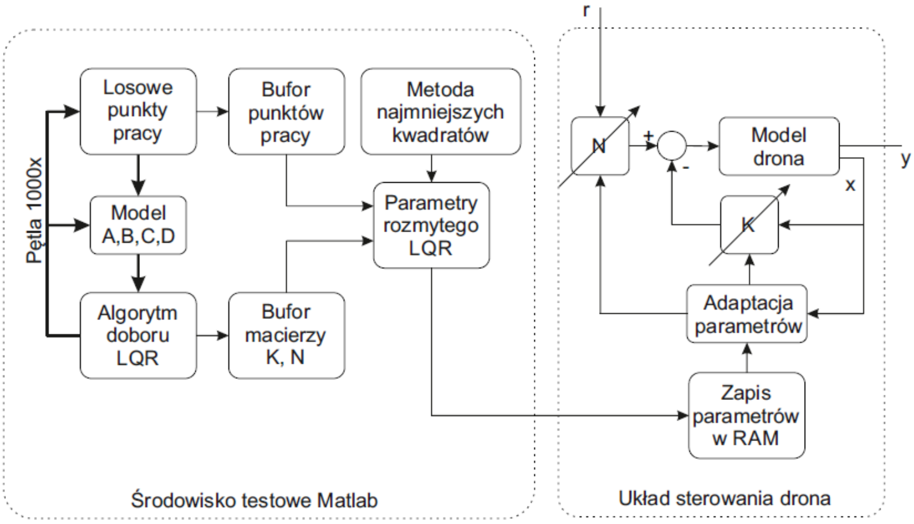
```
Kk=LQR(Ak,Bk,Qk,Rk);
Kk= 0.4000    0.1549   -0.0000   -0.0000         0
    -0.0000   -0.0000    0.4000    0.1265         0
       0         0         0         0    0.4000
Nk=-1/(Ck*((Ak-Bk*Kk))^-1)*Bk);
Nk= 0.4000   -0.0000         0
    -0.0000    0.4000         0
         0         0    0.4000

Kv=LQR(Av,Bv,Qv,Rv);
Kv= 2.5000

Nv=-1/(Cv*((Av-Bv*Kv))^-1)*Bv);
Nv= 2.5000
```

Rozwiązanie takie jest poprawne jednak mało satysfakcjonujące. Ideą zastosowania autorskiego rozwiązania jest rozmycie nastaw macierzy sprzężenia zwrotnego w regulacji LQR względem aktualnie występującego punktu pracy układu. W takim przypadku macierze wzmocnień *K* potraktowano jako zbiór wartości zależnych w każdej chwili *t* od punktu pracy układu.

$$\begin{gathered} \mathrm{K_k} = \mathrm{K_k}(\mathrm{x_8}, \mathrm{x_{10}}, \mathrm{x_{12}}, \Omega_\mathrm{r}) \\ \mathrm{N_k} = \mathrm{N_k}(\mathrm{x_8}, \mathrm{x_{10}}, \mathrm{x_{12}}, \Omega_\mathrm{r}) \\ \mathrm{K_v} = \mathrm{K_v}(\mathrm{x_6}) \\ \mathrm{N_v} = \mathrm{N_v}(\mathrm{x_6}) \end{gathered} \tag{10}$$

Zrezygnowano jednak z klasycznego rozmycia wartości bazujących na funkcjach przynależności z uwagi na skomplikowanie rozwiązania i brak jednoznacznych zależności między punktem pracy a wartościami macierzy wzmocnień ***K***. Zdecydowano się na rozwiązanie problemu metodą aproksymacji funkcji wielu zmiennych w bazie wielomianowej. Tok postępowania:
-wygenerowanie 1000 próbek reprezentujących losowe punkty pracy;
-rozwiązanie problemu liniowo kwadratowego dla każdego z punktów pracy zapisując każde z rozwiązań w pamięci;
-określenie bazy wielomianowej na podstawie przyjętych zmiennych punktu pracy;

-wykonanie aproksymacji metodą najmniejszych kwadratów poprzez lewostronne dzielenie macierzowe;
-zapisanie otrzymanego wektora współczynników;

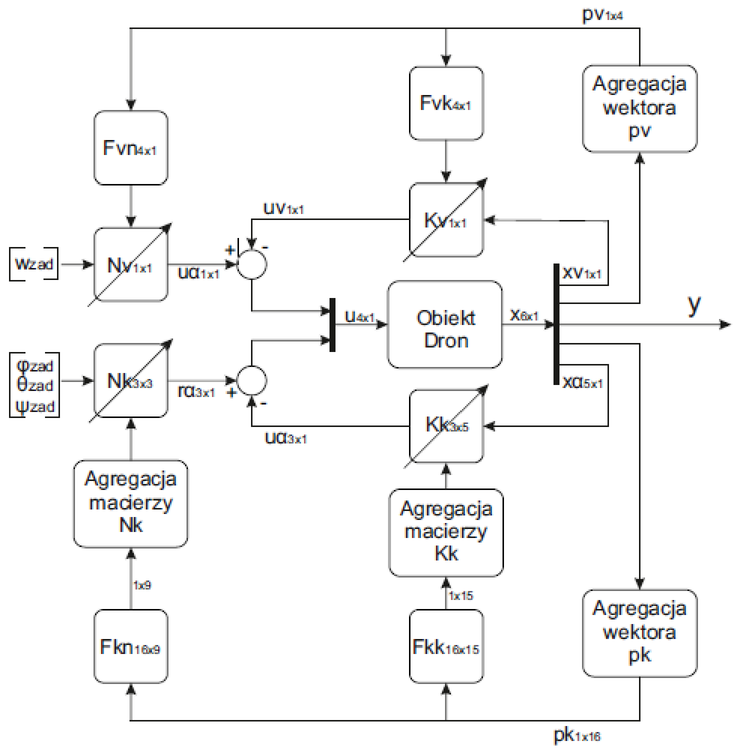


Rysunek 6. Algorytm postępowania przy projektowaniu rozmytego adaptacyjnego układu regulacji LQR

Otrzymany wektor współczynników w każdej pętli regulacyjnej będzie przemnażany przez aktualny punkt pracy zebrany w jeden w wektor stanowiący bazę wielomianową. Pozwoli to na uzyskanie macierzy wzmocnień ***K*** zależnej od nieliniowości układu i będącej przybliżeniem rozwiązania problemu LQR w danej chwili *t* na podstawie aktualnego punktu pracy uwzględniając nieliniowość układu. Mimo znacznych rozmiarów macierzy współczynników takie podejście oszacowano jako mniej wymagające obliczeniowo i łatwiejsze do zaimplementowania w sterowniku głównym.

$$\begin{aligned} K_k &= p_k * F_{Kk[1x15]} \\ N_k &= p_k * F_{Nk[1x9]} \\ K_v &= p_v * F_{Kv[1x1]} \\ N_v &= p_v * F_{Nv[1x1]} \end{aligned} \tag{11}$$

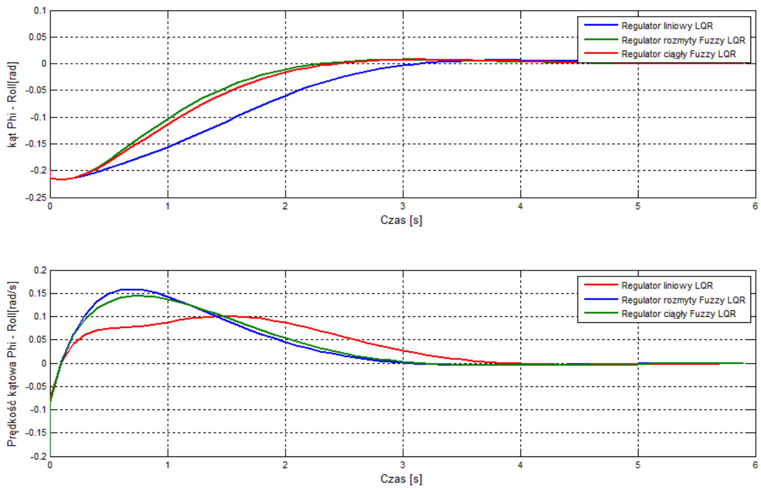
Do klasycznego układu zostaje dodana część adaptacyjna wyliczająca na podstawie aktualnego stanu odpowiednie macierze sprzężeń zwrotnych i dokładności statycznej.



Rysunek 7. Układ regulacji modalnej z wykorzystaniem rozmytej metody adaptacyjnej zależnej od wektora stanu

4. Testy numeryczne układu liniowego i nieliniowego

Zaprojektowane uprzednio układy sterowania liniowo kwadratowego LQR w wersji dla układu zlinearyzowanego oraz w wersji rozmytej zostały zaimplementowane w formie skryptu w oprogramowaniu inżynierskim Matlab. Głównym aspektem do zweryfikowania byłą poprawność działania algorytmów tak, aby w sposób poprawny stabilizować pozycję (attitude) oraz prędkość wnoszenia ciała sztywnego (drona) przestrzeni trójwymiarowej. Weryfikowano to ustalając losowe wartości początkowe stanu a następnie starając się ustabilizować układ w przestrzeni. Tak więc wartości zadane to odpowiednio: kąt przechylenia i pochylenia równy zero oraz prędkość kątowa obrotu własnego i prędkość wznoszenia równa zero.



Rysunek 8. Stabilizacja kąta i prędkości kątowej przechylenia Roll

5. Sterownik główny

Układ Arduino Due jest mikrokontrolerem bazującym na układzie Atmel SAM3X8E oraz procesorze głownym ARM Cortex-M3 CPU. Jest pierwszym układem Arduino bazującym na mikroprocesorze 32 bitowym. Posiada 54 wejścia/wyjścia cyfrowe (z czego 12 z nich może pracować jako analogowe wyjście PWM), cztery sprzętowe porty szeregowe, 84MHz zegar, złącze USB OTG, dwa przetworniki cyfrowo-analogowe, dwa złącza TWI, zasilanie poprzez klasyczne złącze jack [6].

5.1. Struktura sprzętowa

W kolejnym etapie opracowano strukturę całego sterownika. Całość wymagała przeanalizowania możliwości montażu na głównej płycie nośnej drona, wspólnej integracji elementów elektronicznych oraz wymiany danych pomiędzy nimi. Na początku określono możliwe metody wymiany danych pomiędzy urządzeniami elektronicznymi. Uwzględniając komplet sprzętu mamy więc do czynienia z:

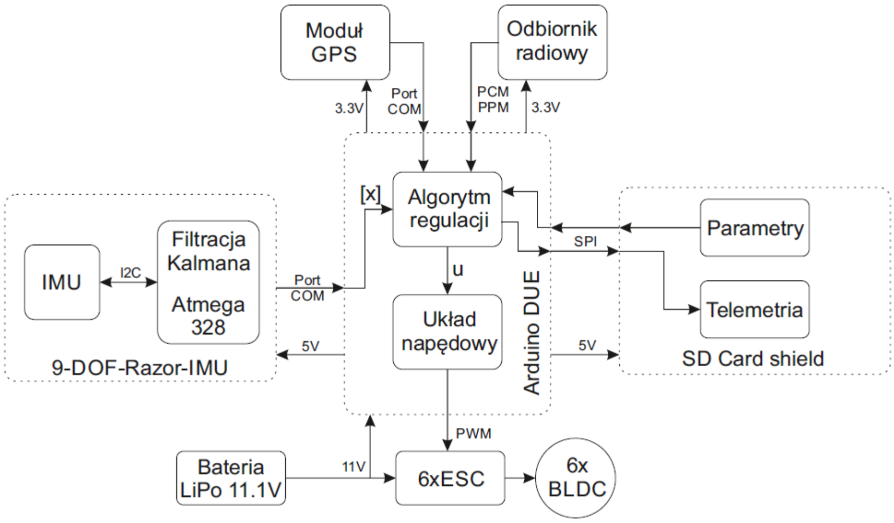
-trzema układami zawierającymi swój własny procesor sterujacy – Arduino DUE, 9-DOF-Razor-IMU oraz moduł GPS,

-jednym urządzeniem traktowanym jako urządzenie peryferyjne sterowane poprzez zdefiniowany protokół komunikacyjny – SD Card Shield

-jednym urządzeniem sterującym z modulowanym sygnałem wyjściowym PCM lub PPM – odbiornik radiowy Turnigy

-jednym urządzeniem wykonawczym z wymaganym sygnałem wejściowym PWM – sterowniki ESC

W przypadku tak rozbudowanego systemu z wieloma połączonymi wspólnie urządzeniami zaproponowano poniższą strukturę sprzętową.



Rysunek 9. Struktura sprzętowa sterownika lotu drona.

Sercem układu jest jak już wspominano moduł Arduino DUE z mikroprocesorem ARM Cortex M3 84MHz. Przy starcie programu głównego z karty SD pobierane są dane poprzez port SPI do pamięci RAM. Następnie układ Arduino wykorzystując jeden z 4 dostępnych portów szeregowych pobiera dane z procesora opracowującego dane z czujników pomiarowych MEMS. Protokół komunikacji oparty jest na zasadzie Master-Slave i wzorowany na otwartym protokole Modbus. Jednak z uwagi na niewielką ilość danych o sprecyzowanej ilości i długości słów protokół ten został maksymalnie uproszczony. Następnie wykorzystując 6 pinów obsługujących przerwania czasowe odbierane są dane z magistrali sygnałowej PCM/PPM o napięciu 3.3V z odbiornika radiowego. Tak skonfigurowany model ma możliwość odbioru danych stanu obiektu, danych parametrycznych dla algorytmu regulacji oraz danych zadawanych przez użytkownika będących sygnałem zadanym dla układu regulacji. Na tej podstawie algorytm określa zmienne sterujące i oblicza wymagane prędkości obrotowe zależne od parametrów konstrukcji. Wartości te przesyłane są do regulatorów ESC silników BLDC wykorzystując sygnał o modulacji wypełnienia PWM o napięciu 3.3V. Dopełnieniem funkcjonalności układu jest nieomawiana w pracy telemetria czyli zapis ciągły parametrów lotu na kartę SD oraz odczyt aktualnej pozycji modelu w przestrzeni z wykorzystaniem modułu GPS. Moduł ten komunikuje się z procesorem głównym wykorzystując kolejny dostępny port szeregowy. Całość zasilana jest z 3 baterii litowo polimerowych LiPo 11.1V. Dwie z nich o pojemności 3300mAh zasilają regulatory ESC i silniki BLDC a jedna mniejsza, o pojemności 1100mAh służy do zasilania elektroniki.

5.2. Algorytm regulacji

Algorytm regulacji zaimplementowany jest w całości w sterowniku głównym Arduino DUE. Dane na temat stanu modelu pobierane są z układu Razor-IMU poprzez port szeregowy z częstością odpytywania równą częstości wywoływania algorytmu. Wartość okresu czasu między przerwaniami ustawiana jest za pomocą zmiennej *#define interval_algorithm 20* i ustawiona standardowo na 20ms co odpowiada częstotliwości pracy 50Hz. Zmienne stanu, wartości zadanych i zmienne sterujące zgodne są z opisem modelu matematycznego i układu regulacji w poprzednich rozdziałach pracy.

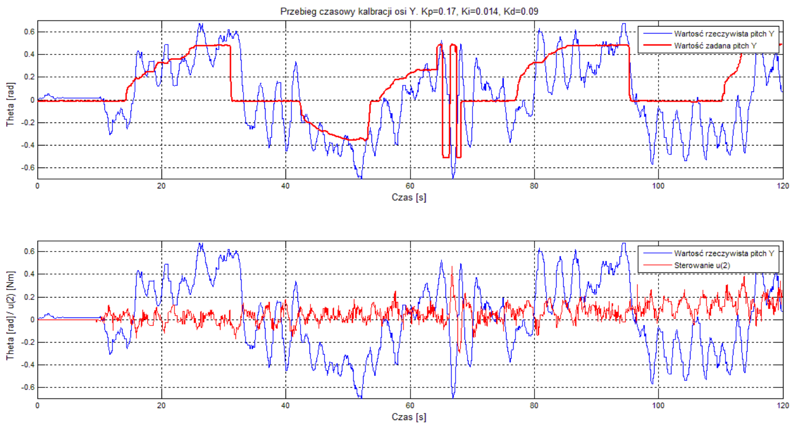
5.3. Testy stanowiskowe

Na podstawie powyższych parametrów oraz założeń z etapu projektowania dokonano powtórnego wyznaczenia macierzy wzmocnień algorytmu LQR.
Na tej podstawie oszacowano pierwotne nastawy PID:

$$\begin{aligned} Kp_{roll} &= K_k(1,1) = 0.8944 \\ Kd_{roll} &= K_k(1,2) = 0.3330 \\ Kp_{pitch} &= K_k(2,3) = 0.8944 \\ Kd_{pitch} &= K_k(2,4) = 0.3330 \\ Kp_{yaw} &= K_k(3,5) = 0.8944 \end{aligned} \tag{12}$$

Następnie zgodnie zasadami strojenia parametrów dostrojono układ tak, by w akceptowalny sposób pozostawał w stanie równowagi i reagował na zadaną wartość pochylenia pitch. W początkowych próbach wzmocnienie członu całkującego było równe zero. Następnie zostało stopniowo zwiększane do takiej wartości, aby obiekt szybciej reagował na wartość zadaną ale jednocześnie, aby nie opuścić obszaru stabilności.

Poniżej przedstawiono przebiegi czasowe na stanowisku testowym dla kilku różnych nastaw dobieranych wg zasady niezależnego wpływu parametrów PID. Początkowe wyznaczone na drodze symulacji numerycznej i przedstawione w równaniu 12 okazały się nieodpowiednie i układ w chwilę po uruchomieniu tracił stabilność.



Rysunek 10. Przebieg czasowy testu osi Y. Nastawy: Kp=0.17, Ki=0, Kd=0.19

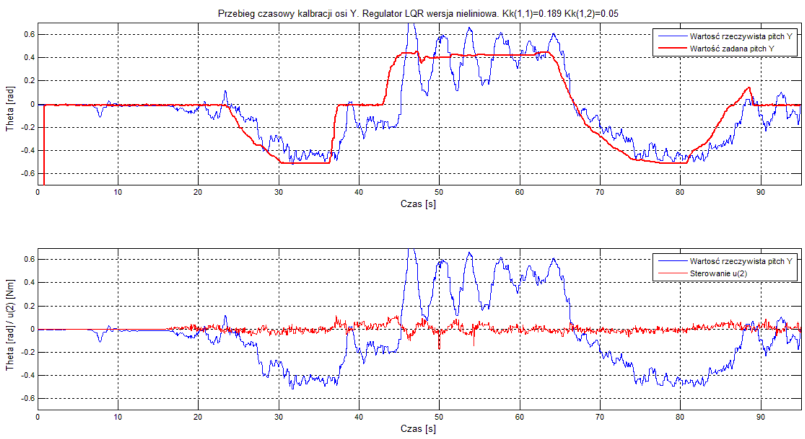
W przypadku przebiegu na rysunku 10 stwierdzono bardzo duże oscylacje o stosunkowo wysokiej jak na obiekt częstotliwości. Dokładność odwzorowania wartości zadanej również nie była satysfakcjonująca. Zdecydowano się więc na dodanie niewielkiego wzmocnienia członu całkującego. Dobierając jego wartość tak aby obiekt nie wyszedł poza obszar stabilności uzyskano wartość Ki=0.014. Spowodowało do dokładniejsze odwzorowanie wartości zadanej, jednakże nadal występowały oscylacje, a wartość sterowania miała bardzo szybkozmienny przebieg. Zdecydowano się więc na obniżenie wzmocnienia członu różniczkującego oraz zwiększenie wywoływania algorytmu PID z 20ms na 35ms aby wyeliminować problemy z różniczkowaniem numerycznym przez algorytm PID. Uzyskano znaczną poprawę przebiegu czasowego. Oscylacje mają w takim przypadku mniejszą amplitudę oraz częstotliwość a odwzorowanie wartości zadanej pozostaje na niezmienionym poziomie. Przyglądając się wartościom sterowania u(2) w Nm zaobserwować można poprawne zachowanie algorytmu. W przypadku większego wychylenia przyłożony zostaje odpowiednio duży moment do danej osi aby bardzo szybko sprowadzić układ do położenia zadanego. Jednakże z uwagi na dynamikę obiektu nie występuje zjawisko „wyhamowania” układu przed osiągnięciem stanu zadanego. Napotkano więc sprzeczność wymagań stawianych członowi D układu regulacji. Z jednej strony intuicyjne wydaje się zwiększenie wzmocnienia członu różniczkującego, który umożliwia analizę pochodnej wartości zadanej (prędkości kątowej) powinno spowodować wyhamowanie obiektu na podstawie stanu aktualnej prędkości kątowej, z drugiej jednak strony nie jest wskazane zwiększanie wzmocnienia Kd z uwagi na wzmacnianie błędów różniczkowania numerycznego i powstawanie szumów na wyjściu regulatora, co jeszcze bardziej wytrąca układ z równowagi.

Kolejne próby przeprowadzono na zmodyfikowanych wartościach zaprojektowanego uprzednio regulatora LQR w wersji nieliniowej (adaptacyjnej). Dobierając odpowiednio wartości macierzy wag $\boldsymbol{Q_k}$ i $\boldsymbol{R_k}$ uzyskano zbliżone do metody ręcznej nastawy odpowiadające proporcjonalnemu wzmocnieniu uchybu. Następnie modyfikując masowy moment bezwładności dobrano wzmocnienie części pochodnej uchybu, który w przypadku regulacji modalnej i zastosowaniu bloku dokładności statycznej ***Nk*** odpowiada prędkości kątowej modelu w danej osi.

$$\mathrm{Q_k} = \begin{bmatrix} 0.36 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.36 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.36 \end{bmatrix} \mathrm{R_k} = \begin{bmatrix} 10 & 0 & 0 \\ 0 & 10 & 0 \\ 0 & 0 & 10 \end{bmatrix} \tag{13}$$

$$\mathrm{K_k} = \begin{bmatrix} 0.1897 & 0.0485 & 0 & 0 & 0 \\ 0 & 0 & 0.1897 & 0.0485 & 0 \\ 0 & 0 & 0 & 0 & 0.1897 \end{bmatrix} \tag{14}$$

W wyniku tak dobranych nastaw uzyskano przebiegi charakteryzujące się mniejszą częstotliwością i amplitudą oscylacji obiektu wokół wartości zadanej.



Rysunek 11. Przebieg czasowy testu osi Y. Regulator LQR w wersji nieliniowej

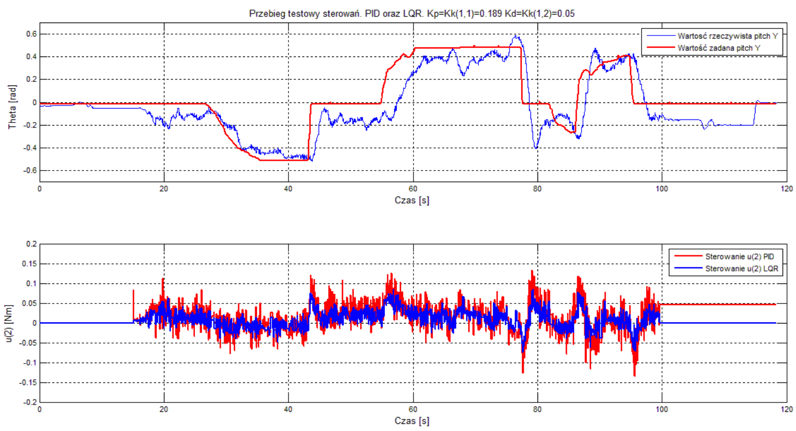
Dalsze próby strojenia układu nie przynosiły pożądanych efektów a zachowanie obiektu nie wiele różniło się od tego przedstawionego na rysunku 11 w przypadku regulacji PID jak i adaptacyjnej LQR. Zdecydowano się na analizę możliwych przyczyn problemu oscylacji obiektu oraz nad sposobem ich eliminacji.
-bezwładność układu napędowego,
-zawirowania powietrza pod dronem na stanowisku testowym,
-drgania modelu i zakłócenia układu pomiarowego IMU,
-problemy z różniczkowaniem numerycznym w przypadku PID,
-nieodpowiedni czas aktualizacji pomiarów orientacji obiektu (obecnie 20ms),
-nieodpowiedni czas wywoływania algorytmu PID (obecnie 35ms),
-nieodpowiednie parametry filtracji NKF dla układu IMU,
-różniczkowanie wewnątrz algorytmu PID.

5.4. Testy porównawcze algorytmów

Obserwując przebiegi z wcześniejszych pomiarów stwierdzono, że bardzo duży wpływ na stabilizację obiektu wywiera część odpowiadająca za pochodną uchybu kąta. W przypadku regulatora PID jest to wzmocnienie części różniczkującej, w przypadku regulacji modalnej jest to część macierzy wzmocnienia ***Kk*** odpowiadająca za wzmocnienie prędkości kątowej modelu. W obu tych przypadkach wartości podlegające wzmocnieniu wyznaczane są w inny sposób mający znaczący wpływ na jakość regulacji.

1. W przypadku algorytmu PID w każdej pętli regulacji w mikroprocesorze wyznaczany jest uchyb regulacji metodą różnic skończonych a następnie wzmacniany poprzez odpowiedni współczynnik. W takim przypadku jeśli częstotliwość pracy jest nieodpowiednio dobrana do częstotliwości aktualizacji danych pomiarowych jest prawdopodobne, że w pewnych momentach wyznaczona na drodze różnic skończonych wartość pochodnej uchybu będzie zerowa, a następnie znacznie większa niż rzeczywista wartość pochodnej. Tak naprawdę będzie to błąd metody numerycznej a w przypadku wyznaczenia wartości zerowej, rzeczywista wartość

pochodnej uchybu będzie niezerowa. Jest to ewidentna wada algorytmu PID w przypadku gdy wartość pochodnej uchybu jest istotna do stabilizacji obiektu.
2. W przypadku algorytmu LQR w wersji liniowej bądź nieliniowej powyższy problem można wyeliminować przy zastosowaniu filtracji sygnałów pomiarowych wartości regulowanych bądź przy zastosowaniu obserwatora pełnego lub obniżonego rzędu Luenbergera. W pracy opisano filtrację przy pomocy filtru Kalmana, która okazuje się idealnym rozwiązaniem w tej sytuacji. Eliminuje problemy obliczania pochodnych metodą różnic skończonych gdyż każdy z sygnałów pomiarowych – kąt jak i prędkość kątowa – wyznaczane są w drodze filtracji. Wówczas nawet gdy cyfrowy sygnał pomiarowy w pewnym przedziale *dt* będącym okresem wykonywania algorytmu nie ulega zmianie, to jego pochodna w tym samym czasie nie jest zerowa tylko odpowiada rzeczywistej – odfiltrowanej – wartości pochodnej (w tym przypadku prędkość kątowa). Takie postępowanie pozwala na bardziej efektywne wykorzystanie wzmocnienia odpowiadającego za prędkość kątową modelu. Czasy wykonywania algorytmu regulacji są w znacznym stopniu uzależnione od jakości filtracji a nie od aktualizacji stanu danych pomiarowych.
Wykonując badania testowe dostosowano program sterujący tak aby jednocześnie wykonywał się algorytm regulacji PID oraz LQR. Sam pomiar wykonano najpierw ręcznie odchylając drona od zerowego położenia równowagi na stanowisku pomiarowym oraz wprowadzając ręcznie w oscylacje o różnej amplitudzie i częstotliwości. Okres wykonywania algorytmu ustawiony na 20ms dla obu pętli regulacji.

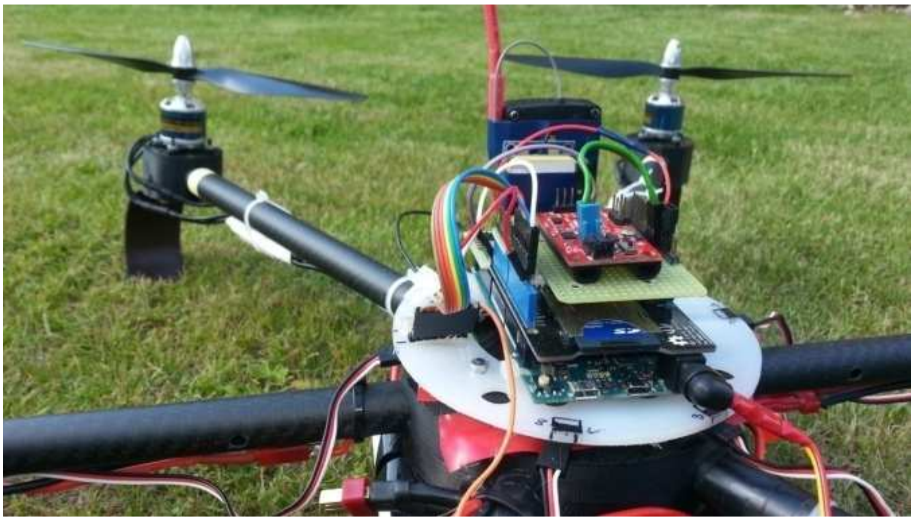


Rysunek 12. Porównanie sterowania wg algorytmu PID oraz LQR dla tych samych nastaw – praca algorytmu LQR w wersji nieliniowej

Powyższe przebiegi potwierdzają założenia dotyczące błędów różniczkowania numerycznego regulacji PID. Dla tego typu regulatora wartości sterowania u_2 charakteryzują się większym zaszumieniem sygnału. W efekcie praca takiego algorytmu przy zwiększaniu parametru Kd powoduje zwielokrotnianie szumów spowodowanych metodami numerycznymi a nie zwiększanie faktycznej pochodnej sygnału regulowanego. Dla regulacji modalnej zjawisko to jest zminimalizowane z uwagi na uprzednie filtrowanie przebiegów wszystkich zmiennych stanu modelu które następnie są zwielokrotniane w pętli sprzężenia zwrotnego. Uwagę zwraca również uchyb w stanie ustalonym zwłaszcza w przypadku zerowej wartości zadanej (gdy blok dokładności statycznej nie jest brany pod uwagę). Błąd ten jest wielkości około 0.15 rad co skutkuje trwałym przechyłem drona. Powodem jest najprawdopodobniej brak wyważenia obiektu lub asymetria ciągu śmigieł spowodowana niedokładnym montażem lub uszkodzeniem powierzchni samego śmigła. W przypadku zastosowania regulacji PID problem ten może zostać wyeliminowany z uwagi na występującą w algorytmie część całkującą. Przy zastosowaniu regulacji modalnej wymagane okazuje się więc dodanie dodatkowej części całkującej w osobnej pętli regulacji z minimalnym wzmocnieniem.

6. Testy lotu i wnioski

Po wykonaniu serii pomiarów, testów i adaptacji parametrów, uwolniono obiekt od więzów i wykonano serię kilku prób lotu modelu. Jak się okazuje nastawy dobrane w teorii na stanowisku testowym okazały się zbyt agresywne. Model przy próbie wzniesienia reagował zbyt gwałtownie, i nawet niewielkie przechylenia powodowały natychmiastową reakcje układu i przechył w stronę przeciwną. Dopiero kolejnie zmniejszenie współczynników wzmocnienia proporcjonalnego $\boldsymbol{Kp_{roll}=K_{k(1,1)}}$ oraz $\boldsymbol{Kp_{pitch}=K_{k(2,3)}}$ skutkowało stabilniejszym lotem na niewielkiej wysokości. Nastawy dobierane były doświadczalnie po każdej próbie lotu zgodnie z doświadczeniem autora nabytym na etapie testów stanowiskowych.



Rysunek 13. Modułowy układ sterowania. Sterownik, IMU, karta SD, radio 2.4GHz, GPS

Nie udało się jednak osiągnąć długotrwałego stabilnego lotu na wysokości powyżej 1m. Problemem okazywało się stabilizowanie prędkości obrotu własnego wokół osi z – prędkość rotacji Yaw. Dobór nastaw regulacji okazuje się bardzo trudny z uwagi na brak konkretnych danych o współczynniku oporu powietrza śmigła *d*. Ponadto sam model matematyczny, którym posłużono się do wyznaczania nastaw regulacji nie uwzględniał bezwładności pojedynczego śmigła, a to właśnie ta wielkość ma znaczący wpływ na wprowadzenie do układu momentu obrotowego wokół osi pionowej, dzięki któremu oś ta stała by się w pełni sterowalna. Ignorując na chwilę obecną tą część pętli regulacji dążono do stabilnego zwisu nad ziemią, nawet z obracającym się wokół osi pionowej dronem. Takie próby kończyły się jednak gwałtownym zwiększaniem prędkości liniowej w kierunku horyzontalnym. Dron obracając się wokół osi pionowej z prędkością około 1 obr/sek przemieszczał się nad ziemią starając stabilizować przechyły wokół osi ***X*** oraz ***Y*** co potwierdza działanie tej części algorytmu stabilizacji wg nastaw dobranych na podstawie modelu matematycznego i skorygowanych na etapie testów stanowiskowych. Testy stanowiskowe obrotu Yaw są trudne do zrealizowania a dobieranie nastaw regulatorów jest możliwe jedynie na drodze licznych testów lotu modelu, co autor pozostawia to późniejszych rozważań i badań.

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SYMULACJA MES PROCESU TECHNOLOGICZNEGO OBRÓBKI PLASTYCZNEJ

Streszczenie: W referacie zaprezentowano symulację MES procesu technologicznego produkcji przykładowej wytłoczki. Dla tej wytłoczki zaproponowano proces technologiczny składający się z 12 operacji, wykonano odpowiednie model CAD narzędzi, zbudowano ich modele dyskretne oraz przeprowadzono symulację. Omówiono najważniejsze wyniki symulacji. Sformułowano wnioski.

Słowa kluczowe: tłoczenie, MES, CAD, Autoform

SIMULATION FEM OF SAMPLE METAL FORMING TECHNOLOGY

Summary: The paper presents the FEM simulation of technological proces accomplishment of sample drawpiece. Proposed technological process consists of 12 operations. Done appropriate model CAD tools, created their discrete models and done simulation. The main results of the siumlation were discussed. Conclussions were drawn.

Keywords: metal forming, FEM, CAD, Autoform

1. Wstęp

Projektowanie procesów technologicznych obróbki plastycznej (tłoczenie) wytłoczek jest bardzo trudne i wymaga od inżynierów dużej wiedzy oraz doświadczenia. Inżynierowie zajmujący się tego typu problemami na wstępie zbierają wszelkie niezbędne dane takie jak: wymagania dotyczące dokładności kształtowo wymiarowej wytłoczki, rodzaj materiału z jakiego jest wykonana wytłoczka, specjalne wymagania i zalecenia odbiorcy [1]. Po analizie tych danych opracowują wstępny proces technologiczny składający się z poszczególnych operacji takich jak wykrawanie, ciągnienie, zaginanie, dziurowanie itp. Inżynierowie zajmujący się tego typu

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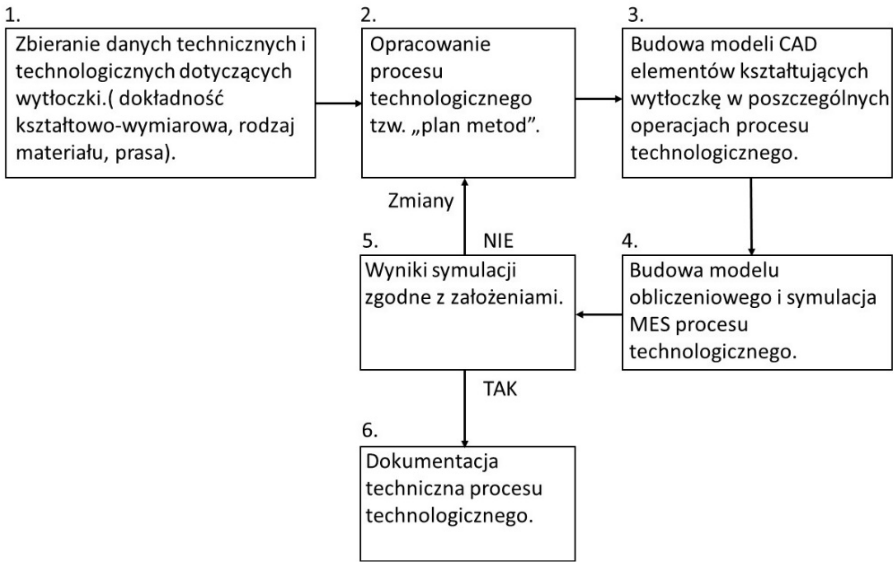
problemami nazywają taki proces technologiczny **planem metod** [2]. Po opracowaniu procesu technologicznego należy sprawdzić czy jest on poprawny, czy po wykonaniu wszystkich operacji na samym końcu otrzyma się wytłoczkę, która spełnia wymagania odbiorcy. Do analizy poprawności procesu technologicznego bardzo przydatne są programy do symulacji Metodą Elementów Skończonych procesów tłoczenia takie jak PamStamp, Autoform, DynaForm. W tego typu oprogramowaniu można wykonać symulacje poszczególnych operacji procesu technologicznego wytwarzania wytłoczki i na końcu sprawdzić czy wytłoczka nie posiada rejonów ze zbyt dużymi pocienieniami lub nawet pęknięciami lub rejonów ze zmarszczeniami materiału [4]. Można też zjawisko sprężynowania powrotnego nie jest zbyt duże. Oprogramowanie to pozwala także obliczyć siły jakie są niezbędne do wytłoczenia wyrobu – a tym samym określić nacisk prasy na której będzie produkowana wytłoczka. Sposób postępowania podczas prowadzenia analizy numerycznej procesów tłoczenia przedstawiono na rysunku 1. Pierwszym etapem jest zbieranie wszelkich informacji technicznych i wymagań kształtowo wymiarowych dotyczących analizowanej wytłoczki. W drugim etapie projektuje się proces technologiczny wytłoczki, opracowuje się poszczególne operacje. W kolejnych etapach buduje się model CAD narzędzi (matryc, stempli, docisków, wykrojników) biorących udział w poszczególnych operacjach procesu technologicznego. Opracowane modele CAD narzędzi (głównie są to modele powierzchniowe elementów kształtujących narzędzi) służą do przygotowania modeli dyskretnych na potrzeby symulacji numerycznych procesu. W kolejnym kroku wykonywana jest symulacja Metodą Elementów Skończonych i analiza uzyskanych wyników.

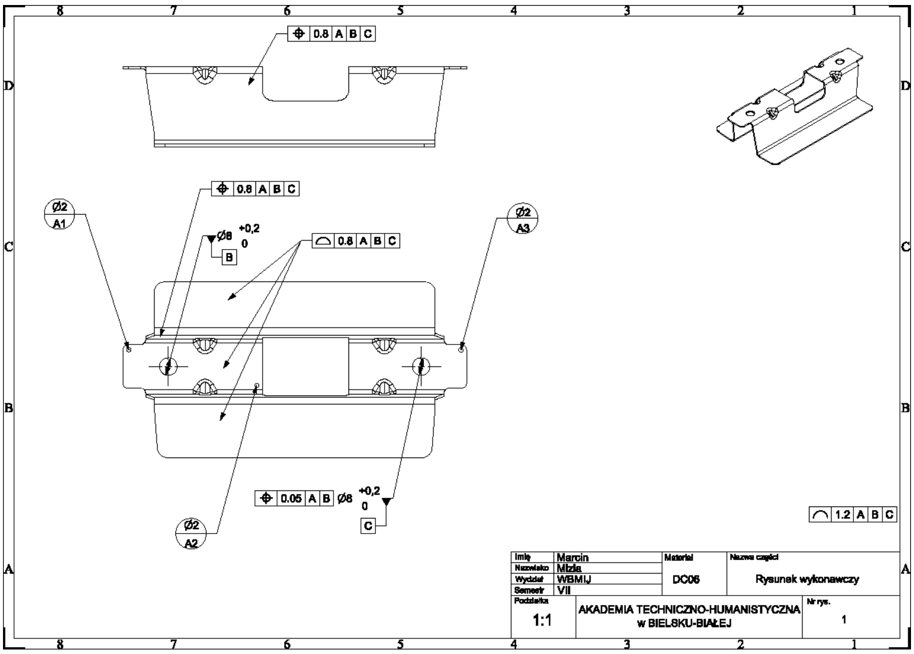


Rysunek 1. Plan postępowania przy projektowaniu procesu technologicznego - planu metod

Jeśli wyniki symulacji są poprawne i satysfakcjonujące, to zakłada się że opracowany proces technologiczny jest poprawny. Jeśli wyniki wskazują na duże prawdopodobieństwo pęknięć wytłoczki, zlokalizowano zbyt duże rejony ze zmarszczkami lub sprężynowanie powrotne ma zbyt duże wartości, zmienia się proces technologiczny poprzez dodanie kolejnych operacji. Czasami proponuje się nieznaczną korektę kształtu wytłoczki w taki sposób aby poprawić jakość wytłoczki (jej technologiczność, dokładność kształtowo-wymiarową). Opisane wyżej etapy zostaną przedstawione na przykładowej wytłoczce, która jest częścią składową karoserii samochodu.

2. Proces technologiczny (plan metod)

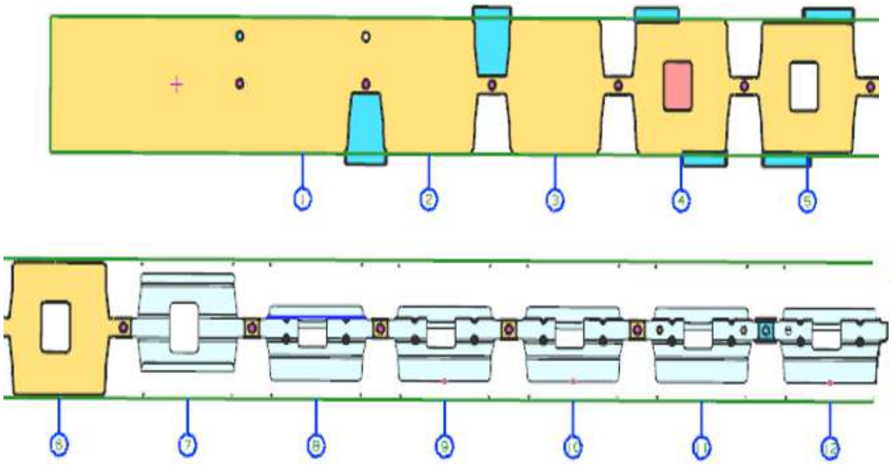
Planowanie operacji procesu technologicznego tłoczenia jest bardzo ważnym etapem planowania produkcji, bo decyduje o jakości wytłoczki, rodzaju tłocznika oraz o ekonomice produkcji danej wytłoczki. Na rysunku 2 przedstawiono rysunek techniczny części karoserii samochodu osobowego wraz ze stosownymi wymaganiami technicznymi.



Rysunek 2. Rysunek wykonawczy wytłoczki

Dla tej części został opracowany proces technologiczny składający się z 12 operacji przeprowadzanych na tłoczniku postępowym. Pierwsze sześć operacji to operacje dziurkowania i okrawania, kolejne operacje to operacje kształtujące wytłoczkę. Ostatnie dwie operacje to operacje obcięcia wyrobu. Duże znaczenie w projektowaniu planu operacji ma doświadczenie technologa, ponieważ w literaturze nie można znaleźć zbyt wielu pozycji opisujących ten problem.

Plan operacji został opracowany w programie NX [5]. Posiada on specjalny moduł Progressive Die Wizard. Można w nim budować plan operacji dzięki wielu przydatnym i specjalizowanym narzędziom CAD, m.in. do rozwijania powierzchni, odginania krawędzi itp. Przystępując do projektowania planu operacji w pierwszym etapie należy utworzyć rozwinięcie wytłoczki. W dalszej kolejności modelujemy następne operacje tak aby z płaskiej wstęgi blachy na początku procesu uzyskać gotowy wyrób po ostatniej operacji [2, 3]. Cały proces technologiczny produkcji analizowanego wyrobu, wykonany w oprogramowaniu NX przedstawiono na rysunku 3.



Rysunek 3. Model CAD planu operacji

Poszczególne operacje procesu technologicznego:

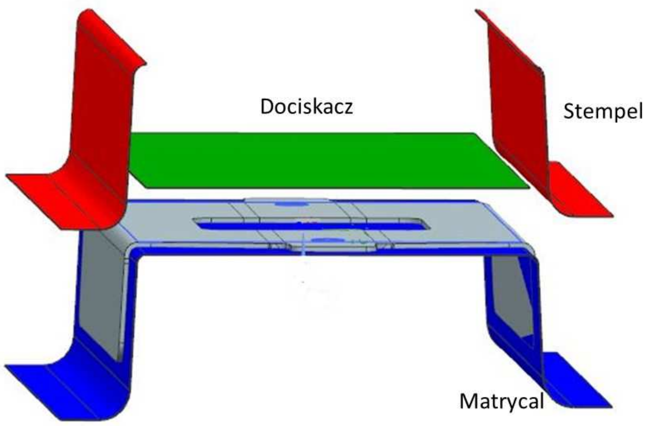
1. pilotowanie,
2. wykrawanie,
3. wykrawanie,
4. wykrawanie,
5. wykrawanie,
6. pusty skok,
7. gięcie do góry,
8. gięcie w dół,
9. dotłaczanie,
10. pusty skok,
11. dziurkowanie,
12. odcinanie.

3. Symulacje

Symulacje wszystkich operacji procesu tłoczenia wykonano w oprogramowaniu AutoForm, który przyjął się jako standard w przemyśle samochodowym, szczególnie do analizy poprawności poczynionych założeń w procesie technologicznym produkcji wytłoczek. Proces przygotowania modeli do symulacji można podzielić na dwa etapy:

a) Przygotowanie modeli CAD narzędzi (matryc, stempli, docisków), linii okrawania dla każdej z 12 zaplanowanych operacji. Te prace prowadzi się w środowisku CAD na przykład w NX, CATIA.
b) Budowa modeli dyskretnych narzędzi na potrzeby symulacji, podobnie jak w etapie pierwszym dla wszystkich 12 zaplanowanych operacji. Modele dyskretne buduje się w środowisku Autoform.

Na rysunku 4 przedstawiono przykładowe powierzchnie narzędzi dla operacji siódmej (rys. 3), które składają się z powierzchni stempla, matrycy oraz docisku.

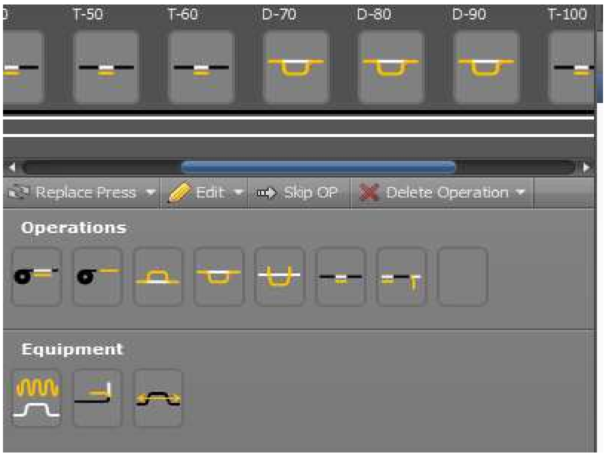


Rysunek 4. Model CAD narzędzi operacji siódmej

W środowisku Autoform buduje się modele dyskretne formatki, narzędzi (matryc, stempli, dociskaczy), linii okrawających wytłoczkę, linii wykrawających otwory itp. Prace te wykonuje się w następujących etapach:

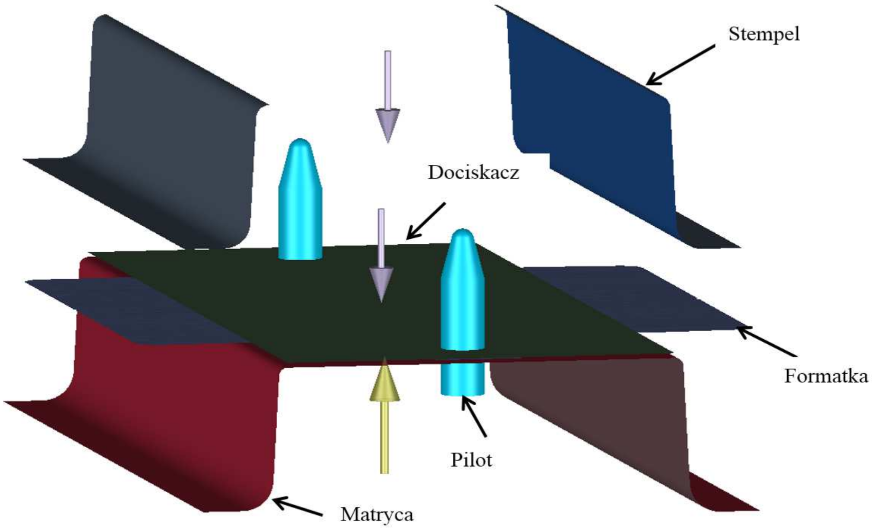
1. Import powierzchni CAD narzędzi tłoczących, linii okrawających oraz modelu CAD formatki.
2. Zdefiniowanie operacji, które będą wchodzić w skład symulacji procesu technologicznego.
3. Określenie kierunku tłoczenia (ruchu matryc lub stempli).
4. Zdefiniowanie właściwości materiału (wybór z bardzo bogatej bazy materiałów stosowanych w przemyśle samochodowym). Dla analizowanego przypadku zdefiniowano materiał DC05.
5. Zdefiniowanie formatki i grubości, orientacji itp. W analizowanym przypadku formatka miała grubość 1,15 mm.
6. Opracowanie modeli dyskretnych stempli, matryc, dociskaczy, linii okrawających w kolejnych operacjach.
7. Zdefiniowanie parametrów procesu (szybkości ruchomych elementów narzędzi, współczynników tarcia).
8. Przeprowadzenie symulacji wszystkich operacji procesu technologicznego wytwarzania wytłoczki.
9. Analiza wyników.

Na rysunku 5 przedstawiono okno dialogowe narzędzi do projektowania poszczególnych operacji procesu technologicznego w oprogramowaniu Autoform. Dostępne są operacje wykrawania, tłoczenia na prasie pojedynczego i podwójnego działania, zaginanie itp.



Rysunek 5. Okno dialogowe narzędzi do projektowania procesu technologicznego tłoczenia

Na rysunku 6 przedstawiono model dyskretny narzędzi i formatki siódmej operacji procesu technologicznego analizowanej wytłoczki. Składa się on z matrycy, stempla, dociskacza, formatki oraz pilotów. Modele matrycy, stempla, dociskacza, oraz pilota są modelami sztywnymi. Formatka jest modelowana elementami powłokowymi. Do zamodelowania interakcji pomiędzy tymi elementami zastosowano elementy kontaktowe z tarciem.

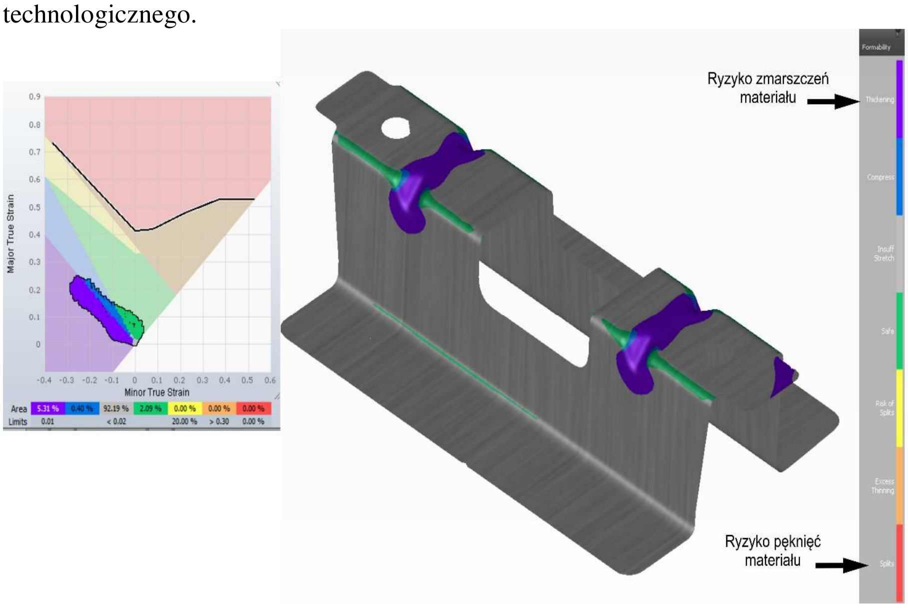


Rysunek 6. Modele dyskretne narzędzi dla operacji siódmej w programie AutoForm

Zaprojektowany proces technologiczny produkcji wytłoczki był analizowany w solverze oprogramowania AutoForm.

4. Wyniki analizy

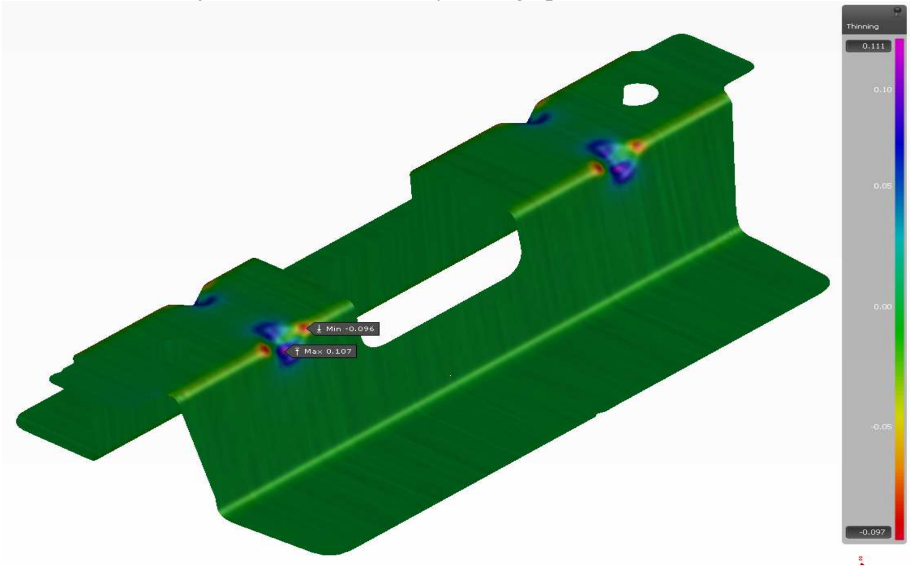
Inżynierowie zajmujący się projektowaniem procesów obróbki plastycznej przede wszystkim analizują warstwice na tzw diagramie FLD który jest wykresem odkształceń wytłoczki w płaszczyźnie odkształceń głównych ε_1 i ε_1. W zależności od wartości odkształcenia w konkretnym miejscu wytłoczki, można określić ryzyko powstawania pęknięć czy też zmarszczeń [1].
Warstwice FLD (Forming Limit Diagram) – są to warstwice które pokazują na zarysie wytłoczki, miejsca występowania pęknięć oraz zmarszczeń materiału. Na rysunku 7 przedstawiono warstwice FLD wytłoczki po ostatniej operacji analizowanego procesu technologicznego.



Rysunek 7. Warstwice FLD po ostatniej operacji procesu technologicznego

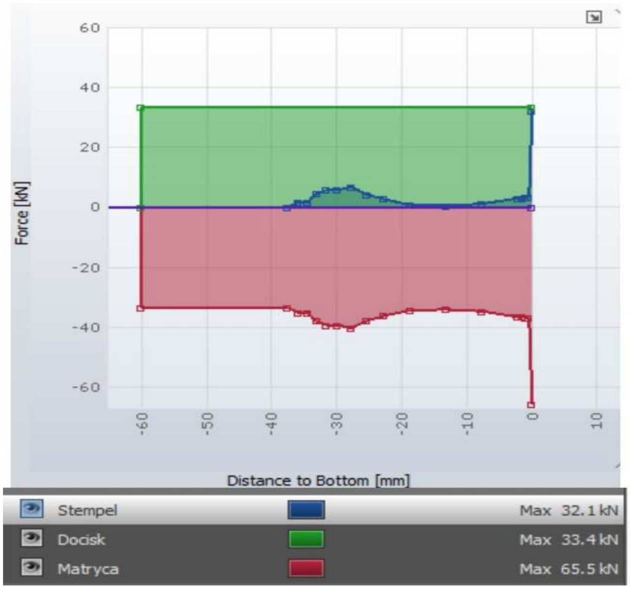
Analizując rysunek 6 można zauważyć, że na 5% powierzchni wytłoczki występuje ryzyko powstania zmarszczek. Jest jednak ono w miejscach które nie są powierzchniami przylegania wytłoczki do innych części karoseryjnych. Dlatego można uznać to za dopuszczalne. Większość powierzchni wytłoczki (92.19%) nie odkształciła się plastycznie.

Warstwice przedstawiające pocienienie wytłoczki są kolejnym ważnym wynikiem symulacji procesów tłoczenia. Na rysunku 8 przedstawiono warstwice pocienienia analizowanej wytłoczki. Maksymalne pocienienie wytłoczki wynosi 9,6%. Jest to wartość dużo mniejsza niż wartości maksymalnego pocienienia (38%) dla stali DC05.



Rysunek 8. Warstwice pocienienia wytłoczki po ostatniej operacji procesu technologicznego

Na rysunku 9 przedstawiono siły działające na narzędzia, które zostały obliczone w siódmej operacji – operacji gięcia. Analizując rysunek 8 można zauważyć że siła działająca na stempel to 32,1 kN, na docisk to 33,4 kN – a na matrycę to suma tych dwóch sił – 65,5 kN.



Rysunek 9. Siły działające na narzędziach w operacji siódmej (gięcia)

Aby obliczyć niezbędny nacisk prasy potrzebny do wykonania danej wytłoczki należy zsumować wszystkie siły występujące w kolejnych operacjach. Dla przykładowej wytłoczki niezbędny nacisk prasy wynosi 490kN (50T).
Jak pokazały przedstawione wyniki symulacji MES zaproponowany proces technologiczny produkcji wytłoczki jest poprawny. Nie stwierdzono nadmiernego pocienienia wytłoczki, nie ma dużego prawdopodobieństwa powstawania zmarszczek. Proces technologiczny nie wymaga korekty.

5. Wnioski

Analizując uzyskane wyniki można stwierdzić że:

1. Projektując proces technologiczny tłoczenia części karoserii samochodowej należy wziąć pod uwagę szereg czynników takich jak: dokładność kształtowo- wymiarowa wytłoczki, rodzaj materiału z jakiego ona jest wykonana, wymagania i zalecenia zamawiającego wytłoczkę, rodzaj prasy jaką dysponuje producent itp. Należy też mieć duże doświadczenie i wiedzę fachową w tej dziedzinie.
2. Poprawność opracowanego procesu należy zweryfikować na drodze symulacji numerycznych. Wyniki tych symulacji pozwolą na sprawdzenie czy proces technologiczny jest poprawny, czy nie należy dodać kolejnych operacji lub zmodyfikować istniejące.
3. Wyniki symulacji numerycznych są bardzo pomocne dla inżynierów zajmujących się problematyką projektowania procesów technologicznych obróbki plastycznych. Pozwolą uniknąć kosztownych błędów już na etapie projektowania procesu.

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SIMULATION OF NON-TRANSVERSE SURFACE CRACKS IN THE MACHINERY AND STRUCTURES ELEMENTS

Summary: In this paper the analysis of the stress intensity factors (SIF) for semielliptical cracks in low alloy steel is performed based on finite element method. The results of the study of stress intensity factors along the front surface cracks under uniaxial tensile of plate of finite size and the results of SIF distribution under mutual influence of two collinear cracks is presented.

Keywords: semielliptical surface crack, finite element method, stress intensity factor

SYMULACJA PĘKNIĘĆ POWIERZCHNIOWYCH W ELEMENTACH MASZYN

Streszczenie: W niniejszym artykule wyznaczono wartość współczynników intensywności naprężeń (SIF) dla pęknięć pół eliptycznych w niskostopowej stali wykorzystując metodę elementów skończonych. Zaprezentowano wyniki badań dla płyty o skończonej wielkość, obciążonej w wzdłuż powierzchni normalnej do płaszczyzny przekroju. Zasymulowano jedno oraz dwa pęknięcia zmęczeniowe w materiale.

Słowa kluczowe: pęknięcia pół eliptyczne powierzchniowe, metoda elementów skończonych, współczynnik intensywności naprężeń

1. Introduction

Much of machinery and building construction elements have structural and technological stress concentrators, which in operating conditions cause the accumulation, formation and development of damage [1]. The most common defects causing the destruction of products are semielliptical surface cracks. At the same time, the emergence and development of multiple surface cracks interacting with each other takes place [2]. Durability (residual life) assessment of structures with cracks is usually associated with the definition of stress intensity factor (SIF), which

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characterizes the stress-strain state (SSS) at the crack tip. Calculation of SIF in real designs is a difficult task, given the geometry and boundary conditions, especially for three-dimensional objects.

Analysis of publications [3, 4, 5] shows that to date there have not been received analytical values of the SIF along a contour of an elliptical or semielliptical crack. For the evaluation of SIF for such cracks the computational methods are used, in particular finite element method (FEM) [6], which is the most versatile due to its simple interpretation and developed mathematical software. The task of determining SIF is much more complicated when considering several surface cracks that are close to each other and undergo mutual influence. The study on the subject is published in [2,6,7,8]. These studies are of significant practical value to make geometrical schemes of the defects required for the calculation of structures strength and durability, since in [6] sufficiently conservative approximation of the two cracks replaced with one longer is reflected.

In this regard, the purpose of the paper is to simulate the interference of two collinear surface semielliptical cracks under the uniaxial tensile of plates of finite size with the finite element methods.

2. Main thesis

Stress intensity factor K_{I} in any part of the front surface semielliptical crack can be calculated as [3]:

$$K_{\mathrm{I}} = \frac{\sigma_n \cdot \sqrt{\pi a}}{E(k)} \cdot F_s\left(\frac{a}{c};\frac{a}{t};\frac{c}{b};\varphi\right) \tag{1}$$

where σ_n – nominal tension, MPa; $F_s\left(\frac{a}{c};\frac{a}{t};\frac{c}{b};\varphi\right)$ – correction function, which includes the effect of free surfaces; $E(k)$ - complete elliptical integral of the second kind.

2.1. Calculation of SIF for one crack

To determine the SIF at the deepest point A and points B and C of semielliptical surface crack (Fig.1) located on the surface of the element, the computational methods [10] are used to obtain the following dependence:

$$K_{I.A} = \sigma\sqrt{\pi a}(M/F) \tag{2}$$

$$K_{I.B} = \sigma\sqrt{\pi a}(M/F)S \tag{3}$$

Where:

$$M = (1{,}13 - 0{,}09\alpha) + \left(-0{,}54 + \frac{0{,}89}{0{,}2 + \alpha}\right)\beta^2 +$$

$$+\left(0{,}5\frac{1}{0{,}65+\alpha} + 14{,}0(1-\alpha)^{2{,}4}\right)\beta^4 \tag{4}$$

$$F = \sqrt{1 + 1{,}464\alpha^{1.65}} \tag{5}$$

$$S = (1{,}1 + 0{,}35\beta^2)\sqrt{\alpha} \tag{6}$$

Where: $\alpha = a/c$; $\beta = a/t$; a – crack depth; c – half length of the crack; t – thickness of the sample.

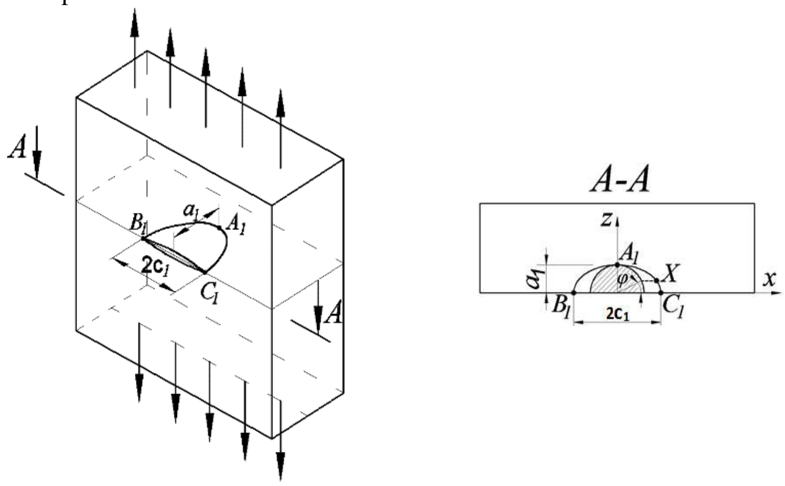


Figure 1. Semi-elliptical surface crack in a finite size plate

The distribution of stress intensity factors along the crack front is obtained with finite elements method. A specialized software package «ANSYS» is used [11]. Semielliptical surface crack is simulated in finite size plate under tensile stress. A three-dimensional sample model with a global elements mesh and model of the crack area with a local mesh are created (Figure 2).

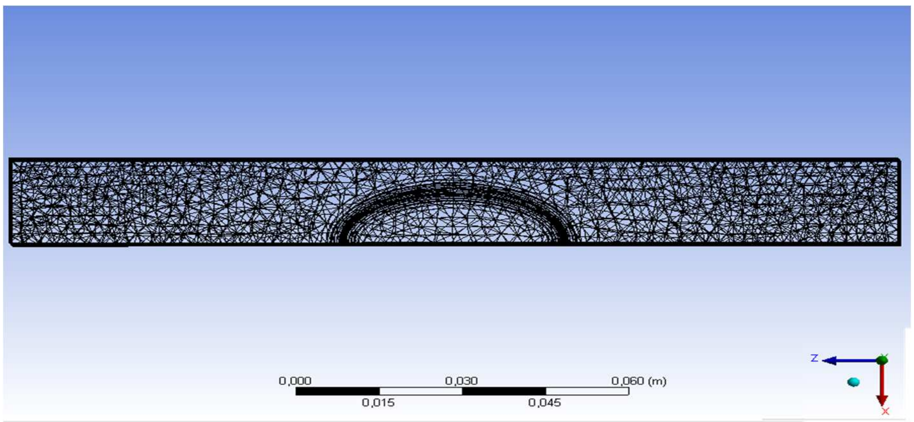
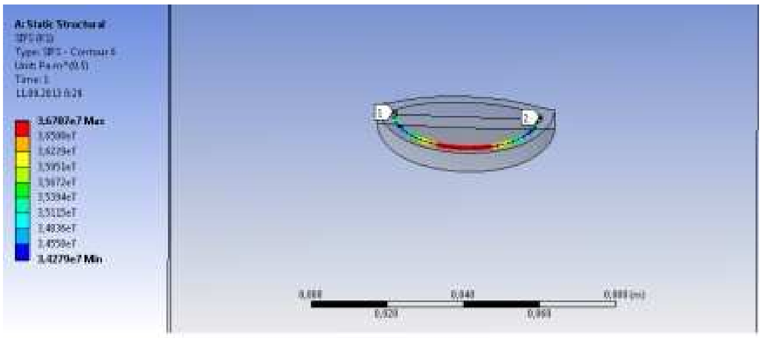


Figure 2. Finite element model of semi-elliptical surface crack

Mesh elements are tetrahedral. The total number of elements is 375,000. The size of global mehs elements is 2.75 mm, for a local mesh the size is 0.1 mm. The sample of thickness t=20 mm made of low-alloy steel with yield stress limit σ=350 MPa is modelled. Poisson's ratio at elastic deformation is ν=0,3.

As a result of calculations the SIF values along the contour of surface cracks φ= 0… 2π identified at 33 points are obtained.



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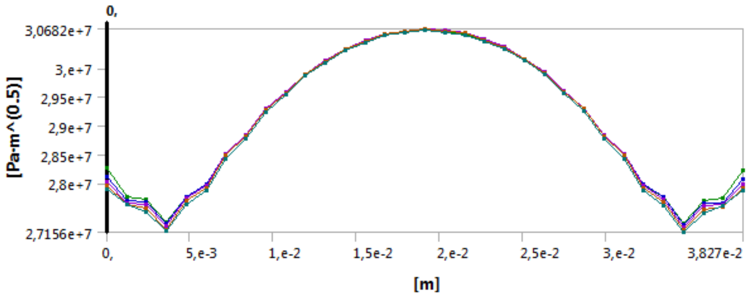

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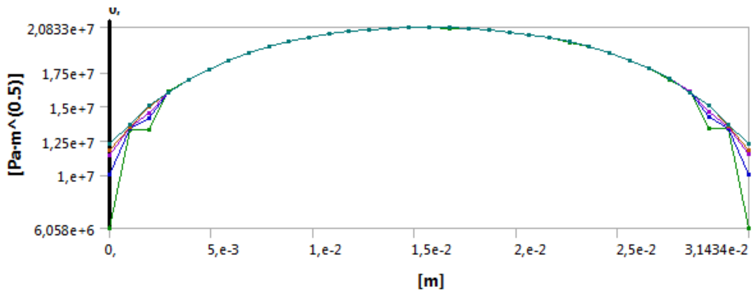

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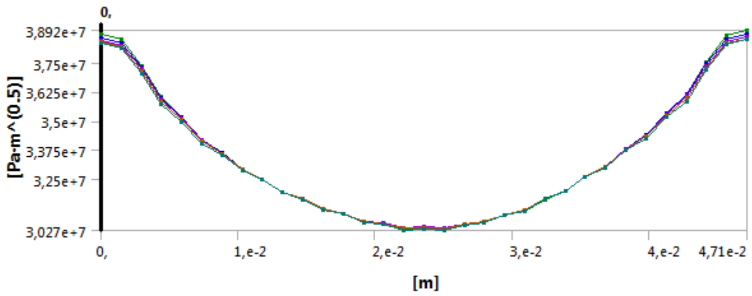


Figure 3. Calculation of SIF along the front of semi-elliptical surface crack:
a) a/c=0,6; b) a/c=0,2; c) a/c=1,0

Fig. 3 shows the results of SIF calculations for three cases: *a/c*=0.2; *a/c*=0.6 and *a/c*=1.0 with a fixed size of surface semielliptical crack of 2c=15 mm.

Comparison of the SIF K_I calculation results along the crack front, obtained using formulas 2-6, with the data acquired with FEM [9] indicates the following. Qualitative changes in SIF along cracks contour in both studies coincide. Comparing the value of SIF K_I indicates a good convergence of results (a difference of 2%) (Fig.3,a).

Analysis of the SIF values along the contour of surface cracks with different characteristic dimensions of *a/c*=0.2 and *a/c*=1.0 indicates a significant energy instability at the crack contour. This is evidenced by the ratio of maximum and minimum values of SIF at the crack contour: $\frac{K_{I_A}}{K_{I_{B,C}}}$ = 1,67 at *a/c*=0,2 and $\frac{K_{I_{B,C}}}{K_{I_A}}$ = 1,29 at *a/c*=1. With such proportions crack contour reaches energetically stable form: in the first case at *a/c*=0.2 the crack will advance deeper; and in the second case at *a/c*=1.0 the crack first expands on the surface until certain stabilization of contour is attained at *a/c*=0,6…0.7 [3]. Thus, at *a/c*= 0.6 – $\frac{K_{I_A}}{K_{I_{B,C}}}$=1.08 (Fig.3,a). Analyzing the results of research (Fig.3,a) it is worth pointing out that for the mentioned relative parameters (*a/c*=0.6) the maximum value for SIF is observed in the deepest point of the surface contour. The smallest value of SIF K_I is observed at a certain distance from crack surface at the relative values of the angle $2\varphi/\pi \approx 0.125 \ldots 0.25$, which indicates certain energy instability at the specified areas of the crack contour. These results show the possible accelerated direction of crack surface spread under cyclic loading. This prediction of front crack propagation is confirmed by experimental data presented in [8].

2.2. Calculation of SIF for two interacting cracks

In the second case the influence of surface cracks of different sizes is modelled (Fig. 4). Herewith one of the cracks has unchanged dimensions $2c_1$=20 mm, the distance between the cracks also remains unaltered (2 mm), and the size of the second crack is varied ($2c_2$=2.5; 5.0; 7.5; 10; 15; 20 mm). SIF along the surface cracks front is calculated at the uniaxial tensile of samples at σ=200 MPa.

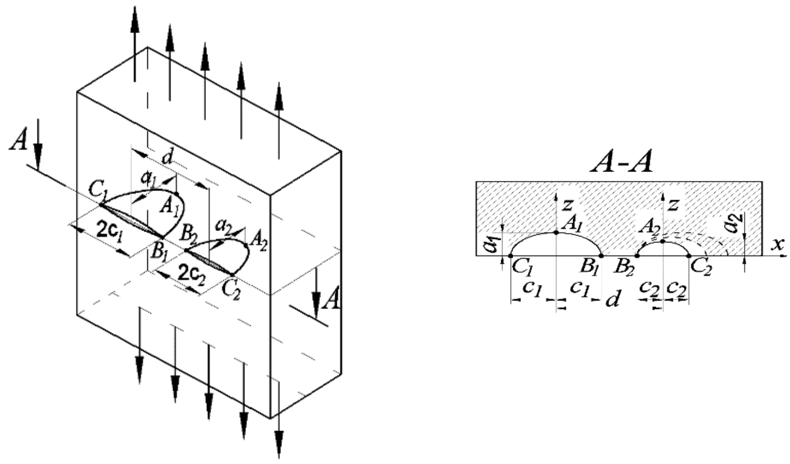
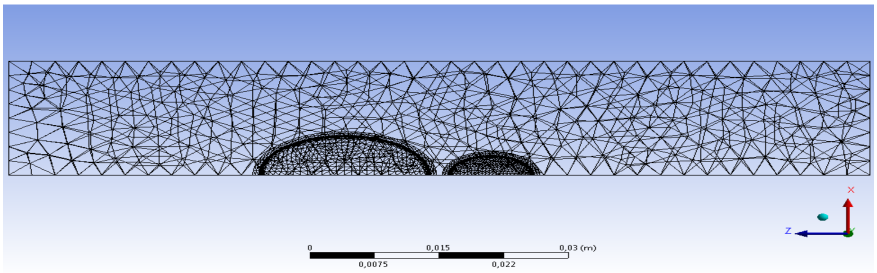
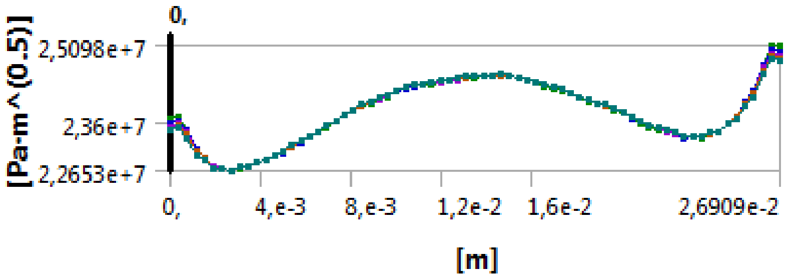


Figure 4. Surface semi-elliptical collinear cracks of different sizes in a finite size plate

Finite-element model for one of the cases is shown in Fig.5, a; the distribution of SIF values along each of the cracks (except identical cracks) is shown in Fig.5, b.



a)



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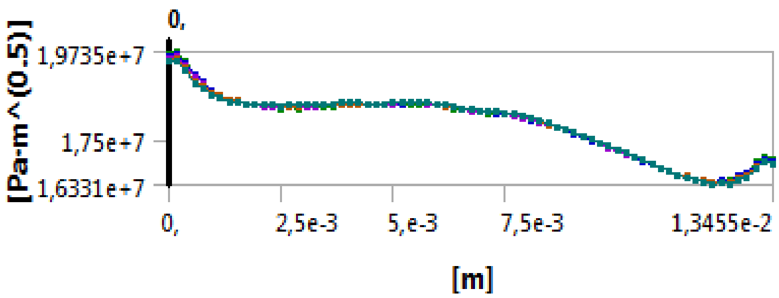

Figure 5. Finite element model – a) and the typical distribution of SIF – b) along the front of two surface cracks of different sizes during their interaction

It is evident that with the short distance between the cracks, their mutual influence is manifested in the increase (as in the previous case) of SIF values in the inner area of their interaction. Moreover, the nature of the SIF change consists in the fact that the maximum value of SIF K_I for smaller crack is shifted towards the inside point of surface crack contour.

The mutual influence of two cracks based on the comparison of results of SIF K_I at each inner point of one the cracks with a corresponding outer surface point of another crack is represented in Fig.6.

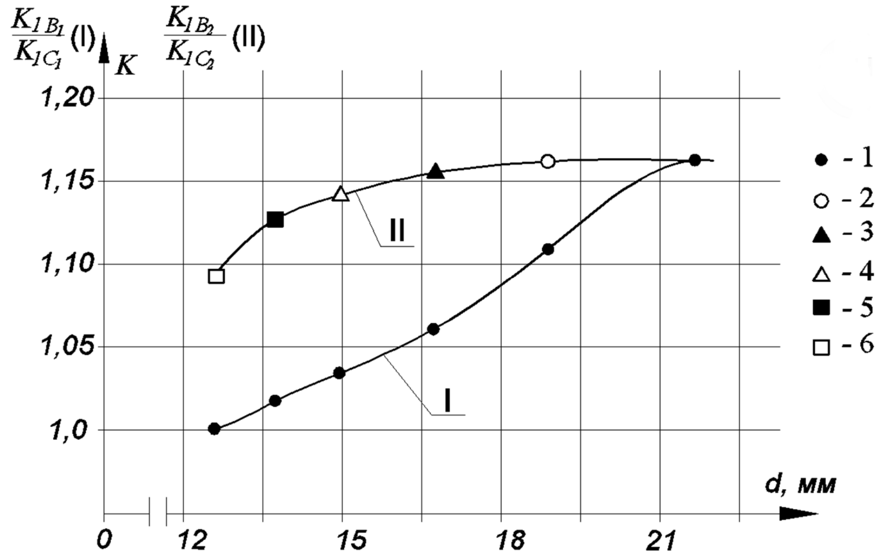

Figure 6. The ratio of SIF K_1 for inner surface points B_1 and B_2 to relevant outer surface points C_1 and C_2 during the interaction of different size semi-elliptical cracks: I - for bigger crack; II – for smaller cracks: $2c_1 = 20$ mm; $2c_2 = 20$ mm (1); $2c_2 = 15$ mm (2); $2c_2 = 10$ mm (3); $2c_2 = 7.5$ mm (4); $2c_2 = 5.0$ mm (5); $2c_2 = 2.5$ mm (6)

The curve I is built based on the research results for the more interacting crack $2c_1$=20 mm, curve II is for the crack $2c_2$=2.5; 5.0; 7.5; 10; 15 and 20 mm accordingly. It is important to note that the larger crack has a dominant influence on the change of SIF (see Curve II), while the relatively small cracks have little impact on changing the SIF of the larger crack.
For the mentioned relations of the surface cracks sizes, the change of SIF values does not exceed 4% (see three extreme points on the curve I), while the impact of a larger crack on the smaller ones is 9...14% for the same ratios cracks.

3. Conclusions

The distribution of SIF values along the cracks contour has been received for two collinear cracks of different sizes at different distances between the cracks centers. A more significant impact of larger crack on smaller ones, as well as the increase in SIF values when the two cracks approach has been observed.

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ANALIZA WPŁYWU POCHYLENIA OPON NA ODPORNOŚĆ NA BOCZNE ZNOSZENIE

Streszczenie: Artykuł opisuje wpływ pochylenia koła na siłę boczną generowaną podczas ruchu krzywoliniowego pojazdu. Ze względu na to, że kąty znoszenia kół wpływają na ruch pojazdów na zakrętach, zmiana siły bocznej a tym samym kątów znoszenia może mieć istotny wpływ na stateczność i kierowalność pojazdu. W pracy wykonano szereg badań pozwalających na ocenę wpływu kąta pochylenia koła. Badania były prowadzone na oponie modelu w skali 1:5.

Słowa kluczowe: dynamika ruchu pojazdu, współpraca opony z jezdnią, pochylenie koła

ANALYSIS OF IMPACT OF THE CAMBER ANGLE FOR TIRE CORNERING STIFFNESS

Summary: The article describes the impact of camber on the lateral force generated during the curvilinear motion of the vehicle. Due to the fact that the side-slip angles of the wheels affect on the movement of vehicles on curves, change of lateral force and thus the abolition of the side-slip angles may have a significant impact on the stability and steerability of the vehicle. In this work, was been carried out a series of tests to assess the impact of camber. Studies have been conducted on the tire of physical vehicle model in a scale of 1: 5.

Keywords: the vehicle dynamics of motion, road-tires interaction, camber of wheel

1. Wprowadzenie

Powierzchnia, na której następuje styk wszystkich czerech opon samochodu klasy średniej jest niewiele większa niż powierzchnia kartki A4. Z tego względu współczesne opony powinny spełniać szereg wymagań m. in.: zdolność przenoszenia dużych sił napędowych, amortyzować częściowo drgania powstające w wyniku toczenia się koła po nierównej nawierzchni, powinny wykazywać się zdolnością do

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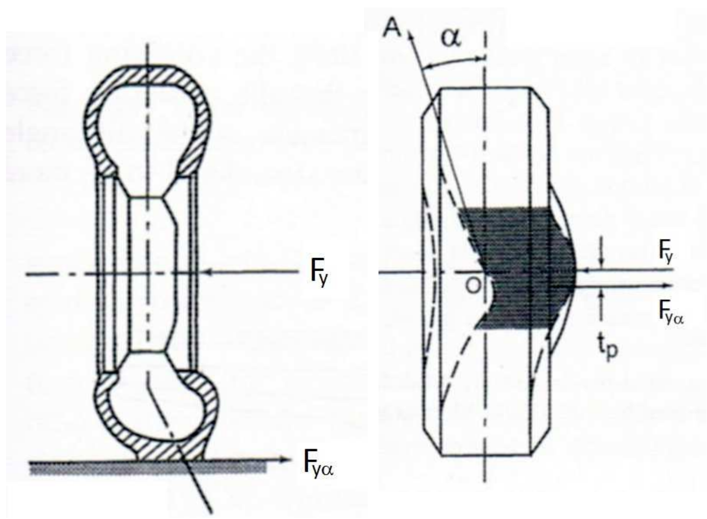
przenoszenia znacznych obciążeń pionowych, posiadać duży zakres temperaturowy pracy, emitować jak najmniejszy hałas przy dużych prędkościach obrotowych, cechować się dużą odpornością na zużycie, umożliwiać przenoszenie maksymalnych sił hamowania i skracać drogę hamowania oraz umożliwiać pokonywanie oporów ruchu przy jak najmniejszym zapotrzebowaniu mocy silnika. Spełnienie wymienionych powyżej wymagań zapewnia bezpieczeństwo ruchu użytkownikom pojazdów. Opony i ich właściwości, dopóki samochody będą poruszały się z ich wykorzystaniem, będą bardzo ważnym zagadnieniem w dziedzinie przemysłu samochodowego. Dlatego też powstała potrzeba zbadania współpracy opony z nawierzchnią, czyli zjawisk powstających na styku opony z jezdnią przy różnych ustawieniach kąta bocznego pochylenia koła.

2. Zjawisko bocznego znoszenia opony

Gdy na toczące się koło oddziałuje siła poprzeczna F_y, która jest przyłożona do jego osi, to opona ulega sprężystemu odkształceniu (co przedstawia rysunek 1), a wektor prędkości koła odchyla się od kierunku wyznaczonego przez płaszczyznę symetrii koła o kat α czyli o kąt bocznego znoszenia opony. W wyniku czego, kształt i powierzchnia styku opony z nawierzchnią jezdni ulegają zmianie.

a) b)



Rysunek 1. Odkształcenie opony pod wpływem działania siły bocznej a) widok w płaszczyźnie pionowej, b) widok z góry [1,3]

Powoduje to, że opona porusza się w kierunku zaznaczonym linią OA a nie w kierunku wyznaczonym przez oś symetrii koła. Siła boczna działająca na styku opony z jezdnią wynika z odkształcenia opony a więc zależy od kąta znoszenia koła. Siłę tą można zapisać w następujący sposób:

$$F_{y\alpha} = -C_{\alpha} \cdot \alpha \tag{1}$$

Gdzie $F_{y\alpha}$ - siła boczna na styku opony z jezdnią, α - kąt znoszenia koła, C_{α}- współczynnik odporności opony na boczne znoszenie.
Współczynnik odporności opony na znoszenie boczne jest definiowany jako stosunek zmian siły bocznej do zmian kąta znoszenia koła:

$$C_{\alpha} = \left(\frac{dF_{y\alpha}}{d\alpha}\right)_{\alpha=0} \tag{2}$$

Przy małych kątach skrętu zależność ta jest liniowa, przy większych kątach znoszenia zależność jest nieliniowa i zależność (1) daje wyniki obarczone dużym błędem.
Z reguły koła zamontowane w pojazdach są pochylone o pewien kąt. Kąty pochylenia kół są zazwyczaj niewielkie, podczas ruchu pojazdu następuje jego przechył, co wpływa na zmianę kątów pochylenia. Podobnie jak w przypadku kąta znoszenia kąt pochylenia kola wpływa na wielkość siły bocznej działającej na styku koła z jezdnią.
Z analogii do zależności (1) można zapisać równanie:

$$F_{y\alpha} = -C_{\alpha} \cdot \alpha - C_{\gamma} \cdot \gamma \tag{3}$$

W którym przez γ oznaczono kąt pochylenia koła a C_{γ} - współczynnik odporności opony na pochylenia koła.
Współczynnik odporności opony na pochylenie koła jest definiowany jako stosunek zmian siły bocznej do zmian kąta pochylenia koła.
Przebieg tej zależności dla danej opony zależy od wielu czynników, a przede wszystkim od:

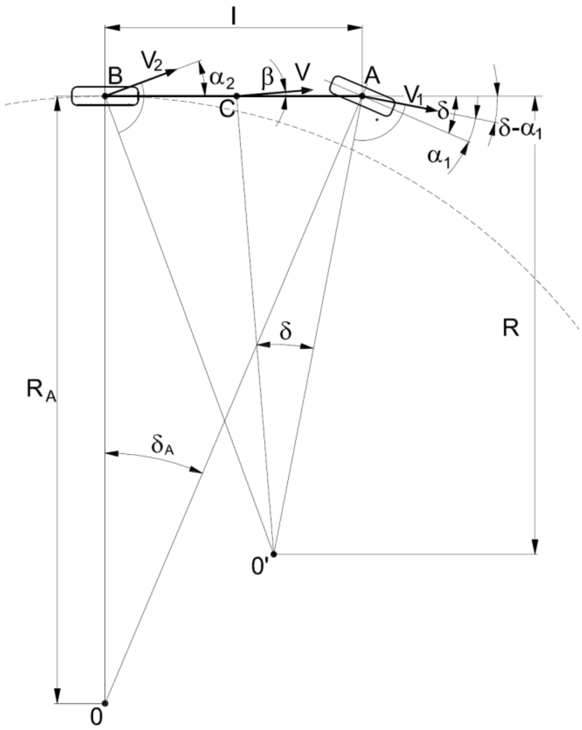
- ciśnienia powietrza w oponie,
- obciążenia pionowego koła,
- kąta pochylenia koła,
- rodzaju nawierzchni,
- panujących warunków atmosferycznych.

Czyli:

- wzrost reakcji normalnej Z powoduje wzrost współczynnika C_{α} do pewnej granicy, a następnie spadek (dla samochodów osobowych), dla samochodów ciężarowych nie obserwuje się maksimów,
- zwiększenie reakcji stycznej X zwykle powoduje zmniejszenie współczynnika C_{α},
- współczynnik C_{α} rośnie ze wzrostem ciśnienia w ogumieniu,
- współczynnik C_{α} rośnie ze spadkiem wysokości profilu ogumienia i wzrostem szerokości obręczy,
- pochylenie boczne koła w kierunku działania siły bocznej F_y zmniejsza siłę, zaś pochylenie przeciwne zwiększa.

3. Wpływ bocznego znoszenia kół na ruch pojazdu

Zmiana położenia chwilowego środka obrotu pojazdu, w którym nie występuje boczne znoszenie kół może powodować zwiększenie lub zmniejszenie tego promienia. W przypadku zwiększenia chwilowego promienia skrętu średni kąt znoszenia kół tylnych jest mniejszy niż średni kąt znoszenia kół przednich. Taki przypadek nazywany jest podsterownością, gdy pojazd porusza się po większym promieniu od zadanego. W przeciwnym przypadku, gdy średni kąt znoszenia kół tylnych jest większy niż średni kąt znoszenia kół przednich, następuje zacieśnienie zakrętu a chwilowy promień skrętu jest mniejszy od zadanego. Taki przypadek nazywany jest nadsterownością, gdy pojazd porusza się po mniejszym promieniu od zadanego. Na rysunku 2 przedstawiono zmianę promienia skrętu wywołaną kątami znoszenia kół.



Rysunek 2. Zmiana promienia skrętu wywołana kątami znoszenia kół [2,7]

4. Określenie bocznego znoszenia koła, model fizyczny opony w skali 1:5

Porównanie parametrów opon wymaga przeprowadzenia szeregu badań pozwalających na określenie: sztywności wzdłużnej, promieniowej i poprzecznej, odporności opon na boczne znoszenie, oporu toczenia, śladu współpracy opon z jezdnią itp. Powinno się również określić współczynnik przyczepności opony. Ze

względu na brak możliwości przeprowadzenia pomiaru odporności pełnowymiarowej opony badania przeprowadzono na oponie modelu fizycznego pojazdu wykonanego w skali 1:5. Badania modeli pojazdów w skali są prowadzone w Katedrze Silników Spalinowych i Pojazdów Akademii Techniczno-Humanistycznej w Bielsku-Białej. Aktualnie Katedra posiada szereg modeli o różnej skali, wykorzystywanych do badań poligonowych oraz stanowiska pozwalające na zdejmowanie charakterystyk ich zespołów i elementów [8, 9].
Do badań wykorzystano oponę z modelu fizycznego pojazdu z wkładką z poliuretanu. W tych wymiarach w zasadzie nie spotyka się opon pneumatycznych. Wkładki występują w dwóch grupach sztywności – miękkie i twarde. Do badań wybrano oponę 190/60 Desert Buster HD.

Rysunek 3. Opona wybrana do badań [8]

5. Stanowisko do pomiaru siły bocznej

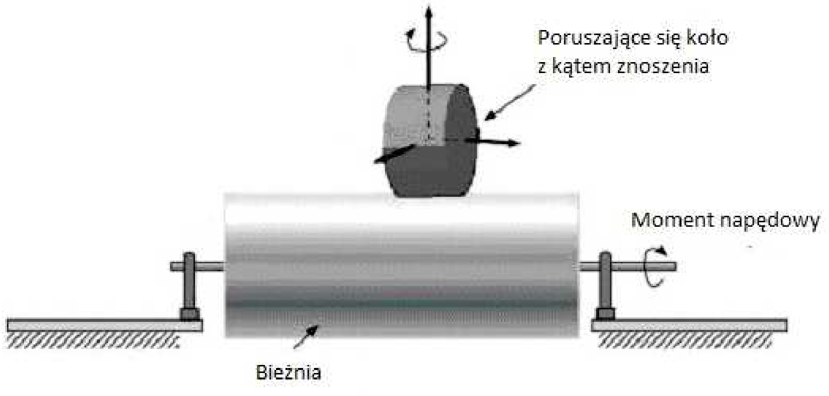
Do konstrukcji stanowiska pomiarowego wykorzystana została bieżnia sportowa, na której umieszczone zostało badane koło. Do ramy mocowana jest, głowica pozwalająca na swobodny ruch pionowy koła. Siła nacisku koła na jezdnię wynika z ciężaru głowicy, w której mocowane jest koło, koła oraz masy dodatkowych obciążników.
Ustawienie kątowe koła względem bieżni wynika z położenia kątowego głowicy względem ramy. Położenie to jest ustalane za pomocą śrub.
Pochylenie koła wynika z ustawienia długości linki, łączącej czujnik pomiaru siły, mocowany do ramy z osią koła. Siła ta jest wyznaczana z zależności:

$$F_y = F_{y\_pomiar} \cdot \frac{t}{t + r_e} \tag{4}$$

gdzie F_{y_pomiar} – jest to siła uzyskana z pomiarów, t – odległość osi koła do osi obrotu głowicy a r_e – promień efektywny koła

Ruch obrotowy koła zapewnia łożyskowanie jego osi w obudowie.
Rama, była także podstawą dla kilku czujników pomiarowych.
Do pomiarów wykorzystaliśmy czujniki takie jak:

- tensometryczny czujnik siły - ZEPWN CL 16U,
- czujnik prędkości obrotowej badanego koła - ISC4406-Rotary encoder,
- czujniki optyczne do badania odległości– Laser sensor Keyence IL-100
- Laser sensor Keyence IL-300,
- czujnik prędkości ruchu bieżni – Corrsys Corevit S-CE,
- wzmacniacz sygnału Keyence IL – 1000.



Rysunek 4. Schemat stanowiska pomiarowego

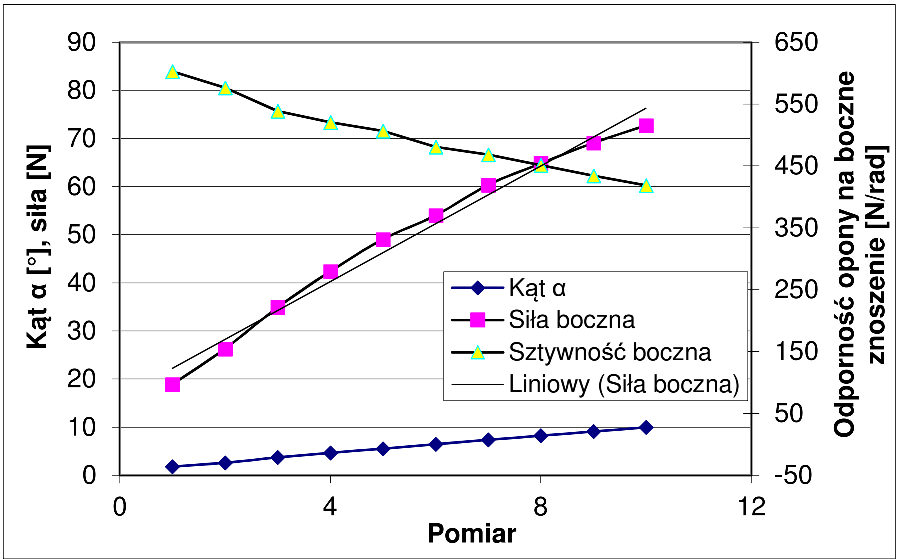
Rysunek 5. Widok stanowiska pomiarowego

Czujniki optyczne zostały tak rozmieszczone, aby za ich pomocą można było wyznaczyć: kąt bocznego znoszenia opony, promień toczącego się koła oraz kąt pochylenia koła. Głowicę Correvit wykorzystano do pomiaru prędkości ruchu bieżni. Za pomocą czujnika siły wyznaczano siłę boczną F_y.

Na rysunkach 4 i 5 pokazano schemat stanowiska pomiarowego oraz jego widok.

6. Wyniki pomiarów siły bocznej $F_{y\alpha}$ dla różnych kątów pochylenia koła

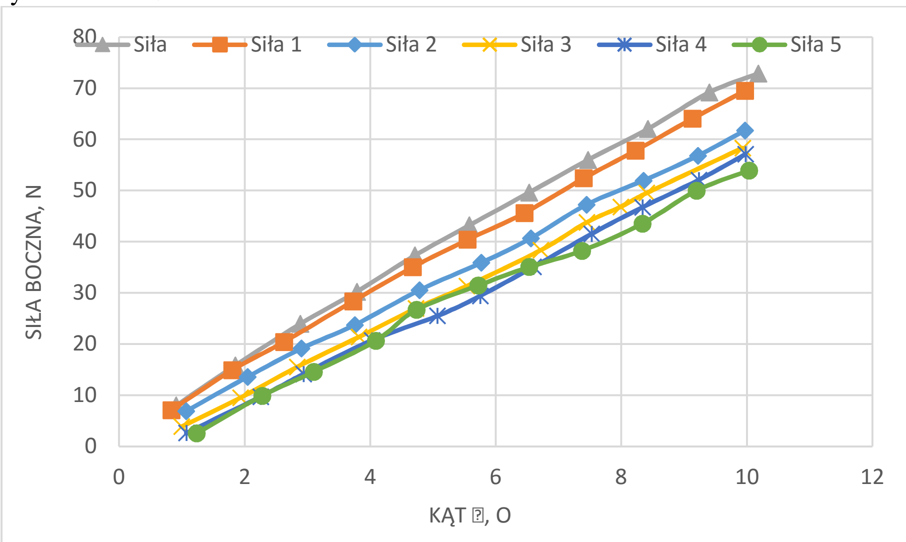
Pomiary wykonane zostały w następujący sposób, rama wraz z kołem, któremu za pomocą śruby rzymskiej zamocowanej przy czujniku siły nadano zerowy kąt pochylenia, została ustawiona tak by koło toczyło się równolegle do osi wzdłużnej bieżni, po ustaleniu tej pozycji została ona oznaczona kreda na podstawie pod rama a koło zostało postawione na powierzchni bieżni i dociążone masa własną ramy. Bieżnia została włączona, ustalona została zadana prędkość ruchu bieżni równa około 4km/h. Po ustaleniu ruchu koła został wykonany pierwszy pomiar, kolejny pomiar był wykonany dla tego samego kąta pochylenia koła oraz tego samego ustawienia ramy koła, przy czym zostało zmienione obciążenie koła. Dociążone zostało zrealizowane za pomocą ciężarka o masie 4kg. Dla każdego kąta pochylenia koła wykonano po 22 pomiarów, gdzie dla każdej zmiany kąta położenia ramy wykonano jeden pomiar bez dodatkowego obciążenia oraz jeden pomiar z dodatkowym obciążeniem. Pomiary zostały wykonane dla 6 różnych ustawień kąta pochylenia koła gdzie kolejny pomiar był wykonywany przy zmianie o ~1 stopień. Podczas każdego z pomiarów mierzono następujące parametry: siłę boczną, siłę nacisku koła na bieżnie, kąt pochylenia koła, kąt bocznego znoszenia, prędkość obrotową koła i prędkość ruchu bieżni.



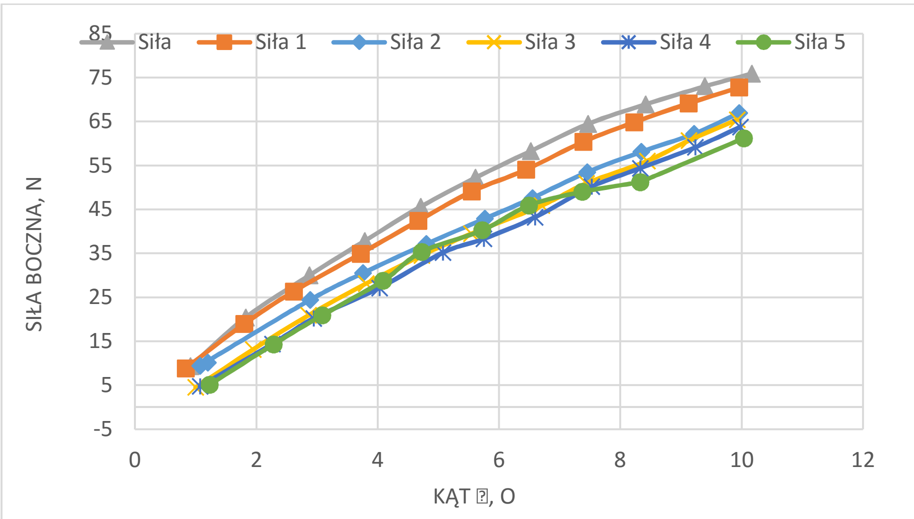
Rysunek 6. Przykładowe wyniki uzyskane z pomiarów na stanowisku

Uzyskane dane z poszczególnych czujników zostały odpowiednio przetworzone oraz opracowane w programie Microsoft Excel, za pomocą którego zostały obliczone poszczególne parametry tj. maksymalny kąt bocznego znoszenia, maksymalna siła

bocznego znoszenia, sztywność kątowa oraz zostały wykonane wykresy obrazujące zmiany poszczególnych parametrów w czasie pomiarów. Pomiary przeprowadzono dla koła z różnym kątem pochylenia γ począwszy od 0 do ~10°.
Na podstawie wykonanych pomiarów wyznaczono siłę boczną w zależności od kąta znoszenia koła dla wszystkich serii pomiarowych. Przebiegi te pokazano na rysunkach 7 i 8.



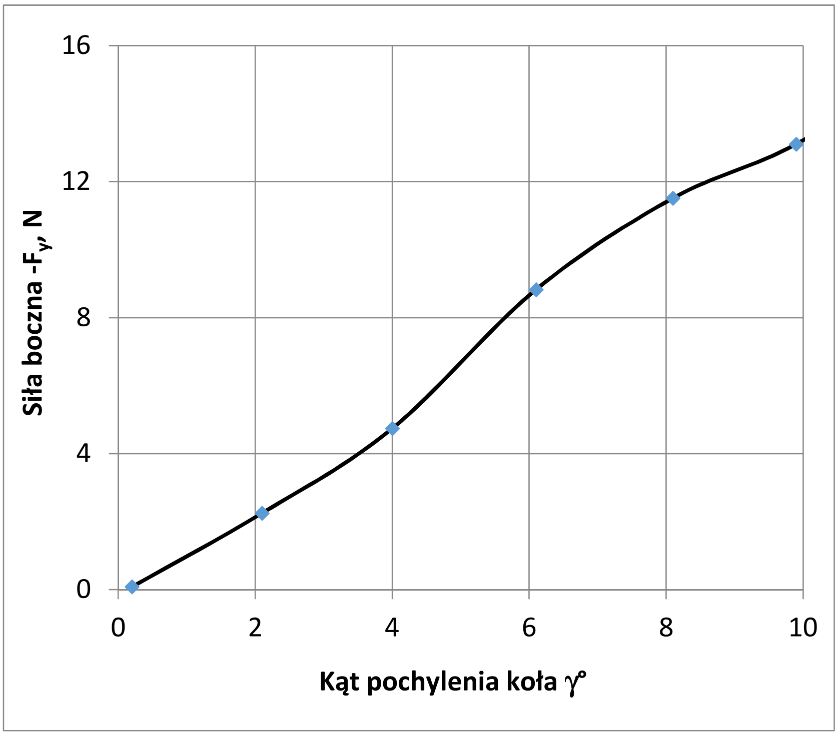
Rysunek 7. Przebieg siły bocznej w zależności od kąta znoszenia koła, przy różnych pochyleniach koła (bez dodatkowego obciążenia)



Rysunek 8. Przebieg siły bocznej w zależności od kąta znoszenia koła, przy różnych pochyleniach koła (z dodatkowym obciążeniem)

7. Podsumowanie, wyznaczenie zmiany odporności opony na boczne znoszenie pod wpływem kąta pochylenia opony

Jak można zaobserwować siła boczna wzrasta wraz z obciążeniem koła. Ponadto, przy dodatnich kątach pochylenia koła, siła boczna maleje w porównaniu do siły przy zerowym pochyleniu koła. Na tej podstawie można wyznaczyć wpływ kąta pochylenia koła na siłę boczną powstającą podczas ruchu koła z bocznym znoszeniem. Na rysunku 7 i 8 pokazano wpływ pochylenia koła na siłę boczną. Ponadto obserwując przebiegi krzywych na obu rysunkach możemy zaobserwować, że krzywe na rysunku 7 gdzie pokazane są zależności dla badań koła bez dodatkowego obciążenia posiadają przebieg zbliżony do linii prostych. Obserwując przebiegi krzywych na kolejnym rysunku dla serii badań dla koła z dodatkowym obciążeniem można stwierdzić, iż przy większych kątach pochylenia bocznego koła przebieg krzywej wyraźnie ulega zakrzywieniu, co jest spowodowane poślizgiem bocznym koła.



Rysunek 9. Zależność siły bocznej od kąta pochylenia koła

Przeprowadzone badania pozwalają na wysunięcie następujących wniosków:

1. Przebieg siły bocznej przy obciążeniu siłą pionową 73,5N jest zbliżony do linii prostej. Po zwiększaniu obciążenia pionowego do 112,7N przebieg krzywej wyraźnie się zakrzywia dla dużych kątów znoszenia koła.
2. Pochylenie boczne koła γ w kierunku dodatnim powoduje obniżenie siły bocznej o ~11%

3. Stosunkowo duży spadek siły następuje przy mniejszych kątach pochylenia i jego spadek zmniejsza się wraz ze wzrostem kąta pochylenia koła.
4. Pokazany na rysunku 10 spadek wartości siły wraz ze zwiększaniem kąta pochylenia koła pozwala na wyznaczenie zmian odporności na boczne znoszenie wynikającej z pochylenia koła. Zmiana ta stanowi od 10 do 15% wartości siły bocznej.

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WYZNACZANIE PŁASZCZYZN ZA POMOCĄ ALGORYTMU RANSAC

Streszczenie: W artykule przedstawiono zasadę działania oraz wady i zalety Algorytmu RANSAC służącego do wykrywania prymitywów geometrycznych w chmurach punktów obarczonych znacznym szumem pomiarowym. W pracy przedstawiono również wyniki pomiarów segmentowanych za pomocą opisanego algorytmu.

Słowa kluczowe: RANSAC, prymitywy geometryczne, chmura punktów, błąd pomiaru

DETERMINATION OF PLANES BY THE RANSAC ALGORITHM

Summary: The article presents the principle of operation and the advantages and disadvantages of RANSAC Algorithm used to detect geometric primitives in point clouds burdened with considerable noise measurement. The paper also presents the results of measurements segmented by the described algorithm.

Keywords: RANSAC, geometric primitives, points cloud, Measurement error

1. Wstęp

Postęp technologiczny w dziedzinie bezdotykowych pomiarów takich jak skaning laserowy, pomiar realizowany czujnikami optycznymi bądź z użyciem skanerów 3D, czy też kamer strukturalnych niesie ze sobą coraz większe możliwości w dziedzinie pozyskiwania tzw. chmur punktów pomiarowych, dane te charakteryzują się przypisanymi współrzędnymi w kartezjańskim układzie współrzędnych (X,Y,Z) oraz często dodatkowymi parametrami, takimi jak:

- współczynnik odbicia powierzchni [4],
- liczba punktów,
- szerokość/wysokość chmury,

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- barwa punktów,
- położenie względem urządzenia rejestrującego [1].

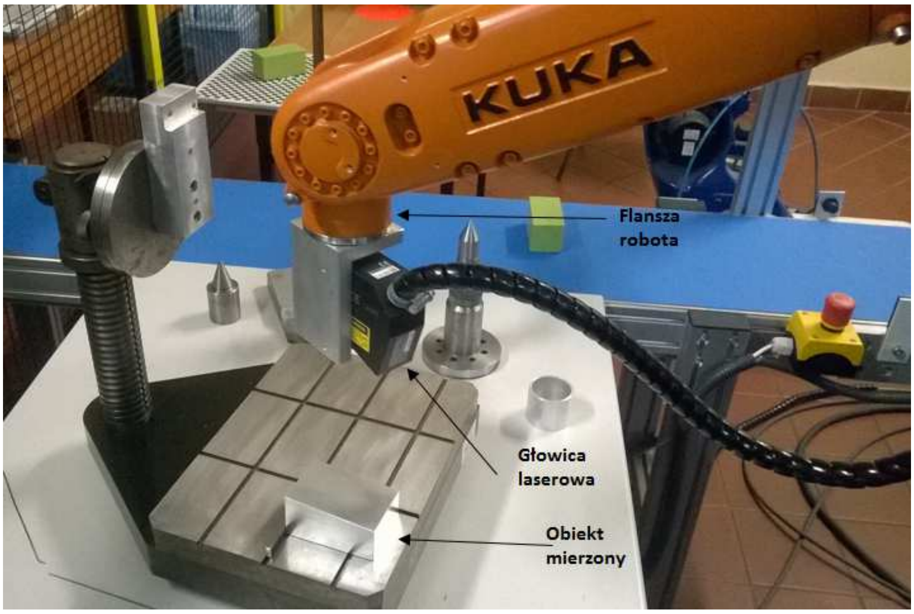
Informacje pozyskane z tychże pomiarów znajdują z powodzeniem coraz szersze zastosowanie w dziedzinach takich, jak:

- modelowanie geoinformacji (Uzyskiwanie trójwymiarowych modeli budynków, detekcji połaci dachowych z użyciem lotniczego skaningu laserowego, generowanie trójwymiarowych modeli miast na potrzeby programowania aplikacji GPS urządzeń mobilnych) [3, 5],
- medycyna np. wstępne wyznaczenie płaszczyzny symetrii mózgu,
- rozrywka (konsole do gier, aplikacje mobilne, katalogi produktów) [1],
- potrzeby sztucznej inteligencji (widzenie komputerowe) [1],
- kontrola jakości produkcji z użyciem robotów przemysłowych bezpośrednio na liniach produkcyjnych,
- inżynieria odwrotna,
- procesy inwentaryzacji budynków przemysłowych nie posiadających dokumentacji elektronicznej.

Mimo wielu zalet wspomnianych informacji pomiarowych zapisywanych w postaci chmury (takich, jak szybkość zbierania informacji, np. dla użycia kamer czujnika *Kinect* bądź możliwość pobrania danych ze znacznych obszarów jak w przypadku laserowego skaningu lotniczego) należy w przeważającej ilości przypadków liczyć się z pozyskanymi punktami pomiarowymi niepasującymi do rozpatrywanego elementu. Te błędne informacje muszą zostać przefiltrowane i wykluczone z dalszych rozważań w celu zapewnienia poprawności wyników analizy. Szum pomiarowy wynika m.in. z różnorodności analizowanych powierzchni, zakłóceń emitowanych z zewnątrz (np. w przypadku analizy danych bezpośrednio na linii produkcyjnej), drgań własnych, zmiennej temperatury otoczenia oraz z ograniczeń technicznych urządzenia realizującego pomiar. Dodatkowo dane zawarte w chmurze punktów muszą zostać obrobione, aby pozyskać z nich informacje takie jak kierunek wektora normalnego do skanowanej powierzchni, wzajemne położenie punktów bądź krzywiznę. Informacje te posłużą nam jako kryterium jednorodności rozpatrywanych prymitywów geometrycznych [5].
Koniecznym zatem stało się przeprowadzenie podziału (wyznaczenia fragmentów o tym samym znaczeniu) inaczej mówiąc dążymy do filtracji i klasyfikacji wyników pomiarów mających na celu odseparowanie wartości pożądanych ze względu na przeprowadzone badanie od wartości błędnych (błędów nadmiernych, szumu pomiarowego itp.). W przypadku badania odchyłki płaskości powierzchni będziemy zatem dążyć do oddzielenia punktów rzeczywistych należących do rozpatrywanej płaszczyzny od pomiarów błędnych.

2. Opis stanowiska, niepewność pomiaru

W przypadku badania odchyłek płaskości powierzchni laserem pomiarowym na zrobotyzowanym stanowisku pracy tj. w warunkach warsztatowych (produkcyjnych) dostępnym w Laboratorium Obrabiarek Skrawających i Robotów Akademii Techniczno-Humanistycznej w Bielsku Białej, jako jeden z podstawowych problemów związanych z tą metodą pomiaru wskazano znaczne zwiększenie niepewności wyników w porównaniu z analizą powierzchni przeprowadzoną w odseparowanym od cyklu produkcyjnego laboratorium pomiarowym. Niepewność ta, a co za tym idzie zwiększenie rozrzutu wyników pomiarów od wartości rzeczywistych związana jest ściśle z otoczeniem proponowanego układu pomiarowego. Aby pomiary warsztatowe uczynić konkurencyjnymi dla pomiarów laboratoryjnych koniecznym staje się więc opracowanie dedykowanych strategii pomiarowych, oraz wyznaczenie związanej z przyjętą strategią niepewności pomiaru. Jako znaczące cechy układu pomiarowego złożonego z robota przemysłowego Kuka R-900 AGILUS wyposażonego w laserowy czujnik pomiarowy Keyence LK-150H wpływające na niepewność pomiaru wskazano:
-błąd odczytu wskazań czujnika laserowego, spowodowany czasem relaksacji układu pomiarowego,
-błędy wynikające z nieosiągnięcia przez robot zaprogramowanej pozycji (zostały skompensowane bezpośrednim odczytem rzeczywistego położenia końcowego ramienia robota, do którego przymocowano czujnik pomiarowy),
-błąd odczytu przez układy pomiarowe robota swojej rzeczywistej pozycji.

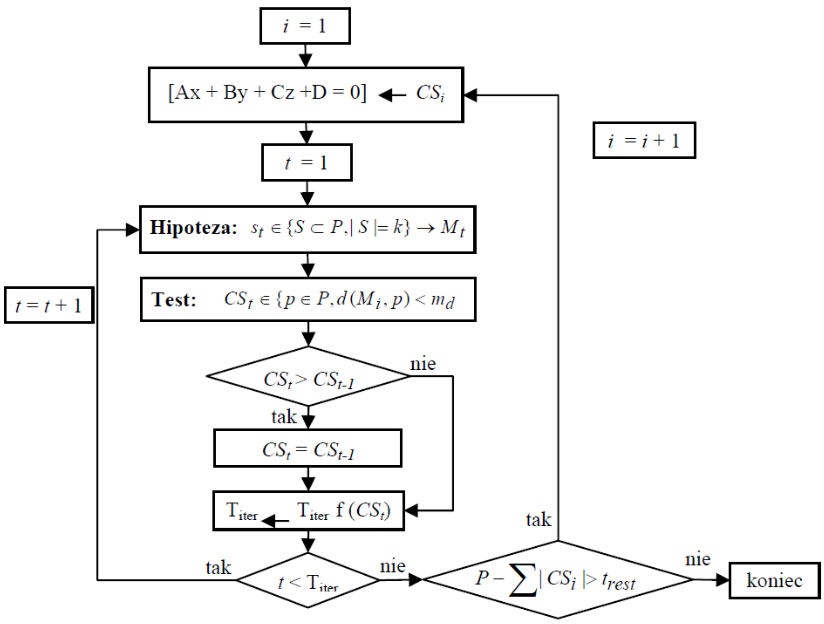


Rysunek 1. Widok stanowiska pomiarowego

3. Algorytm RANSAC

Jako sposób na wyznaczenie parametrów poszukiwanego modelu matematycznego z chmury zebranych danych zawierającej informacje o modelowanej płaszczyźnie jak również informacje nadmiarowe zaproponowano wykorzystanie algorytmu RANSAC. Algorytm ten będzie stosowany od zgrubnego wyznaczania analizowanych płaszczyzn. W celu dokładniejszego badania jako uzupełnienie stosowana będzie metoda „roju cząstek” (ang. PSO - *Particle Swarm Optimization*) będąca metodą optymalizacji nieliniowych funkcji ciągłych opartą na ewolucji obliczeniowej (tzw. Algorytmach genetycznych).[2] Do informacji nadmiarowych podczas prezentowanego sposobu określania płaskości powierzchni mogą zaliczać się: punkty położone blisko powierzchni (lecz należące do innego obiektu) oraz punkty obarczone szumem pomiarowym do których mogą zaliczać się błędy nadmierne. Cechą przesądzającą o wytypowaniu właśnie tego algorytmu jest możliwość modelowania prymitywów geometrycznych (sfer, płaszczyzn, cylindrów lub stożków) na podstawie zbioru danych zawierających do 50% błędnych obserwacji [3]. Algorytm RANSAC (RANdom SAmple Consensus) – RANSAC (konsensus próby losowej) jest iteracyjną metodą wyeliminowania błędnie dopasowanych punktów pomiarowych umożliwiającą automatyczne odtworzenie form zdefiniowanych poprzez prymitywy geometryczne.

Składa się on z dwóch etapów:
- inicjalizacji (określanej również mianem hipotezy),
- testu.



Rysunek 2. Diagram aktywności algorytmu RANSAC [2]

Jako inicjalizację rozumiemy pobranie (najczęściej w sposób losowy) najmniejszej liczby próbek „k" pozwalającej w sposób jednoznaczny określić wszystkie parametry rozważanego prymitywu geometrycznego. Dla wyodrębnienia płaszczyzn na minimalną liczbą próbek składają są trzy punkty. Ten minimalny zbiór oznaczymy jako s_t

$$s_t \in \{S \subset P, |S| = k\} \rightarrow M_t \tag{1}$$

gdzie:

s_t – minimalna liczba próbek opisująca dany prymityw geometryczny (w przypadku płaszczyzny są to 3 punkty),
P – zbiór wszystkich analizowanych punktów,
S – zbiór,
k – liczba próbek,
M_t – parametry modelu.

Procedura algorytmu rozpoczyna się od wylosowania początkowo ustalonej liczby T_{iter} minimalnych zbiorów s_t opisujących płaszczyznę. Wartość T_{iter} w trakcie trwania algorytmu będzie modyfikowana.

Następnym etapem jest wyznaczenie parametrów modelu M_t (rozpatrywać będziemy płaszczyznę przechodzącą przez trzy nie współliniowe punkty). Tak określony model w kolejnym kroku algorytmu „teście" będzie podlegał weryfikacji.

Na potrzeby przeprowadzenia testu konieczne jest zdefiniowane kolejnego pojęcia jakim jest Próg m_d (ang. *threshold*), określający tolerancje, w której zawierają się punkty pasujące do płaszczyzny, wartość ta w krytyczny sposób wpływa na stabilność algorytmu oraz jakość wyodrębnianych płaszczyzn. W znacznej liczbie przypadków jako wartość tę uznaje się maksymalna odległość testowanego punktu od modelu teoretycznego. W przypadku pozytywnego porównania punktu z zadeklarowanym progiem tolerancji trafia on do zbioru – CS (*ang. Consensus Set)* – zawierającego wszystkie punkty, które pomyślnie przeszły test porównawczy z progiem.

$$CS_t \in \{p \in P, d(Mi, p) < m_d \tag{2}$$

gdzie:

CS_t - zbior – CS (*ang. Consensus Set)* – zawierający wszystkie punkty, które pomyślnie przeszły test porównawczy z progiem w kroku „t",
P – zbiór wszystkich analizowanych punktów,
$d\,(Mi\,, p)$ - odległość punktu od założonego modelu,
m_d – Próg określający tolerancje w której zawierają się punkty pasujące do płaszczyzny.

Po przeprowadzonym teście, rozpatrywany jest następny zbiór minimalny, w oparciu o który kolejny raz zostają przeprowadzone podstawowe kroki algorytmu (hipoteza oraz test). W razie znalezienia liczniejszego zbioru CS w porównaniu z poprzednią iteracją, zbiór liczniejszy będzie poddany kolejnej analizie. Nową wartość przyjmuje parametr T_{iter} (liczba zbiorów minimalnych),

$$T_{iter} = \frac{\log \varepsilon}{\log(1-q)} \tag{3}$$

T_{iter} – liczba minimalnych zbiorów $s_{t,}$
ε - prawdopodobieństwo identyfikacji niewłaściwej płaszczyzny,
q – parametr obliczany według wzoru [3].

$$q = \left(\frac{N_I}{N}\right)^k \tag{4}$$

w którym:

N_I – liczba punktów należących do zidentyfikowanej płaszczyzny,
N – liczba wszystkich punktów należących do wejściowego zbioru danych,
k – najmniejsza liczba danych pozwalająca na jednoznaczne wyznaczenie modelu.

Po znalezieniu pierwszej płaszczyzny chmura punktów kolejny raz jest analizowana, wykluczone z niej zostają jednak punkty już zaliczone do płaszczyzny. Poszukiwanie kolejnych płaszczyzn zostaje przerwane, gdy liczba punktów niedodanych jest mniejsza od zadeklarowanej wartości progowej t_{rest}. [3]

3.1. Wady Algorytmu

Autorzy publikacji [1, 4, 5] wskazują na problemy związane z działaniem algorytmu, w przypadku badań [4] stwierdzono błędne wyniki w rzeczywistym skanowaniu obiektów przemysłowych o powierzchni kilkudziesięciu metrów kwadratowych, w przypadku analizy tak dużych ilości danych zaproponowano metodę wstępnej klasyfikacji punktów i zgrubnemu ich przypisaniu do walców i płaszczyzn. Postępowanie takie pozwoliło na wykorzystanie metody w tym konkretnym zastosowaniu oraz znacznie zredukowało liczbę wymaganych iteracji.

Z kolei autor pracy [1] wskazuje na problemy w poprawnym wykrywaniu płaszczyzn obiektów 3D skanowanych kamerą urządzenia „*Kinect”* w przypadku występowania obiektów na drugim planie. Problem polegał na przypisywaniu błędnych płaszczyzn do niektórych obiektów, w celu poprawy wyników autor zaproponował podział chmury na podzbiory.

W publikacji [5] zauważono, iż punkty skumulowane wokół powierzchni dominujących, zostają w modelu matematycznym płaszczyzny do niej przydzielone, jednak w rzeczywistości należą do innych obiektów. Jako sposób rozwiązania nieścisłości „*uwzględniono relacje sąsiedztwa pomiędzy punktami przynależnymi.*” W celu realizacji chmurę danych zinterpretowano jako graf nieskierowany, dla którego poszukiwane są składowe zwięzłe. Zmiana wprowadza dodatkowo konieczność: wygenerowania listy „sąsiadów” dla każdego punktu oraz klasyfikacji segmentów.

Dodatkowo jako sposób na przyśpieszenie czasu przeszukiwania punktów sąsiednich autorzy wskazują na reorganizację struktury chmury punktów, np. w wykorzystaniem kd-drzewa (kd-tree), które jest strukturą danych służącą do podziału przestrzeni. Jest to drzewo binarne, w którego „gałęziach” przechowywane są punkty o k-wymiarach. Węzły te tworzą hiperpłaszczyzny podziału, stosowane do dzielenia przestrzeni. [1]

Analizując jednak wyżej wymienione publikacje i wymienione w nich problemy możemy dostrzec wspólny mianownik jakim jest ogromna w porównaniu z naszym przypadkiem chmura danych. Analiza aglomeracji miejskiej, budynków przemysłowych, czy rozpoznawanie obiektów 3D to analizy znacznie bardziej złożone ze względu na ilość punktów pomiarowych niż badania zaproponowane w Laboratorium Obrabiarek Skrawających i Robotów. Powołując się na wnioski autorów którzy stwierdzają iż po zabiegach redukujących bazę danych pomiarowych algorytm RANSAC z powodzeniem realizuje powierzone mu zadania, można spodziewać się poprawności wykrywania płaszczyzn w przestrzeni 2D dla chmury pomiarowej nie przekraczającej 1000 elementów. Dane o takiej pojemności analizujemy w naszych badaniach. Dodatkowo omawiamy Algorytm służy do zgrubnej detekcji płaszczyzn, wyniki jego działania będą służyły jako odfiltrowane dane wejściowe dla algorytmu PSO.

3.2. Odmiany algorytmu

- PROSAC - (*ang. PROgressive SAmple Consensus*), jest to najpopularniejsza odmiana podstawowej wersji algorytmu, różnica polega na założeniu, iż nie wszystkie punkty są jednakowej jakości z tego względu została podjęta próba oceny tego znaczącego parametru. Posortowane elementy przydzielane są do podzbiorów, które segregowane są według ocenionej jakości. Jakość zbioru determinuje najgorszy punkt wchodzący w jego skład. Podejście takie powoduje, iż próbki analizowane są w innej kolejności niż w pierwotnej wersji algorytmu, powoduje to, że algorytm wcześniej może zakończyć swoje działanie – analizuje on próbki począwszy od jakościowo najlepszych [1].

- MSAC – wprowadza modyfikację co do minimalizowanej funkcji kosztu w podstawowej odmianie algorytmu. Dla przypadków szczególnych w odmianie RANSAC wszystkie rozwiązania będą cechowały się identyczną funkcją kosztu, z tego względu każde z nich może zostać zakwalifikowane jako poprawne [1]. Na ten efekt może wpływać przyjęta zbyt duża wartość progowa t_{rest}.

RANSAC wykorzystuję funkcję kosztu postaci:

$$C = \sum_i \rho(e_i^2) \tag{5}$$

gdzie $\rho()$ definiujemy jako:

$$\rho(e_i^2)\begin{cases} 0, & e^2 < t_{rest}^2 \\ constant, & e^2 \geq t_{rest}^2 \end{cases} \tag{6}$$

Dla Metody MSAC wprowadza się modyfikację:

$$C_2 = \sum_i \rho_2(e_i^2) \tag{7}$$

gdzie $\rho()$ definiujemy jako:

$$\rho(e_i^2)\begin{cases} e^2, & e^2 < t_{rest}^2 \\ t_{rest}^2\ , & e^2 \geq t_{rest}^2 \end{cases} \tag{8}$$

Punkty niepasujące wnoszą pewną wartość stałą, dla punktów pasujących weryfikowana jest nie tylko przynależność lecz również jakość dopasowania.

4. Wyniki badań w Laboratorium Obrabiarek Skrawających i Robotów Akademii Techniczno-Humanistycznej w Bielsku-Białej

Na stanowisku badawczym zebrana została chmura 25 punktów pomiarowych: płaszczyzny podstawy (będącej płaszczyzną stołu pomiarowego), płaszczyzny płytki wzorcowej o wymiarach 35x100mm oraz górnej płaszczyzny kostki nachylonej do podstawy pod kątem w 4 ustawieniach. Dane te jako współrzędne w kartezjańskim układzie współrzędnych posłużyły do wyznaczenia równania ogólnego płaszczyzny w postaci $Ax + By + Cz + D = 0$ za pomocą programu komputerowego z zaimplementowanymi algorytmami RANSAC oraz PSO. Oprogramowanie to zostało stworzone w Katedrze Technologii Maszyn i Automatyzacji Akademii Techniczno-Humanistycznej jako środowisko testowe dla zebranych danych. Plikiem wejściowym były współrzędne 25 punktów zapisane w pliku w formacie (.txt). Wyznaczone przez program równania płaszczyzn posłużyły do obliczenia wysokości płytki wzorcowej (jako odległość płaszczyzny podstawy od punktów znajdujących się w narożnikach płytki wzorcowej), oraz kątów nachylenia płaszczyzny kostki względem podstawy dla 4 ustawień. Procedurę generowania parametrów równania płaszczyzny przez program powtórzono dwudziestokrotnie, w celu oszacowana błędów metody obliczeniowej.

W tabeli 1 zestawiono wynik pomiaru wysokości płytki dla czterech narożników, obliczeń dokonano na podstawie równania płaszczyzny podstawy oraz powierzchni górnej płytki wzorcowej. Według zależności:

$$D(m,p) = \frac{|Ax_p + By_p + Cz_p + D|}{\sqrt{A^2 + B^2 + C^2}} \tag{9}$$

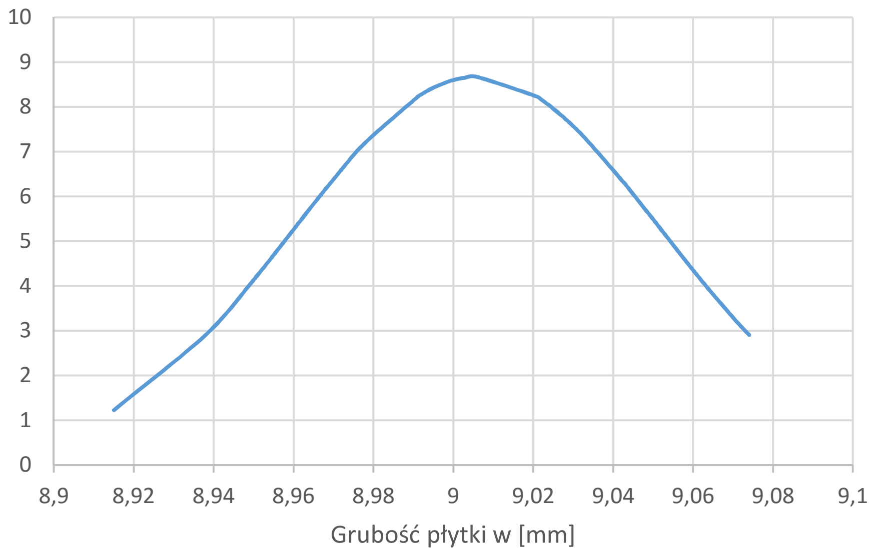
w której:

$D(m,p)$ – odległość punktu od płaszczyzny,
A,B,C,D – parametry równania płaszczyzny podstawy,
x_p, y_p – współrzędne punktów narożników płytki wzorcowej,
z_p – współrzędna wyznaczona z równania płaszczyzny płytki wzorcowej.

Pomiary wysokości płytki przyrządem mikrometrycznym wahały się w zakresie 8.998÷9.005 mm

Tabela 2. Wynik pomiaru wysokości płytki dla czterech narożników

	Narożnik 1 (0,0)	**Narożnik 2 (0,35)**	**Narożnik 3 (100,0)**	**Narożnik 1 (100,35)**	**Wszystkie**
Liczba testów	20	20	20	20	80
Wartość max [mm]	9.074	9.058	9	9.029	9.074
Wartość min [mm]	8.991	8.996	8.955	8.915	8.915
Średnia [mm]	9.047	9.045	8.968	8.966	9.006
Odchylenie standardowe [mm]	0.027	0.019	0.015	0.031	0.046



Rysunek 3. Rozkład normalny dla średniej 9.006

W tabeli 2 przedstawiono wyniki pomiarów kąta nachylenia powierzchni górnej kostki do płaszczyzny podstawy. Wynik wyznaczono w oparciu równanie płaszczyzn i zależność

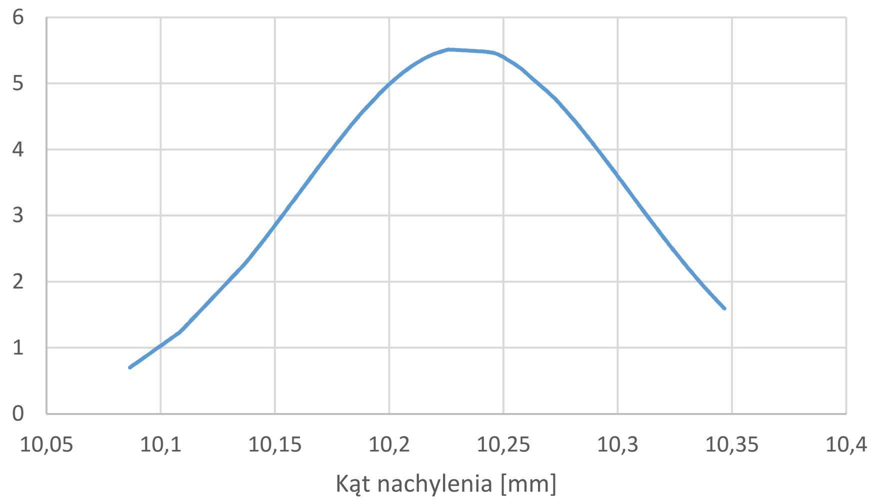
$$\theta = acos\left(A_x B_x + A_y B_y + A_z B_z\right) \tag{10}$$

w której:

Ax, Ay, Az, - parametry równania płaszczyzny odniesienia,
Bx, By, Bz, - parametry równania płaszczyzny pochylonej.

Tabela 3. wyniki pomiarów kąta nachylenia powierzchni górnej kostki do płaszczyzny podstawy

	Pozycja 0^0	**Pozycja 90^0**	**Pozycja 180^0**	**Pozycja 270^0**	**Wszystkie**
Liczba testów	20	20	20	20	80
Wartość max [^{0}]	10.34	10.324	10.215	10.347	10.347
Wartość min [^{0}]	10.182	10.141	10.087	10.225	10.087
Średnia [^{0}]	10.277	10.209	10.148	10.299	10.233
Odchylenie standardowe [^{0}]	0.049	0.049	0.03	0.032	0.072



Rysunek 4. Rozkład normalny dla średniej 10.233

5. Podsumowanie

Jak wynika z przeprowadzonych badań Algorytm RANSAC umożliwia tylko wstępnie wyznaczyć parametry płaszczyzn, błędy popełniane na tym etapie są zbyt duże dla zastosowań przemysłu maszynowego. To zgrubne oszacowanie daje jednak bardzo dobrą podstawę do analizy bardziej rozbudowanymi narzędziami (jak np. wspomniany już algorytm PSO), wpływa na to wyeliminowanie nadmiernych błędów mogących znajdować się w chmurze danych oraz znaczne zawężenie obszaru poszukiwań dla kolejnych kroków analizy danych. Dodatkową zaletą przemawiającą za wykorzystaniem metody RANSAC w zgrubnym szacunku jest łatwość jej implementacji.

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PORÓWNANIE WYNIKÓW EMISJI UZYSKANYCH Z TESTÓW JEZDNYCH NEDC ORAZ WLTC

Streszczenie: Artykuł zawiera analizę wyników pomiarów emisji, uzyskaną podczas badań samochodu na hamowni podwoziowej, z wykorzystaniem testów: europejskiego NEDC oraz ogólnoświatowego WLTC.
Słowa kluczowe: emisja szkodliwych składników spalin, NEDC, WLTC.

COMPARISION OF POLLUTANT EMISSIONS OBTAINED OVER NEDC AND WLTC DRIVING CYCLES

Summary: This research article presents the results of the analysis of exhaust components measured on a chassis dynamometer over the NEDC and WLTC driving cycles.
Keywords: pollutant emissions, NEDC, WLTC.

1. Wstęp

Nowy test jezdny WLTC, służący do wykonywania pomiarów emisji na hamowni podwoziowej, opracowany został tak, aby symulować rzeczywiste warunki obciążenia silnika spalinowego pojazdu samochodowego, a nie jak do tej pory przy pomocy testu NEDC, pracę głównie tylko w korzystnych warunkach. Uzyskane w nowy sposób wyniki emisji mogą być odniesione do limitów EURO, a samochód je spełniający charakteryzuje się bardziej rzeczywistą emisją zgodną z jej wymaganiami.

2. Badanie emisji samochodów

Badanie emisji pojazdów wykonuje się na hamowniach podwoziowych podczas tzw. testów jezdnych. Na całym świecie istnieje wiele odmiennych testów jezdnych

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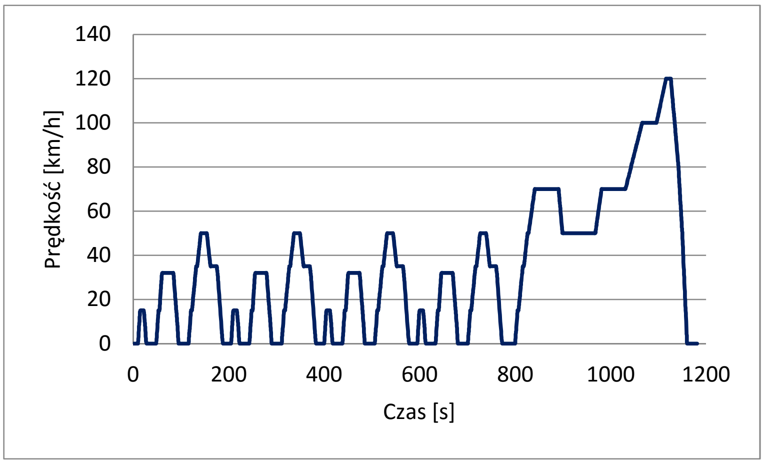
wykorzystywanych do badań legislacyjnych, pomiarów zużycia paliwa czy oceny oddziaływania motoryzacji na środowisko naturalne. W zależności od przepisów obowiązujących w państwie, w którym pojazdy są sprzedawane, muszą one spełniać normy emisji badane według ustalonego prawnie tam testu. Poważnym problemem jest potrzeba homologowania pojazdu osobno np. w Europie, USA czy Japonii. Z uwagi na to dąży się do zastąpienia wykorzystywanych obecnie testów, jednym testem ogólnoświatowym.

2.1. Test jezdny NEDC

Obecnie, na terenie Unii Europejskiej, w celu pomiaru emisji oraz zużycia paliwa samochodów osobowych i dostawczych, wykorzystywany jest test NEDC. Powstał on w latach 80-tych ubiegłego wieku, a dokładnie opisują go regulaminy EKG ONZ nr 83 oraz 101. Jego nazwa wywodzi się od angielskich słów New European Driving Cylce. Składa się z czterech powtórzeń cyklu jazdy miejskiej UDC (Urban Driving Cycle), oraz jednego cyklu jazdy pozamiejskiej EUDC (Extra – UDC).
Pojedynczy cykl UDC trwa dokładnie 195 sekund i składa się z trzech faz przyspieszania kolejno na pierwszym, pierwszym i drugim oraz pierwszym, drugim i trzecim biegu. Fazy te rozdzielone są okresami pracy silnika na biegu jałowym. Z uwagi na niewielką średnią prędkość pojazdu podczas tego cyklu (18,7 km/h), otrzymywana wartość emisji jest zaniżona. Wobec powyższego drugą częścią testu NEDC jest cykl pozamiejski odzwierciedlający jazdę po autostradzie, posiadający znacznie wyższą prędkość średnią, dzięki czemu wyniki z całego testu zbliżają się do rzeczywistej emisji pojazdu podczas ruchu drogowego.



Rysunek 1. Test jezdny NEDC

2.2. Test jezdny WLTC

Z uwagi na liczne niedoskonałości wcześniej wymienionego testu, a co za tym idzie, przydzielaniu homologacji samochodom niespełniającym norm w rzeczywistych warunkach ruchu, został opracowany nowy test jezdny nazywany WLTC. WLTP – Worldwide Harmonized Light Duty Test Procedure – to ogólnoświatowa procedura

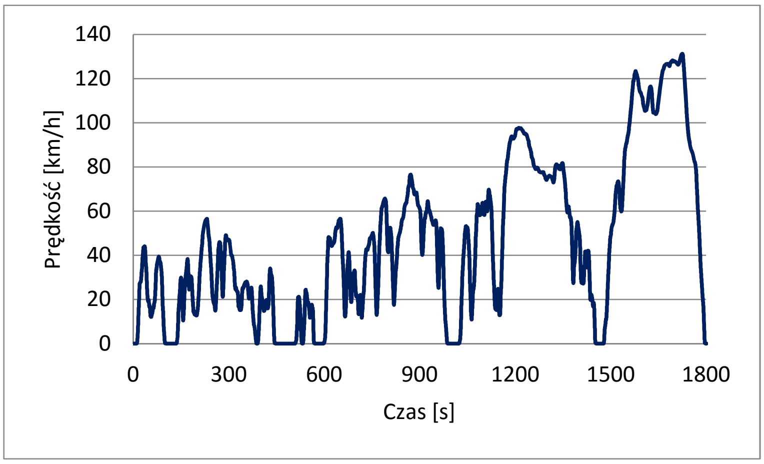
opublikowana w regulaminie GTR-15, zawierająca opis badań lekkich samochodów, w szczególności pomiarów zużycia paliwa oraz emisji CO_2.
Test jezdny, podczas którego dokonuje się pomiarów, nie jest stały, lecz ściśle zależy od stosunku maksymalnej mocy pojazdu do jego masy oraz od prędkości maksymalnej, co opisuje zależność (1):

$$P_{mr} = \frac{P_{rated}}{m} \quad \left[\frac{W}{kg}\right] \tag{1}$$

gdzie:

- P_{rated} - maksymalna moc silnika badanego samochodu,
- m – masa badanego samochodu.

Dodatkowo dużą różnicę testu WLTC w stosunku do testu NEDC stanowi dobór przełożeń, które są wykorzystywane podczas badań pojazdu. Test WLTC wymaga, aby dla każdego badanego samochodu wykonać oddzielne obliczenia dotyczące wyboru biegów oraz czasu ich zmiany.



Rysunek 2. Test jezdny WLTC

3. Aparatura pomiarowa oraz obiekty badań

3.1. Pomieszczenie badawcze

Pomiary przeprowadzono w laboratorium badawczym znajdującym się w Instytucie Badań i Rozwoju Motoryzacji Bosmal Sp. z o.o., które zostało zaprojektowane do wykonywania badań emisji, zużycia paliwa oraz pozostałych pomiarów opisanych w warunkach homologacji samochodów. Składa się ze specjalnej komory klimatycznej, hamowni podwoziowej i pomieszczenia sezonowania pojazdów.

3.2. System poboru i analizy spalin

Laboratorium badawcze w Instytucie Bosmal wyposażone jest w system poboru spalin HORIBA. System ten składa się z:

- układu próbkowania spalin CVS-CFV,
- tunelu rozcieńczającego Horiba DLT-7020,
- analizatorów spalin MEXA 7400 HRTLE,
- licznika cząstek stałych Horiba MEXA2000SPCS,
- urządzeń dodatkowych,
- systemu zarządzania Horiba VETS-7000NT.

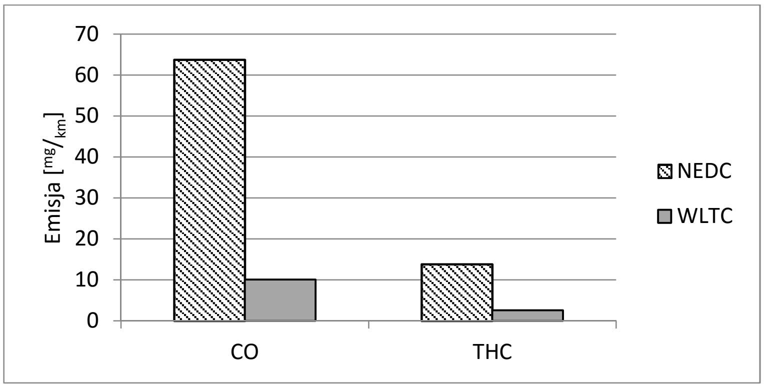
3.3. Hamownia podwoziowa

Do wykoania pomiarów wykorzystywana była dwuosiowa hamownia podwoziowa AVL ROADSIM o średnicy bębnów 48”, pozwalająca na bardzo dokładną symulację znanych oporów ruchu pojazdu.

3.3. Obiekt badań

Do badań wykorzystany był samochód osobowy wyposażony w czterocylindrowy, turbodoładowany silnik o zapłonie samoczynnym i pojemności skokowej 2 dm^3. Oczyszczanie spalin odbywało się za pomocą zabudowanego blisko silnika utleniającego reaktora katalitycznego oraz filtra cząstek stałych. Silnik wyposażono w komory spalania z bezpośrednim wtryskiem. Układ napędowy wykorzystywał sześciostopniową manualną skrzynię biegów. Pojazd nie posiadał układu Stop&Start. Przybliżony przebieg przed przystąpieniem do badań to 20 000 km.

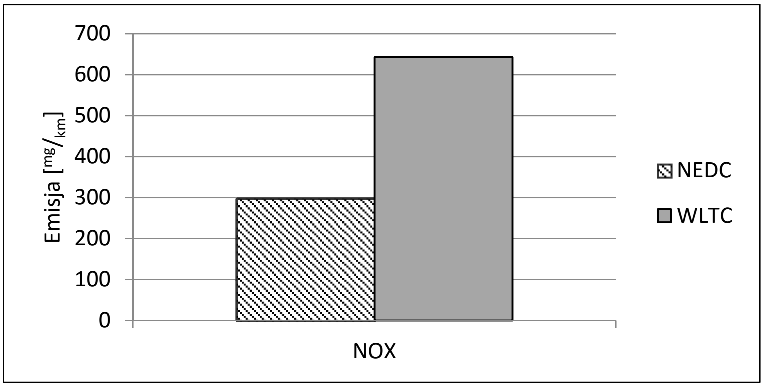
4. Wyniki pomiarów



Rysunek 3. Emisja tlenku węgla (II) oraz węglowodorów. Limit EURO 5 wynosi kolejno 500 $^{mg}/_{km}$ i 50 $^{mg}/_{km}$

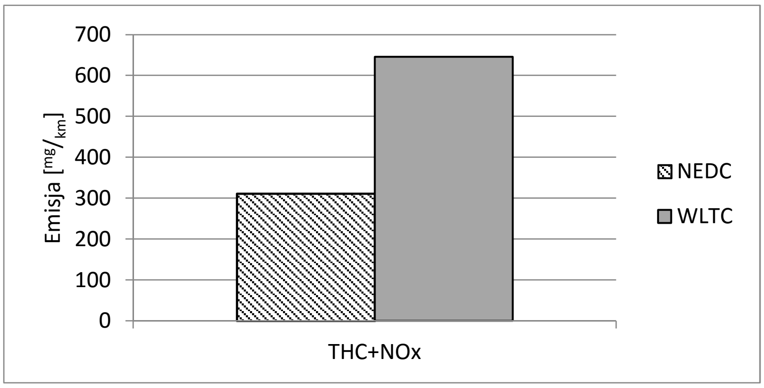
Emisja CO pojazdu jest przedstawiona na rysunku 3. Dla testu WLTC uzyskany wynik jest mniejszy w stosunku do testu NEDC aż o ponad 80 %. Wynika to z precyzyjnego sterowania przygotowaniem mieszaniny i spalania we współczesnych silnikach o zapłonie samoczynnym oraz tego, że zimny rozruch jest mniejszą częścią całego testu (to podczas niego wytwarzana jest największa ilość tlenku węgla).

Z rysunku nr 4 przedstawiającego emisję tlenków azotu, możemy odczytać wyraźny wzrost emisji podczas testu WLTC (o około 115%). Jest to spowodowane między innymi brakiem możliwości użycia zaworu EGR, który podczas dużych obciążeń silnika występujących podczas testu nie jest otwierany.

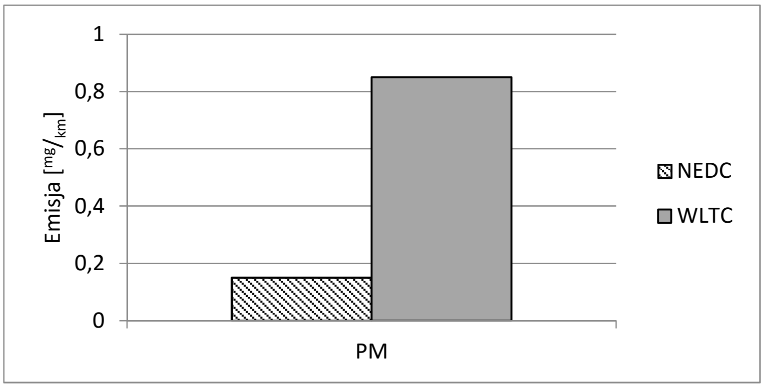


Rysunek 4. Emisja tlenków azotu. Limit EURO 5 wynosi 180 $^{mg}/_{km}$

Według przepisów europejskich, dla pojazdów wyposażonych w silnik o zapłonie samoczynnym, emisja węglowodorów limitowana jest jako suma emisji THC + NO_x. Takie wartości sumarycznej emisji są przedstawione na rysunku 5.



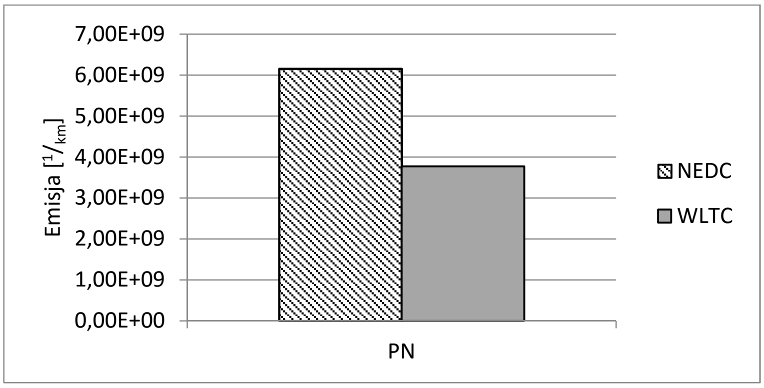
Rysunek 5. Emisja sumaryczna węglowodorów i tlenków azotu. Limit EURO 5 wynosi 230 $^{mg}/_{km}$



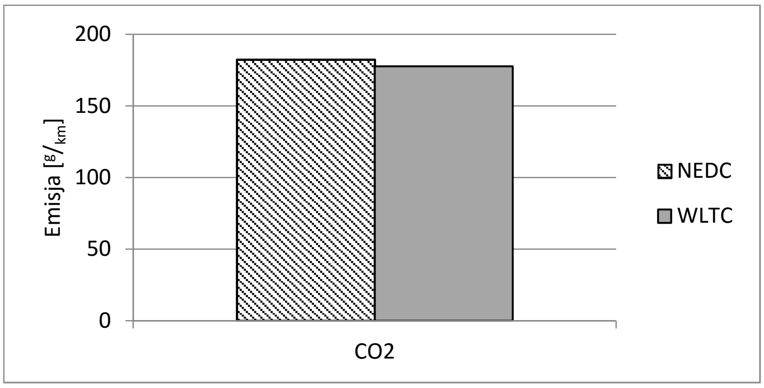
Rysunek 6. Masa cząstek stałych. Limit EURO 5 to 5 $^{mg}/_{km}$

Badany pojazd cechuje się niską emisją cząstek stałych, co zostało pokazane na rysunku 6. Jednak można zauważyć, że wynik uzyskany podczas testu WLTC jest aż o niemal 500 % większy niż podczas testu NEDC. Przeciwnie jest dla liczby emitowanych cząstek stałych. Tutaj widoczne jest zmniejszenie liczby cząstek o 40 %. Zgodnie z europejskimi przepisami pojazd spełnia wymogi normy EURO 5 odnośnie liczby emitowanych cząstek stałych, co jest pokazane na rysunku 7.

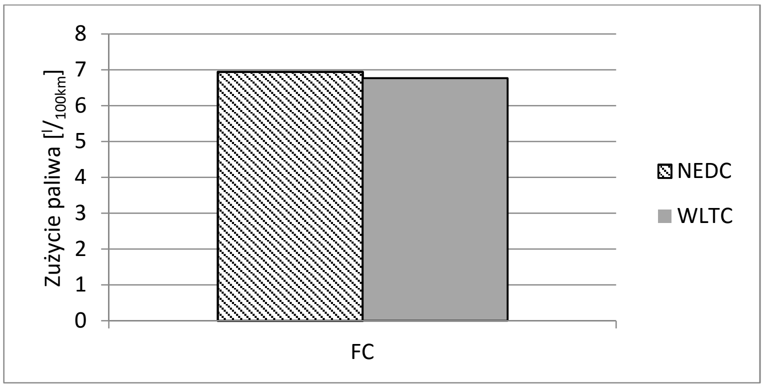
Emisja CO_2 (pokazana na rys. 8), uzyskana podczas testu WLTC w stosunku do NEDC, jest niższa o 2,6 %. Analogiczny wynik został otrzymany dla zużycia paliwa. Przedstawia to rysunek 9.



Rysunek 7. Liczba cząstek stałych. Limit EURO 5 to 6x10^{11} $^{1}/_{km}$



Rysunek 8. Emisja dwutlenku węgla



Rysunek 9. Zużycie paliwa

5. Podsumowanie

Określone przez przepisy limity emisji mogą być spełnione przez wykorzystanie kilku odmiennych rodzajów metod pomiarowych. Z uwagi na to opracowana została ogólоświatowa procedura pomiarowa, wprowadzająca jednakową metodykę. Praca ta zawiera porównanie wyników emisji otrzymanych w drodze badań nowym ogólnoświatowym testem WLTC, oraz obowiązującym testem europejskim NEDC. Pomimo założeń, wyniki uzyskane z pomiarów testem nowego typu, nie różnią się znacząco od uzyskiwanych aktualnie. Wyjątkiem są bardzo szkodliwe tlenki azotu, których zmierzona emisja wydaje się być bardziej realistyczna.

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DEVELOPING FLEXIBLE AUTOMATION SYSTEMS BASED ON MICROCONTROLLERS OF MSP430 SERIES FOR A DWELLING HOUSE

Summary: In this article the construction of devices for automation dwelling house based on TI MSP430 microcontrollers has been suggested. This device can control the state of the gas boiler via wire and get information via wireless channel. The control program was written in ENERGIA.

Keywords: dwelling house, microcontrollers, automation

WIELOFUNKCYJNE AUTOMATYCZNE SYSTEMY DLA INTELIGENTNYCH BUDYNKÓW Z UŻYCIEM MIKROKONTROLERÓW MSP430

Streszczenie: W artykule opisano budowę urządzań do automatycznego zarządzania inteligentnym budynkiem mieszkalnym. Urządzenie zbudowano stosując mikrokontrolery typu TI MSP430. Takie urządzenie może sterować stanem np. bojlera gazowego poprzez połączenie przewodowe, a także zbierać informacje poprzez kanał transmisji bezprzewodowej. Program sterujący zastał napisany przy użyciu oprogramowania ENERGIA.

Słowa kluczowe: inteligentny budynek, mikrokontroler, automatyka

1. Introduction

Today's digital technologies are distributed into all spheres of human activity. The so-called "smart house» is the most effective and popular system. This system can save

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energy, increase the degree of comfort for the residents and ensure the safety of their homes. The market sells already finished technical solutions in the name of many well-known and lesser-known companies, such as Apple [1] and Samsung [2]. To install such systems one should consult with a representative of the company as to the possibility of installation and maintenance of a particular “smart house” system which complies with the tasks of the customer.

This raises a number of difficulties for the customer, especially if it is related to the adaptation of the existing classical system of providing heat to the house or the need for a simple and reliable security system of the house from outside penetration [3]. Therefore, the authors of the project have proposed the implementing of a small system of smart clothes according to individual requirements of the customer. The main terms of this project are the usage of the available component base, simplicity of the system and its low cost.

2. Implementation

Of course, the basis of the project is a microcontroller. The authors used the processor of Texas Instruments company, based on the launchpad modules. Such a solution allows one to test relatively new developments of TI company [4] which are today the alternative for better-known microcontrollers of ATMEGA and MICROCHIP companies and which compete with them in price policy. Besides, TI microcontrollers are characterized by extremely low energy consumption (more precisely - a flexible balance between productivity and energy consumption) and the ability to generate the code for a microcontroller in an accessible ENERGIA [5] environment. This environment is a complete analog to a known ARDUINO environment with the support of most standard libraries for sensors and data transmission systems.

In this project, the system of remote control of the thermal heating boiler and the protection system of the house were chosen as the automation objects.

In the first part of the project, the authors faced with the task of remote control of the gas boiler, as the boiler is located in the distant place (a basement). The manual mode of its switching-on is inconvenient, especially in the summer mode of its functioning when you need to switch on the boiler to heat the water heater for relatively a short period (about 10 minutes). Exceeding this time limit leads to overheating of the water volume in the boiler and as a result - you have an excessive use of precious energy. The reduction of the time limit leads to insufficient heating of water in the boiler. Besides, sometimes there are cases when due to insufficient gas pressure in the supply system the boiler protection halts its functioning. In this case, the user should press the button RESET on the boiler. The user who is at some distance from the boiler may not know at once when this situation has taken place but can find out about it only when there is no hot water in the tap. This causes the emergence of a number of inconveniences in using the hot-water system in the house.

3. Experimental data

The proposed automation device consists of the following parts: a control module, which is located in a convenient place for the user, wired connection and on / off submodule located near the boiler. In the control module there is a microcontroller itself with a system of operation indicators - sound and LED light, the start button of mode activation and the operating mechanism - relay. The program code for the TI MSP430G2553 [6] microcontroller is created in ENERGIA environment. Testing of the whole device operation was conducted on the original TI prototype board. In the final variant, in order to save space in the casing, the microcontroller is located directly on a single circuit board. The power supply is 12V, it is external.

The device should switch on the relay for a fixed period, with sound indication of the start and end of the process, and the blinking LED that indicates the active state of the boiler functioning. The active state is characterized by turning on of 12V to the wire line via relay contacts. This solution increases the safety of use, because no high voltage on the working elements and wired connection of the device is present. On the submodule, this voltage of 12 V from a wired connection is directly supplied to the coils of the power relay whose contacts directly switch on the voltage of the boiler. This provides control of the gas boiler operation. If you need to go back to the manual mode of operation, the button - switch is proposed which duplicates the relay contacts on the submodule.
The operating circuit is shown in Fig. 1.

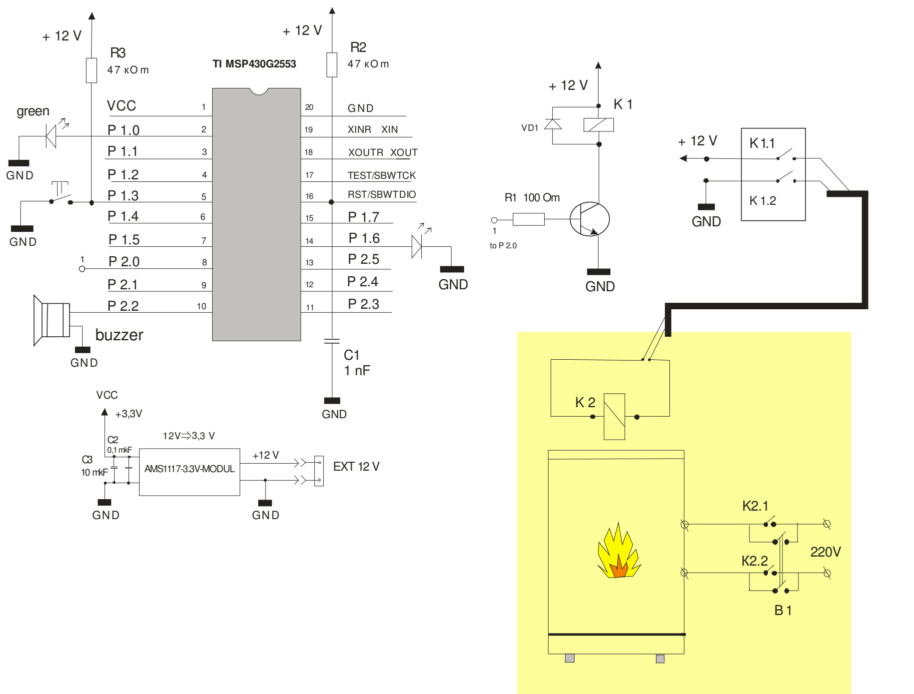

Figure 1. The diagram of device

A picture of the control module with the casing is shown in Fig. 2.

Figure 2. The picture of device in case

The program code for the microcontroller is presented below.

```
const int buttonPin = PUSH2;
const int ledPin = GREEN_LED;
const int led = RED_LED;
int stat=0;
int i=0;
int k=0;
int buttonState = 1; // variable for reading the pushbutton
status
void setup() {
 // initialize the LED pin as an output:
pinMode(ledPin, OUTPUT);
pinMode(led, OUTPUT);
 // initialize the pushbutton pin as an input:
pinMode(buttonPin, INPUT_PULLUP);
digitalWrite(led, LOW);
digitalWrite(ledPin, HIGH);
pinMode(P2_2, OUTPUT);
digitalWrite(P2_2, LOW);
pinMode(P2_0, OUTPUT);
digitalWrite(P2_0, LOW);}
void loop(){
 buttonState = digitalRead(buttonPin);
 if (stat==1) {i=i+1; digitalWrite(led, HIGH); k=1;};
 delay(200);
 if     (i==1)     {digitalWrite(P2_2,     HIGH);delay(400);
digitalWrite(P2_2, LOW);};// start sound
```

```
 if (stat==1 && k==1) {digitalWrite(led, LOW);k=0;};
 if (stat==1) {digitalWrite(P2_0,HIGH );}
 else
 {digitalWrite(P2_0, LOW);};
 delay(200);
 if (stat==1 && k==0) {digitalWrite(led, HIGH);k=1;};
 if (i==3100) {digitalWrite(ledPin, HIGH);digitalWrite(led,
LOW);stat=0;  i=0;  digitalWrite(P2_2,  HIGH);delay(1400);
digitalWrite(P2_2, LOW);};//stop sound
 if (buttonState == LOW) {
 stat=1;
 digitalWrite(ledPin, LOW);
 }
}
```

To control the state of the boiler failure the authors have proposed to use the wireless technology [7]. As this system is indicative, the use of wireless technology is appropriate. For this purpose popular standard NFS2214 modules are used, which allow one to provide a connection up to 50 m under the construction specifications of the house, which is a sufficient condition for this project. Through optocouplers the information about the boiler states is read out from its active light indicators (not presented in this article). This provides the galvanic isolation of input and output circuits of the circuit. After this the high level of signaling (the state indication - boiler failure) is supplied to the input port of the microcontroller, where this state is fixed by the microcontroller program and wirelessly transmitted to the receiving module of the system. The receiving unit, which is built on the same scheme, reflects this state with a luminous and sound signal.

4. Conclusion

So, this development can reliably and efficiently realize the function of remote control of the heating system of the house. In the future, it is planned to carry out the data transmission about the water's temperature in the boiler and present it on the graphic displays of the receiving unit, and also connect the signaling sensor of gas contamination of the premise.

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TELEMETRYCZNY SYSTEM DLA E-UBRAŃ (INTELIGENTNEJ ODZIEŻY)

Streszczenie: W artykule opisano budowę prototypu przenośnego urządzenia elektronicznego do zdalnego ustawiania podstawowych e-ubrań. Takie e-ubranie gdy jest noszone np. przez pracownika stanowi system "ubranie-człowiek". Urządzenie sterujące dla takiego systemu zbudowano używając technologii bezprzewodowych mikrokontrolerów. Mobilny system pomiarowy z zastosowaniem mikrokontrolera TI MSP430 jest opisany w pracy. Ten system śledzi zdalnie (monitoruje) parametry e-ubrania. Ubranie robocze pracownika szklarni zostało przeanalizowane jako przykładowy modelowany obiekt.

Słowa kluczowe: e-odzież, inteligentne ubrania, czujniki, mikrokontrolery, telemetria bezprzewodowa

TELEMETRY SYSTEM FOR SMART CLOTHES

Summary: In this article the construction of an experimental sample of a portable electronic device for fixing the basic parameters of the system "clothes-man" on the basis of modern wireless microcontroller technology has been suggested.The mobile measuring system based on TI MSP430 microcontrollers to track the parameters of "smart clothes" has been presented. The uniform of a worker for the greenhouse has been proposed as a modeling object.

Keywords:smart clothes, sensors, microcontrollers, wireless telemetry

1. Introduction

Today, there are many dangerous professions in our lives. The most dangerous are rescue workers, firefighters, steelworkers, military men and so on. One of the main means of protection from the dangerous environment is protective clothing and

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additional protective devices (e.g. balloons with compressed air, steel plates, and so on). All this leads to a complication of performing the task, but it is necessary for safe health or life. Significantly improved protection of special clothing is the usage of modern electronic systems [1].
The uniform of a worker for the greenhouse has been chosen as a sample. In fact, the incidence of temporary disability of workers in greenhouses is 5 times higher than that of their colleagues who work with similar chemicals on the open soil, and 10 times higher than in people who do not come into contact with pesticides and fertilizers.
The authors offer modern electronic controls of vital functions of the human body integrated in clothing (in under and above local area of a uniform) [2]. The essence of this proposal is that sensors of various types are mounted into the clothing which fix important indicators of internal and external surroundings, such as temperature, humidity, duration of stay, sensors of chemically hazardous substances, and so on (Fig.1). Modern developments in the field of microcontrollers' technologies allow processing the data with high speed and efficiency, besides, they are easily mounted into portable systems of various types. It is especially necessary to mention the widespread introduction of wireless admission-transmission systems that can significantly improve the efficiency of the so-called "smart clothes" [3]. Thus, in case of critical situations the microcontroller having analyzed the information from the sensors embedded in the worker's clothes by special means of signaling (warning sound or indicative ones, for example, will report on the danger of the worker's state to the controlling remote station, making the occurrence of a critical situation for the health or life of a man impossible) [4].

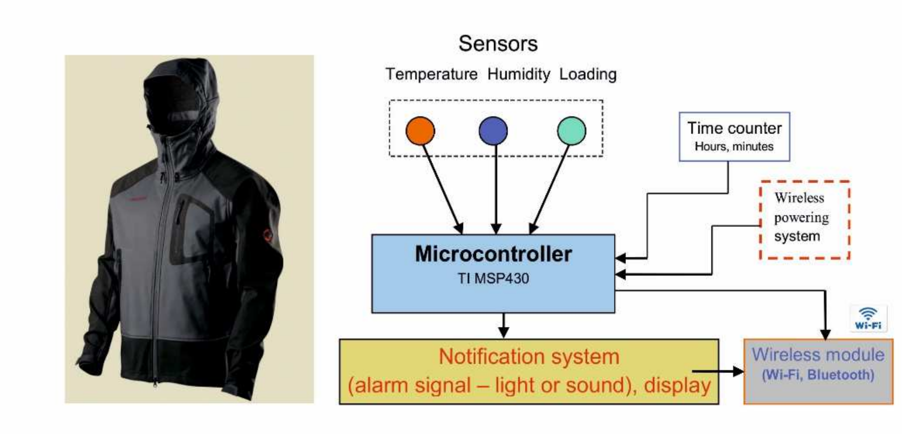

Figure 1. The intelligent uniform based on new digital technologies

2. Implementation

The portable monitoring system for "smart clothes" was designed to be fixed in clothes and worn comfortably. The system consists of the main module (device) and sensors, which are connected with the module through flexible wires.

The measuring system (Fig.2) consists of deformation sensors 1-4 (CP 0152 sensors - 4pcs), pressure (loading) sensors 5-8 and two combined temperature-humidity-pressure sensors 9,10. Because sensors 1-8-are resistive and strain - gauge ones, for their approval the bridge switching circuit is used. The sensors are divided into two groups and powered from digital-to-analog converters (DAC). This allows to adjust their sensitivity within a very wide range. The signal from each bridge reaches the amplifier with variable gain (PGA), and further to the input of the analog-to-digital converter (ADC). The digital code that is responsible for the amount of strain and pressure through digital insulators (TI ISO7341 and ISO7340) is supplied to the input of TI MSP430F5529LP [5] microcontroller, and after pre-processing by wireless technology to the host computer [6]. The use of digital isolators protects a man (on whom the sensors are fixed) from the accidental voltage contact. The level of protection is more than 5000V. In addition, the galvanic isolation provides a significant reduction in noise from the digital part of the measuring system. The reading speed of measurement results changes with the use of the control program and can be within the range of 0-100 measurements per second for one channel.

Two combined temperature-humidity-pressure sensors (Bosch BME280), one of which is under the clothes and the other - outside, allow measuring the microclimatic conditions under the object of study, and controlling the air microcirculation. I^2C interface was used to communicate with the main board for these sensors [7].
CC3100BP modules organize wireless communication of the measuring system. This module gives us a possibility to send data to any suitable receiver. With this module, we can build truly functional low-power wireless solution.CC3100BP and MSP430F5529LP microcontrollers are connected through SPI. The device is powered by TI BOOSTXL-BATPAKMKII.

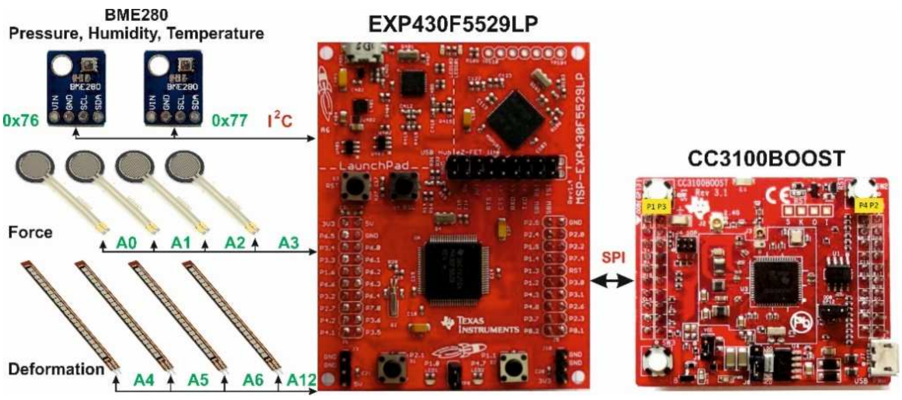

Figure 2. The example of the measuring system for "smart clothes"

3. Experimental data

The whole system operates correctly and the data can be received onto a smartphone, tablet or any Android - based device. The range of the designed system is very appropriate. In free space it is about 120 metres (in case of a short antenna) and more than 200 metres (with a long antenna). The signal easily passes through walls and the floor. The data request takes place every second and continues until the receiving device is connected. The results of transmitted data (pressure, temperature, humidity and strain) to the receiver are presented in Fig. 3 for *Access Point*mode.

4. Software

The main part of the measurement system control software was written in Energia MT v.0101E0017 [8]. For input data from Bosch BME 280 sensors, we used *cactus_io_BME280_I2C* library. Reading the data from analog inputs was realized through standard Energia*analogread* function. For communication with hardware (BME280 and CC3100BP) Energia*Wire* and *SPI* libraries were used. CC3100 was switched to Access Point mode, and Web server on port 80 began to operate. The monitoring data were transmitted to USB-Serial via virtual COM port for debugging.

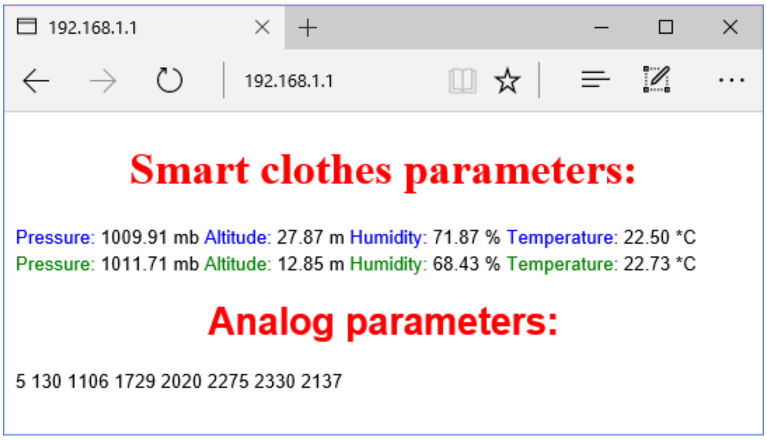

Figure 3. The data received from digital and analog sensors inWeb mode

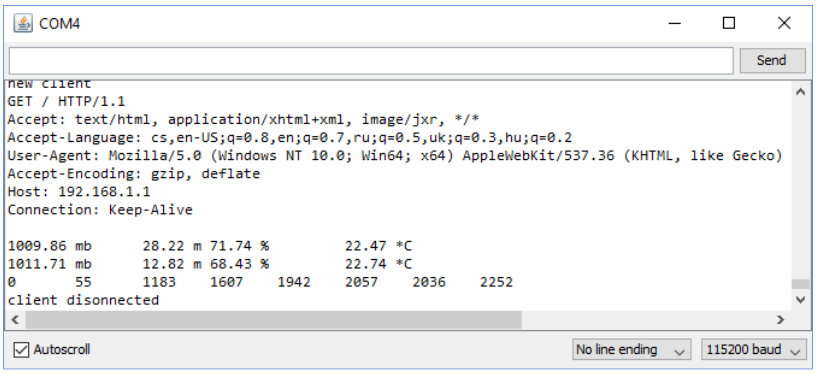

Figure 4. The example of the obtained data for debugging

On the whole, the system operates correctly. The main advantage of this realization is the usage of any type of clients (smartphone, tablet PC etc.) for monitoring. The disadvantage is low speed of data transfer, limited by the refreshing rate of web page (not critical for temperature, humidity and pressure). Unfortunately, without CC31XXEMUBOOST - Advanced Emulation BoosterPack for SimpleLink Wi-Fi CC3100 BoosterPack plug-in module, we don't have a possibility to upload data to the internal CC3100BP flash memory, and realize impressive graphic Web-design of our measurement system interface. We leave this feature for the future.
The sample part (initialization) of the control software is as follows:

```
#include <SPI.h>
#include <WiFi.h>
#include <Wire.h>
#include "cactus_io_BME280_I2C.h"

// Create BME280 object
BME280_I2C bme; // First BME280 sensor I2C using address 0x77
BME280_I2C bmf(0x76); // Second BME280 sensor I2C using
address 0x76

// Constants used to give names to the pins used:
const int analogInPin0 = A0; // Analog input pin A0
.
const int analogInPin12 = A12; // Analog input pin A12

int sensorValue0 = 0; // value read from the A0
.
int sensorValue12 = 0; // value read from the A12

const char ssid[] = "SmartClothes";
const char wifipw[] = "12345678";

WiFiServer server(80);
```

5. Conclusion and summary

Thank to Texas Instruments professional parts, tools, great documentation, reference designs and support community forum we were able to develop, build and test measurement systems in a short time.
Total cost of the designed device in case of manufacture is about 100 $ (without outfit). After integrating in clothes this device can be fully functional and could be used in any branches where a special type of the uniform is needed.
To increase the autonomy of the telemetry system it is advisable to use modern energy harvesting systems for converting movement, deformation and the heat of human body to electricity [9].

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THE USE OF 3D PRINTING TECHNOLOGY FOR RECONSTRUCTION AND REPRODUCTION OF HISTORIC SITES

Summary: The paper considers the concept of 3D printing, its features and modern spheres of applications. The most popular technologies and appropriate types of 3D printers are described in detail. Examples of the use of three-dimensional printing for the restoration of historic sites are given and described.

Keywords: 3D printing, 3D printer, 3D model, Cinema 4D

ZASTOSOWANIE TECHNOLOGII DRUKU 3D DO REKONSTRUKCJI I REPRODUKCJI ZABYTKÓW

Streszczenie: W artykule omówiono koncepcję drukowania 3D, jego cech i zaawansowanych aplikacji. Szczegółowo opisane najbardziej popularne technologie i odpowiednie rodzaje 3D-drukarek. Zaprezentowano przykłady użycia druku trójwymiarowego do rekonstrukcji i reprodukcji zabytków.

Słowa kluczowe: drukowanie 3D, 3D-drukarki, model 3D, Cinema 4D

1. General information about 3D printing

Modern digital technologies have reached a level of development our ancestors could tell about only in science fiction novels. This makes new impressive capabilities in science, medicine, technology, education, architecture etc. available. For example, since the beginning of the new millennium the concept of «3D»is closely included in our daily lives. Now there is no single person who would never heard of 3D printing technology, but not all imagine its possibilities and scope. A few years ago, 3D printer was a technological innovation, and now it is a widely used tool to improve human life.

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Although 3D printing became popular relatively recently, its idea was put forward 80 years ago, in the twentieth century. In 1987, Scott Crump created fused deposition modeling technology that is the most simple and popular now. In 1988, Charles Hull created stereolithographic technology and founded 3D Systems Company, which currently is one of the main manufacturers of 3D printers. However, despite the further development of these technologies, only in 2005 Z Corp. created 3D printer, capable of printing in color and with sufficient quality. Two years later, a printer could print half of its parts [3].

Now 3D printing device is capable to create three-dimensional objects of any shape and of a wide range of materials with different properties. It can be applied in almost all spheres of human activity. Specifically, 3D printers can work with photocurable resins, various kinds of plastic filaments, ceramic powder and metal clay. The use of these materials allows making a printed prototype sufficiently close to the original. Materials in different colors, different flexibility, rigidity or transparency can be used. They can imitate gold, silver, porcelain, wood, rubber and many other metals, minerals or substances [6].

1.1. 3D printing technology

Today the foundation of printing of three-dimensional objects lies in the principle of gradual layering of the necessary material created according to a special computer program model. [8] The approach, which is used in industrial production now, has many shortcoming, the main among them are time expenditure and a high proportion of waste that is simply going to landfill. For an item is made by cutting off excess in various ways, for example, using machine lathe. Therefore, the first field of application of three-dimensional printing is the industry. With 3D printers, this operation appeared to be several times cheaper, quicker and clearer. We can say that 3D printer is a kind of non-waste machine, which can make quite diverse products [2]. To understand how the 3D device works, we need to consider today's most widespread methods of three-dimensional printing, because they differ by speed, by principle of action, by the materials used, and consequently, by the result of the work. For example, only 3D printers, which use inkjet principle, can create full-color products, while others only print monochrome. The most common modern technologies are SLS (selective laser sintering), HPM/FDM (fused deposition modeling) and SLA (stereolithography).

Stereolithography technology works like this: the laser ray is directed to the liquid resin, which makes it to harden in an appropriate way. [5] A liquid resin is a translucent material that easily deforms under the influence of atmospheric moisture. After hardening, it can be fused, mechanically processed and painted.

Selective laser sintering technology uses sintering of powdered agents under the laser ray. [5] To the purpose, it is the only 3D printing technology, which is used to manufacture molds for metal and for plastic casting. Plastic have excellent mechanical properties, providing them significant functionality. SLS technology can also uses ceramics, powdered plastic or already mentioned above metal. According to the established computer models the products of particular molds are formed.

HPM technology (often called FDM) allows one to mold not only models, but also the final details from the standard, construction and high efficiency thermoplastic. This technology of printing is advantageous concerning cleanliness, ease of use and

suitability for everyday needs use. Thermoplastic products are resistant to high temperatures, mechanical loads, chemicals or degree of humidity.
HPM technology allows one to create complex multilevel molds, cavities and holes that are difficult to get using other methods [6].
3D printers based on this technology create objects layer by layer, warming the material to semisolid state and squeezing it using a needle-like nozzle according to the computer generated routes. The plastic filament is fed from 3D printer section to the printing head that moves depending on the change of coordinates X and Y, defined by 3D model. When printing is completed, the product is easily separated from the printing surface and can be ready for use.
In addition, new three-dimensional printing technologies are appearing, such as printers based on DLP technology using digital light processing. They use photocurable resins and DLP projector [5]. Electron-beam melting is commonly used to create a three-dimensional metal objects. For this, such an interesting material as metal clay is used. It is made from a mixture of organic glue, cuttings and a certain amount of water. To form ink into a solid object, it must be heated to a temperature at which glue and water burn out and cuttings melt into a monolith. There are also EBM-machines that generate electronic impulses instead of a laser ray for melting metal clay. It should be noted that this method provides high print quality and excellent manufacturing of fine details.
Of course, as well as technologies differ, 3D printers are quite different that is each device is created only fitting a particular printing technology. Also based on complexity, quality, speed and size of objects made 3D printers are divided into domestic (available to public users) and industrial by means of which quite complicated things can be created. This enables the use of 3D devices in extremely different spheres of production [1].

1.2. Applications of three-dimensional printing

It has been said that in the near future people would not need any factories, and everything could be printed at home. Meanwhile, 3D printing has given great opportunities for experiments in such areas as architecture, construction, medicine, education, fashion design, small-scale production, jewelry, and even food industry.
In architecture, for example, 3D printing allows one to create three-dimensional models of buildings or even entire neighborhoods with the entire infrastructure. In construction, there is every reason to believe that in the near future, the process of construction of buildings will much simplify and accelerate. Scientists will create 3D printing systems for the construction of large-scale facilities that will operate on the principle of the cranes, which build walls from the concrete layers [4].
Now three-dimensional, small-scale production printing is widely used for the manufacture of exclusive products such as pieces of art, figures of different kinds of characters, clothes and shoes, gifts, toys, jewelry, prototypes of certain products or any design details. A few restaurants in the world already give the opportunity to taste food printed on 3D printer.
In medicine, due to three-dimensional printing technology doctors reproduce copies of the human skeleton or certain tissues of the human body [4]. 3D printers are now used in prosthetics and dentistry. Currently, scientists are working on a printing of

human organs. As you can see, the possibilities offered by the 3D printing are truly endless in almost all spheres of human activity.
Before printing a three-dimensional object, one must create its computer 3D model. There are a lot of programs allowing to do it, but the most common today can be considered the following: Autodesk 3Ds Max, Cinema 4D, Blender, Wings 3D, ZBrush, Art Of Illusion, Zmodeler, Luxology Mogo. Of course, each has its own characteristics, but all 3D editors work on the basis of mathematical representation. The created 3D model is represented by a set of points in 3D space, combined by different geometric objects such as triangles or lines. In addition, three-dimensional models for printing can be acquired by using 3D scanners, which greatly facilitates their development.

2. 3D printing as a means of modeling and reconstruction of historic sites

We believe that 3D printing can be a great solution to the question of reconstruction and reproduction of historic sites. Now in the region, as well as throughout Ukraine, there are a lot of completely or partially destroyed churches, castles, and buildings that are important to the history and culture of our country. It is important to keep the memory of them, visually convey to future generations all their beauty, elegance and grandeur [7].
Students of the Department of Computer science and Teaching Techniques of Volodymyr Hnatiuk Ternopil National Pedagogical University decided to give impetus to this process and created a series of 3D models of castles of Ternopil. In particular, a three-dimensional model of Ternopil Castle has been already developed and published. The Department conducted work on finding the necessary archival materials that would demonstrate the perspective, design and scale of certain parts of the building. A range of 3D editors that would allow putting the plan into practice was considered, a selection of the correct dimensions of the castle was made.
Direct development model was conducted using Cinema 4D programming package (Figure 1). The model was established based on found information on the planning of the castle and its front view. In addition, its optimization was held to avoid problems during printing, as well as a division into smaller pieces for faster printing time and minimal use of resources. With a special Slicer program, 3D model was converted into a drive code, understandable by 3D printers.

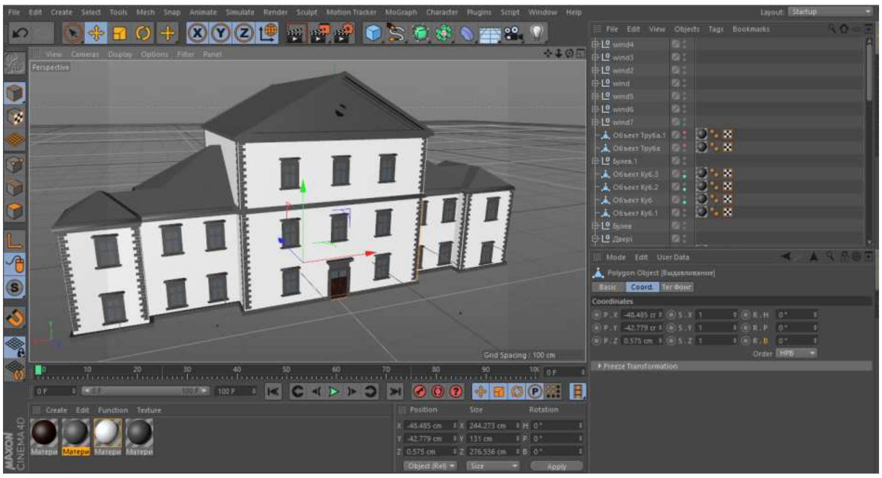

Figure 1. Model of Ternopil Castle in the software environment

Printing of the model was implemented using the technology of fused deposition modeling (HPM/FDM) which benefiting in high accuracy and printing quality. Generally, about two kilograms of white and gray thermoplastic were spent. Since the size of the print surface was smaller than the established model, its individual elements were published and then pieced by the students. The castle took about two weeks to make it after 3D printing is quite a long process. Depending on the complexity, quality and size of the model it can take from several minutes to several days. A diminished finished copy (Figure 2) of Ternopil Castle was presented in April 15, 2016.

Figure 2. Finished model of Ternopil Castle, printed on 3D printer

We have examined the main features of 3D printing, its technology and application, and a software needed to create three-dimensional models. As you can see, although 3D printing is a relatively new field, but it is widely used today in many areas of human activity. The interest deepens in Ukraine, too. Today, 3D printers do not seem to be the devices from fiction films or novels. They are a reality and bring a great benefit to humanity.

We believe that 3D printing is a future of engineering and science. The reconstruction and reproduction of historic sites of our region can be considered as another promising area of application of 3D printing. This process is relatively fast, high quality, inexpensive and visual, and the models created will conform to the originals at the most.

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PROJEKT KONCEPCYJNY DRUKARKI WIELKOFORMATOWEJ DO MURALI

Streszczenie: Praca zwiera opis projektu wykonania drukarki naściennej. Porusza zagadnienia techniczne i teoretyczne, których opracowanie jest niezbędne przed przystąpieniem do pracy nad wykonaniem przedmiotu artykułu.

Słowa kluczowe: drukarka, farba, mural, poligrafia, projekt.

CONCEPTUAL DESIGN OF THE SPECIAL PRINTER FOR MURALS PERFORMANCE

Streszczenie: Praca zwiera opis projektu wykonania drukarki naściennej. Porusza zagadnienia techniczne i teoretyczne, których opracowanie jest niezbędne przed przystąpieniem do pracy nad wykonaniem przedmiotu artykułu.

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1. Wstęp

Projekt drukarki wielkoformatowej ma na celu stworzenie wielkoformatowej drukarki naściennej. W dzisiejszej kulturze bardzo popularne stały się artystyczne malunki naścienne wewnątrz i na zewnątrz budynków zwane muralami. Problemem jest to, iż wykonanie takiej pracy wymaga ogromnego talentu i wielu lat ćwiczeń artysty wykonującego takie prace co przekłada się na wysokie koszty wykonania malunku. O ile wewnątrz budynków wystarczy człowiek z talentem i farbami, o tyle murale zewnętrzne wymagają już użycia profesjonalnego sprzętu tj. podnośników koszowych, tymczasowych rusztowań lub sprzętu alpinistycznego.

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Rysunek 1. Wizualizacja zastosowania drukarki

Mogąc wykonywać takie instalacje maszynowo, w sposób zautomatyzowany, znacznie ograniczy się ilość potrzebnego sprzętu oraz wyeliminuje się potrzebę zatrudnienia człowieka, który posiada umiejętności nabywane w bardzo długim okresie czasu. Zdolności te wymagają również rzadko występujących predyspozycji człowieka tj. talentu.

Zastosowanie

Malunki artystyczne - maszyna będzie mogła wspomóc człowieka w tworzeniu instalacji artystycznych. Artyzm, kunszt to przede wszystkim twórcza praca umysłu, a wykonywanie tego to już rzemiosło czyli mozolne i ciężkie do wykonania przez człowieka działania. Drukarka miałaby zająć się etapem czysto rzemieślniczym.

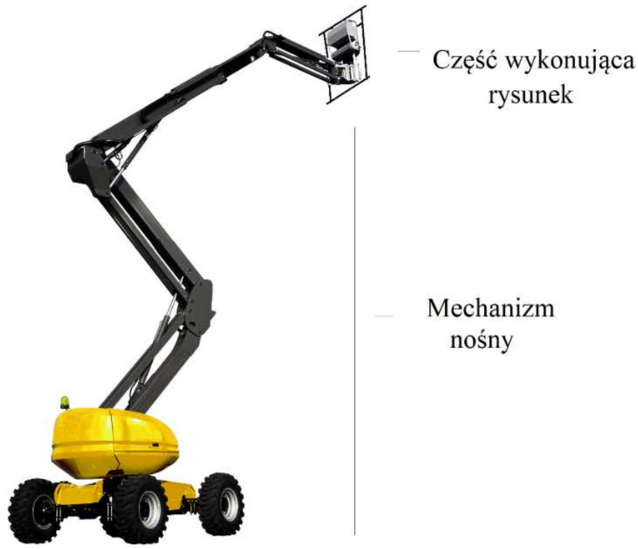
Branża reklamowa- obecnie jesteśmy przyzwyczajeni do wielu wielkoformatowych reklam zainstalowanych w mieście na budynkach. Reklamy te są często mniej estetyczne w porównaniu z bezpośrednimi malunkami na ścianach. Jedyny powód, dla którego firmy wolą bilbordy od murali to cena oraz łatwość instalacji. Są one zdecydowanie mniej trwałe oraz bardziej podatne na uszkodzenia np. przez silny wiatr. Jednym z celów stworzenia wielkoformatowej drukarki murali jest znaczne obniżenie kosztów malunków przez co stworzenie konkurencji dla bilbordów.

Branża remontowo usługowa - chcąc wykonać renowację elewacji budynku, potrzeba grupy pracowników oraz specjalistycznego sprzętu. W przyszłościowych etapach projektu, można uwzględnić również maszynowe wykonywanie elewacji. Wyższy poziom automatyzacji tego procesu oraz możliwość wykonania dowolnych zdobień mogłaby być dużą konkurencją dla obecnych firm pod warunkiem uzyskania konkurencyjnej ceny.

1. Zagadnienia teoretyczne i techniczne

1.1. Opis konstrukcji

Najważniejszym elementem będzie część drukująca mająca możliwość translacji w 2 osiach (XY). Część ta będzie znajdowała się na mechanizmie, którego zadaniem ma być takie ustalenie i zamocowanie części drukującej, aby było możliwe zadrukowanie wybranego obszaru oraz aby konstrukcja mogła się przemieszczać po całym obszarze zadrukowania. Przemieszczanie w odpowiednich osiach mechanizmu nośnego dla elementu drukującego nie powinno wykraczać poza przyjęte dopuszczalne odchyłki.



Rysunek 2. Rysunek poglądowy maszyny[3]

Mechanizmem nośnym może być docelowo podnośnik koszowy, dźwig, podest nastawny lub dowolny mechanizm, który zapewni dostęp części drukującej do wymaganej powierzchni roboczej oraz spełni kryteria związane z wysoką precyzją przemieszczenia się w danych osiach oraz stabilnością konstrukcji. Przedmiotem pracy jest część drukująca. Mechanizm nośny nie zostanie przedstawiony.

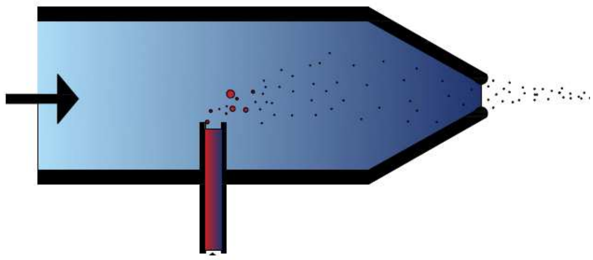
Część drukująca będzie składać się z głowicy drukującej, przemieszczającej się po osiach X i Y. Ruch po osiach będzie wykonywany przez 2 silniki krokowe, a przeniesienie napędu z silnika krokowego na oś będzie realizowane przez pasek zębaty (w osi X -poziomej) i przez napęd śrubowy (w osi Y-pionowej). Ruch ten będą umożliwiały prowadnice szynowe (w osi X) oraz wałki prowadzące (oś Y).

[3] Serwis internetowy: http://www.kiloutou.pl/pracy-na-wysokosci/podnosnik-przegubowy-diesel-177-m-maksymalny-wysieg-106-m/

Głowica drukująca będzie składać się ze zmodyfikowanej listwy wtryskowej gazu LPG (4 zawory sterujące przepływem powietrza). Głowica będzie tak skonstruowana, aby przepływ powietrza zabierał ze sobą cząsteczki farby podawanej za pomocą igły iniekcyjnej o małej średnicy (0,18mm do 0,4mm), a następnie przenosił ją na powierzchnię ściany (jako mieszaninę dwufazową składającą się z powietrza i farby) na jeden punkt o średnicy do 2 mm (Rys. 3).

Rysunek 3. Listwa wtryskowa LPG Tomasetoo[4]

Proces zabierania farby będzie odbywał się dzięki dużej prędkości przepływu powietrza. Wraz ze wzrostem prędkości powietrza maleje jego ciśnienie statyczne co powoduje „zassanie" cząsteczek farby. Zjawisko to wyjaśnia prawo Bernoulliego (Rys. 4).



Rysunek 4. Schemat zasady działania dyszy natryskowej

Jeśli przepływ powietrza okaże się zbyt powolny, będzie można zastosować **eżektor,** to znaczy miejscowo zmniejszyć przekrój przez który przepływa powietrze, aby zwiększyć prędkość przepływu gazu.

Do realizacji napędu planuje się zastosowanie silników krokowych o parametrach:

- oznaczenie: 57H76-2008B (8 przewodowy uniwersalny),
- połączenie uzwojeń: równoległe (paraller),
- moment trzymający: 1,9 Nm,
- pobór prądu przy połączeniu równoległym: do 3 A,

[4] Serwis internetowy: http://www.tomasetto.com/en/products/rail-injectors/it01-plus - 10.2016

- sterownik: E5030X3: 3 osiowy sterownik bipolarny zaprojektowany przez Ryszarda Pachurę. Sygnały do sterownika będą wysyłane z platformy Arduino Uno,
- zasilanie sterownika odbywa się bezpośrednio z transformatora 32V DC (pobór prądu do 6 A).

Sterowanie cewkami elektrozaworów – będzie odbywać się za pośrednictwem układu elektronicznego zaprojektowanego z zastosowaniem tranzystorów mossfet. W pierwszych fazach projektu będzie on sterowany za pomocą platformy Arduino Uno podobnie jak silniki krokowe.

1.2. Pojęcia związane z drukiem

Poligrafia – jest dziedziną techniki zajmującą się drukiem. Zajmuje się zagadnieniami związanymi z farbą, obrazem i sposobami drukowania.

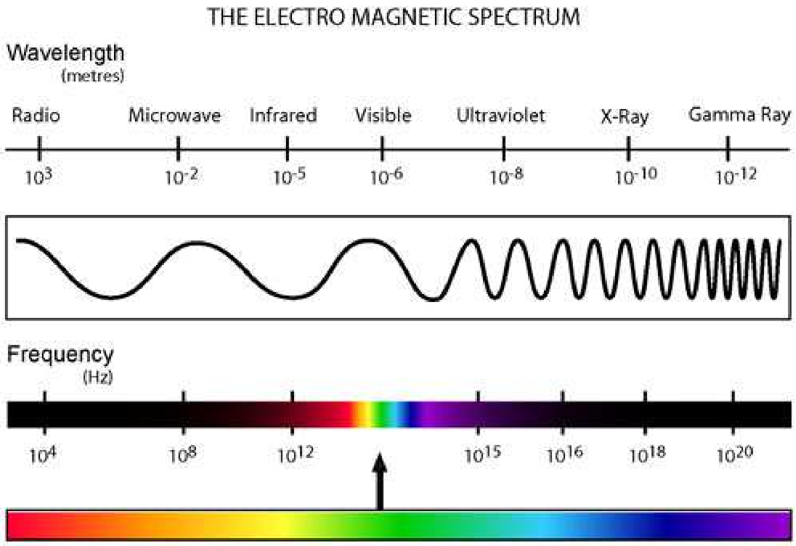
Jakość obrazu to pojęcie względne, jest to odczucie subiektywne. Na jakość obrazu statycznego mają wpływ przede wszystkim 2 czynniki – odwzorowanie barw oraz rozdzielczość widzianego obrazu.

Składowe farby

- <u>substancje barwiące (barwidła)</u> - barwniki, pigmenty,
- <u>spoiwa</u> - olejowe, olejowo-żywiczne, rozpuszczalnikowe,
- <u>substancje pomocnicze</u> - podbarwiacze, plastyfikatory, środki powierzchniowo czynne (dyspergujące), alkalizujące, konserwujące, wypełniacze, środki antysuszące (pasty przeciwutleniające) itd.

Barwy i kolory

Barwa i kolor to określenie odbioru pewnego zakresu fali elektromagnetycznej przez człowieka. Jest to wrażenie psychofizyczne odczuwane za pośrednictwem wzroku. Barwę można podzielić na 3 składowe:



Rysunek 5. Widmo fal elektromagnetycznych[5]

odcień – to najłatwiej rozpoznawalna własność barwy (inaczej kolor) – (czerwony, zielony, niebieski i żółty). Na odcień ma wpływ długość fali elektromagnetycznej jaka dociera do ludzkiego oka oraz kombinacja tych fal o różnych długościach. Odcień najprościej przedstawić na przykładzie zjawiska optycznego jakim jest rozszczepienie światła białego (np. tęcza). Światło (fala elektromagnetyczna) trafiając na przeźroczysty ośrodek zostaje „podzielone" tzn. różne długości fal załamują się pod różnym kątem na granicy 2 ośrodków w skutek czego możemy zobaczyć widmo różnej długości fal elektromagnetycznych czyli np. tęczę. Te różne fale to są właśnie wspomniane odcienie.

Nasycenie - to parametr barwy określający udział poszczególnej barwy chromatycznej (odcieni). Tzn. jeśli kolor to ludzkie odczucie docierających fal elektromagnetycznych o różnych długościach do ludzkiego oka to nasycenie określa ile fal o określonych długościach znajduje się w tym zbiorze fal. Można to porównać do nasycenia roztworu chemicznego.

Jasność- światło to fala elektromagnetyczna czyli również sposób przekazywania energii. Jasnością można określić to ile tej energii zostaje odbitej od ciała lub ile tej energii przepuszcza jeśli ośrodek jest przeźroczysty.

Sposób zapisu koloru w komputerze – stosuje się zapis heksadecymalny (znaki: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F). Zapis koloru składa się z 6 znaków. Każde kolejne 2 cyfry określają udział poszczególnych odcieni. #AABBCC – znaki oznaczone AA to udział odcienia czerwonego, BB – zielonego, CC – niebieskiego.

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[5] Serwis internetowy: http://www.encyclopedia.com/earth-and-environment/ecology-and-environmentalism/environmental-studies/electromagnetic-wave

1.3. Typy głowic drukarskich

Proces nakładania farby w początkowych fazach projektu będzie zrealizowany podobnie jak ma to miejsce w aerografach, czyli z użyciem szybkiego przepływu powietrza i wykorzystując zjawisko Bernoulliego. Powodem użycia takiego rozwiązania jest brak możliwości naruszenia patentów i łatwość zastosowania. Jednak najlepszym rozwiązaniem byłoby zastosowanie głowicy atramentowej. Obecnie rozróżnia się technologię DOD (Drop-On-Demand -kropla na żądanie) oraz CIJ (Continuous Ink Jet).

Głowice stosowane w przemyśle drukarskim:

- **Głowica termiczna DOD** – nad każdą dyszą znajduje się komora z farbą, w której znajduje się element grzewczy. Pod wpływem impulsu elektrycznego element grzewczy nagrzewa tusz powodując wzrost ciśnienia w komorze i wyrzut farby przez dyszę i zassanie kolejnej porcji farby. Proces można powtarzać kilkadziesiąt razy na sekundę.
- **Głowica piezoelektryczna DOD** – piezoelektryk to taki materiał, który pod wpływem prądu elektrycznego zmienia swój kształt. W głowicach drukarskich wykorzystuje się piezoelektryki, aby poruszały membraną, która wyrzuca krople tuszu. Cechują się wysoką jakością wydruku.
- **Głowica zaworkowa CIJ** – tusz znajduje się pod ciśnieniem i jego wyrzut na powierzchnie drukującą jest realizowany przez rezonator piezoelektryczny, który działa nieustannie wyrzucając w sposób ciągły strumień mikro kropel tuszu. Krople są następnie ładowane elektrycznie i przelatują przez elektrody odchylające. Nienaładowane krople przelatują bez zmiany swojego toru i zostają zassane z powrotem do zbiornika, a te naładowane pod wpływem pola elektromagnetycznego zmieniają swój kierunek i zostają wyrzucone na powierzchnię drukującą. Wadą takiego rozwiązania jest duży rozmiar głowicy drukującej, niska jakość i wydajność. Głowica zaworkowa CIJ charakteryzuje się niezawodnością i elastycznością (tzn. odległość materiału od głowicy może wynosić nawet 10 cm i może drukować na różnych materiałach). W praktyce głowice te zazwyczaj drukują na 1 kolor (kody kreskowe, daty ważności itp.).

Najbardziej wydajnym sposobem nakładania farby na ścianę budynku byłaby głowica piezoelektryczna DOD. O ile w przypadku dużych budynków rozwiązanie na bazie dysz aerografów będzie się sprawdzać, to w przypadku małych pomieszczeń wysoką jakość uzyska się jedynie głowicą atramentową.

2. Problemy i rozwiązania

Omawiając ten temat należy zacząć od określenia podstawowych wymagań jakie będzie musiał spełniać malunek.

Odzwierciedlenie kolorów i jakość farby [3.1.]

– jak opisano w zagadnieniach teoretycznych na to co odbieramy jako obraz ma wiele czynników. Aby określony obraz przedstawiony na papierze, szkle, tekstyliach czy ścianie człowiek mógł odebrać jako najbardziej zbliżony do naturalnego potrzeba spełnić wiele wymagań.

Trwałość odwzorowania kolorów i zdolność zachowania początkowych właściwości optycznych malunku [3.1.]

- powinna być dłuższa niż okres mocnego zabrudzenia ściany w wyniku działania czynników zewnętrznych (tj. minimum trzy do dziesięciu lat w zależności od lokalizacji). Malunek musi być również odporny na działanie czynników takich jakie działają na zewnętrzne ściany budynków tj. smog, światło słoneczne, deszcz, śnieg, mróz, upały itd.).

Ostrość [3.2.]

– aby malunek znacznie oddalony od oka odbiorcy (więcej niż 5m) był dla niego przyjazny i nie sprawiał wrażenia rozmycia, wielkość pojedynczego piksela musi być nie większa niż 3 mm w średnicy. W przypadku mniejszych malunków, przeznaczonych dla odbiorcy, który ogląda malunek z bliskiej odległości (1 do 5m) średnica piksela powinna wynosić do 0,5 mm).

Równość i równomierność malunku [3.3.]

– nie można dopuścić do sytuacji nie zamalowania całości powierzchni, na który przewidziany jest malunek.

Cena malunku

- docelowo nie powinna znacznie przekraczać ceny reklamy wielkoformatowej (bilbordu) licząc cenę w przeliczeniu na m^2 i w zależności od wielkości powierzchni końcowej instalacji.

Czas wykonania

– docelowo nie powinien przekraczać dwa dni dla nawet największych malunków uwzględniając sprzyjające warunki atmosferyczne. (tj. do dwudziestu godzin pracy maszyny).

Możliwość wykonania na wysokich budynkach

– docelowo końcowym efektem wykonania projektu będzie stworzenie maszyny mogącej wykonywać malunki na budynkach o wysokości do dziesięciu pięter.

2.1. Farba

Jednym z kluczowych problemów mogących mieć wpływ na powodzenie projektu jest jakość farby. Musi ona spełnić szereg wymagań, których uzyskanie wymaga specjalistycznej wiedzy z zakresu farb.
Obecne firmy takie jak, HP, Canon, Xerox itp. mają opracowane swoje rozwiązania wykorzystywane do drukowania na papierze, które wymagały wielu lat badań zgłębiających właściwości farby i samego obrazu. Jest to pilnie strzeżona wiedza, a

ceny niektórych tuszy drukarskich przekraczają cenę najdroższych perfum. Przykładowo cena czarnego tuszu atramentowego do drukarek HP wynosi około 700$ za litr.
Przewidywane właściwości farby, które trzeba będzie dobrać i opracować w trakcie wykonywania projektu:

I. Właściwości wpływające na proces drukowania:

Lepkość farby – powinna umożliwiać swobodny przepływ farby w przewodzie doprowadzającym. Ilość farby wtryskiwanej na 1 piksel będzie zmienna więc lepkość powinna być tak dobrana aby móc swobodnie regulować zużycie farby na dany cykl (cykl wykonania 1 piksela).
Stopień utarcia farby – cząstki pigmentu mają tendencję do łączenia się. Zjawisko to niekorzystnie wpływa na proces drukowania. Stopień utarcia to opisanie tendencji do występowania tego procesu w farbie.
Właściwości reologiczne – grupa właściwości takich jak: lepkość, granica płynięcia, lejność, współczynnik napięcia powierzchniowego.

II. Właściwości wpływające na własności druku

Odpowiednia transparentność farby - z racji iż ściana jest wysoce chropowatą powierzchnią będzie konieczność stosowania dużej ilości farby na m^2 (grubość warstwy nawet do 5 µm). Aby umożliwić odtworzenie barwy przy tak grubej warstwie, 4 składowe odcienie muszą się mieszać. Krycie farby musi być tak dobrane, aby przy nakładaniu etapami kolejnych warstw odcieni uniknąć wzajemnego przysłaniania się ich.
Intensywność kolorów – farba powinna umożliwić odtworzenie nawet głębokich kolorów (intensywnych).
Wysoka odporność na światło – pod wpływem działania promieni słonecznych farba nie powinna tracić swoich właściwości kolorystycznych.

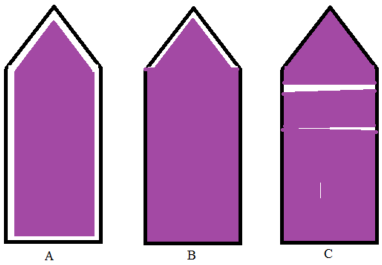
2.2. Rozdzielczość

Podczas niezaawansowanych testów prowizorycznie skonstruowanej dyszy natryskowej udało się uzyskać kropkę z atramentu o wielkości około 4 mm. Biorąc pod uwagę, iż atrament jest stosunkowo rzadką substancją i był podawany przez igłę iniekcyjną pod nieznanym kątem oraz nie znano prędkości przepływu powietrza w dyszy, to uzyskanie piksela o średnicy 2 mm nie powinno stanowić problemu. Wyzwaniem może się okazać samo dobranie farby tak, aby uzyskana kropka (piksel) miał odpowiedni kolor.

2.3. Dokładność pozycjonowania na dużej powierzchni

Sama głowica drukarska będzie docelowo umieszona na podnośniku/dźwigu, który będzie mógł sięgnąć do dziesiątego piętra. Stwarza to problem jakim jest chwianie się konstrukcji, niestabilności członu wykonującego malunek oraz brak możliwości dokładnego pozycjonowania (do 1 piksela). Może to skutkować brakiem wykonania jednolitego malunku. W celu przeciwdziałania temu zjawiskowi należy zastosować mechanizm korygujący składający się z czujnika optycznego i oprogramowania.

Mechanizm ten będzie obliczał i korygował ruchy konstrukcji nośnej przez co umożliwi dokładne pozycjonowanie samej głowicy drukującej.



A -zbyt duże marginesy

B-nie całkowite zapełnienie powierzchni z powodu konstrukcji budynku (spadzisty dach, rynny, klimatyzatory itp.)

C- niezamalowane przestrzenie z powodu niedokładnego pozycjonowania głowicy

Rysunek 6. Przykłady niedozwolonych błędów wydruku

3. Koncepcja rozwoju projektu

3.1. Branża reklamowa

Koszt wykonania reklamy banneru jest różny w zależności od technologii wykonania banneru oraz sposobu i miejsca montażu. Wydruk standardowego banneru reklamowego to koszt około 25 zł/m^2 netto, a w przypadku siatki mesh to jest około 19 zł/m^{2}netto.

Zamocowanie takiej reklamy w zależności od miejsca, wielkości i sposobu zamocowania instalacji to koszt od 12zł/m^2 netto w przypadku montażu bilbordów reklamowych na wolnostojących słupach oraz nawet 30, 40 zł za m^2 w przypadku instalacji na wysokich budynkach, gdzie dodatkowo dolicza się koszt wypożyczenia sprzętu (np. zwyżki).

Uśredniając dane, które uzyskano od firmy z branży reklamowej zajmującej się dystrybucją reklam na całą Polskę przyjęto kwotę konkurencyjności w przypadku wykonania malunku i wynosi 45 zł za m^2 netto. Aby uzyskać taką kwotę – koszt farby potrzebnej na wykonanie malunku nie powinien przekroczyć 20zł za m^2.

3.2. Branża remontowo-usługowa

Cena pomalowania elewacji wynosi około 25 zł za m^2 + koszt farby (około 10zł za m^2). Do tej ceny dochodzą koszty związane z wynajęciem sprzętu np. zwyżki. Uśredniając cenę remontu elewacji na wysokich budynkach to odnowienie elewacji jest dużo droższe niż przywieszenie banera reklamowego (w przeliczeniu na m^2).

4.3. Branża artystyczna

W tej branży jest bardzo duża rozbieżność cenowa. Ceny za metr kwadratowy zaczynają się od 140 zł za proste motywy aż do 400zł za skomplikowane i fotorealistyczne malunki (cena samego artysty bez sprzętu). Warto wspomnieć również o szkodliwości niektórych farb (szczególnie fluorescencyjnych) co wpływa na wzrost ceny wykonania malunku. Są również artyści, którzy za swoje malunki biorą 50 000 zł za metr kwadratowy. Jest to oczywiście cena wygórowana przez prestiż artysty lecz konkurencyjność drukarki naściennej jest w tej branży oczywista.

Podsumowując koncepcje rozwoju projektu, jeśli uda się wykonać maszynowo mural, którego koszt za m^2 wyniesie mniej niż 45 zł to może on być dużą konkurencją w kilku branżach.

4. Przebieg prac

4.1. Pierwszy malunek

- Wykonanie mechaniczne jednej osi.
- Stworzenie oprogramowania mogącego sterować głowicą drukującą.
- Dopracowanie głowicy tak, aby uzyskać precyzyjne położenie piksela o wielkości do 2mm.
- Uaktualnienie oprogramowania, opracowanie farb tak, aby uzyskany piksel mógł mieć dowolny kolor.
- Wykonanie drugiej osi i aktualizacja oprogramowania do sterowania 2 osiami.
- Wykonanie oprogramowania do przetwarzania i pozycjonowania wgranego obrazu.
- Wykonanie pierwszego malunku na ścianie i poprawki.

4.2. Umieszczenie opracowanej głowicy drukującej na mechanizmie nośnym i wykonanie malunku

- Wykonanie lub zakup konstrukcji mogącej podnieść głowicę do wysokości 2 piętra oraz zamocowanie na niej głowicy.
- Opracowanie mechanizmu korygującego ruchy konstrukcji na głowicy drukującej.
- Napisanie oprogramowania do wykonania złożonego rysunku wykorzystującego ruch konstrukcji nośnej – należy poszerzyć wielkość malunku o przynajmniej 6 (3x2) obszarów. Przez 1 obszar rozumie się powierzchnię roboczą głowicy drukującej przy unieruchomionym mechanizmie nośnym.

4.3. Wykonanie malunku na całej ścianie 10-cio piętrowego budynku

- Montaż dopracowanej głowicy na mechanizmie nośnym.
- Aktualizacja programowania mogąca określać wykonanie muralu (jego wielkość, kalibracja punktów bazowych, korygowanie marginesów).
- Wykonywanie malunków.

5. Podsumowanie

Pomysł drukarki naściennej nie jest nowy, został już przedstawiony przez firmę Zeescape w Australii, natomiast zauważa się błędy w jej koncepcji i konstrukcji. Drukarka ta ma mocno ograniczoną wielkość rysunku jaki może wykonać i nie znaleziono informacji na temat rozwoju konstrukcji i możliwości drukowania na większych obiektach. Wykonanie maszyny do drukowania wielkoformatowych murali będzie pierwszym tego typu urządzeniem na świecie.
Prace planuje się ukończyć przed upływem 2017 roku i zamierza się przedstawić ich postęp na konferencji Inżynier XXI wieku w 2017 roku.

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OPRACOWANIE POSTPROCESORA DLA GENEROWANIA ŚCIEŻKI NARZĘDZIA ROBOTA PRZEMYSŁOWEGO

Streszczenie: Niniejszy artykuł poświęcony jest budowie oraz zasadom działania oprogramowania *PCB CAM Processor*. Aplikacja stanowi zintegrowany pakiet CAD / CAM umożliwiający projektowanie i wytwarzanie płyt PCB metodą grawerowania. Programy CNC generowane przez oprogramowanie mogą być elastycznie dostosowane do danego typu obrabiarki. Prezentowany pakiet oprogramowania pozwala wygenerować programy sterujące zarówno dla obrabiarek CNC, jak i robotów przemysłowych.

Słowa kluczowe: CAD, CAM, CNC, PCB, C++, OpenGL grafika komputerowa, postprocesory

POSTPROCESSOR DEVELOPMENT FOR GENERATING INDUSTRIAL ROBOT TOOL PATH

Summary: This article is dedicated to the principles of construction and operation of the *PCB CAM Processor* software. The application is an integrated suite of CAD / CAM enables the design and manufacture of PCB engraving method. CNC programs generated by the software can be flexibly adapted to the type of machine. It is possible to use CNC machines as well as industrial robots.

Keywords: CAD, CAM, CNC, PCB, C++, OpenGL, computer graphics, postprocessors

1. Wstęp

Ręczne opracowanie programów na obrabiarki sterowane numerycznie jest trudne i wymaga niemałego doświadczenia. Programy CNC (Computerized Numerical Control) dla skomplikowanych modeli mogą zajmować nawet kilkaset linii kodu. Ponadto istnieje duże ryzyko popełnienia błędu, którego wykrycie jest możliwe jedynie przy użyciu symulatorów obróbki. Rozwiązaniem tych problemów są pakiety oprogramowania typu CAM (Computer Aided Manufacturing), które na podstawie modelu CAD (Computer Aided Design) generują gotowe programu obróbki.

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Oprogramowania CAM dostępne na rynku mają jednak swoje wady. Ceny takich aplikacji sięgają nawet setek tysięcy Euro, a możliwości bywają ograniczone. Przykładowo, aby generować kod dla konkretnej maszyny CNC należy dokupić odpowiedni moduł zgodny z jej typem, co oczywiście przekłada się na dodatkowe koszty. Rozwiązaniem tych problemów jest własne środowisko CAM, dzięki któremu koszty oprogramowania i rodzaj posiadanej obrabiarki nie mają znaczenia.

Wytwarzanie płyt PCB (Printed Circuit Board) metodą grawerowania jest sposobem na szybkie prototypowanie. Przeznaczone jest dla testowania układów elektronicznych w środowisku domowym czy akademickim. Umożliwia szybkie i tanie budowanie prototypów, podczas gdy zamawianie płytek drukowanych w profesjonalnych zakładach produkcyjnych niesie za sobą duże koszty. Ewentualne błędy w projekcie nie wymagają ponownego zamawiania prototypu, dzięki czemu oszczędza się czas i pieniądze.

2. Możliwości oprogramowania

Oprogramowanie opisane w tym artykule umożliwia szybkie prototypowanie układów elektronicznych. Na podstawie modelu stworzonego w oprogramowaniu generowany jest program na niemal dowolny typ maszyny sterowanej numerycznie. Jest to możliwe dzięki zastosowaniu szablonów zgodnych z wybraną obrabiarką. Program obróbki obwodu drukowanego podzielony jest na dwie operacje: grawerowanie układu ścieżek oraz wiercenie otworów montażowych dla elementów elektronicznych. Każda z tych operacji została rozbita na szereg elementarnych zabiegów, które składają się na gotowy program. Użytkownik musi zdefiniować dwa szablony, po jednym dla każdej z operacji. Każdy szablon składa się z fragmentów kodu CNC zgodnych z językiem wybranej maszyny, zaś każdy fragment opisuje pewien elementarny zabieg. Każde pole szablonu posiada szczegółowy tekst podpowiedzi.

2.1. Wiercenie

Szablon wiercenia definiuje:

- ustawienia generatora,
- początek programu obróbki,
- podprogram wiercenia,
- podprogram wymiany wiertła,
- zakończenie programu.

W ustawieniach generatora definiuje się rozszerzenie pliku wyjściowego zgodne z wybraną maszyną oraz przesunięcie układu współrzędnych. Początek i koniec programu definiują składnie programu w wybranym języku oraz wszystkie wymagane operacje przygotowawczo-zakończeniowe. Podprogram wiercenia opisuje pełny cykl wykonania pojedynczego otworu, zawierający: najazd nad otwór, wykonanie wiercenia oraz wycofanie - przygotowanie do kolejnego wiercenia. Podprogram wymiany wiertła jest uruchamiany po wykonaniu wszystkich otworów danej średnicy. Otwory wykonywane są w kolejności rosnącej.

2.2. Grawerowanie

Szablon grawerowania definiuje:

- ustawienia generatora,
- początek programu obróbki,
- dojazd do materiału,
- ruch roboczy - interpolacja liniowa,
- ruch roboczy - interpolacja kołowa zgodnie z ruchem wsk. zegara,
- ruch roboczy - interpolacja kołowa przeciwnie do ruchu wsk. zegara,
- wyjazd z materiału,
- zakończenie programu.

W tej operacji wykonywane są ruchy robocze po zamkniętych konturach, tworzących na płytce drukowanej pola o wspólnym potencjale elektrycznym, będące całkowicie odizolowane od pozostałej części obwodu drukowanego. Ustawienia generatora zawierają dodatkowo definicję promienia narzędzia, dzięki czemu program umożliwia jego korekcję. Jest to szczególnie istotne dla maszyn takich jak roboty przemysłowe, których oprogramowanie nie posiada funkcji kompensacji promienia narzędzia.

Początek i koniec programu pełni tu analogiczną funkcję jak w operacji wiercenia. Rozpoczęcie i zakończenie obróbki poszczególnych konturów definiują dojazd i wyjazd z materiału. Interpolacja liniowa i kołowa używana podczas prowadzenia narzędzia po zadanym konturze jest również definiowana w odpowiednich polach szablonu. W przypadku opisu interpolacji kołowej istnieje rozróżnienie ze względu na kierunek obróbki. Jest to podyktowane zapisem tego ruchu roboczego w G kodzie, gdzie G2 oznacza ruch zgodny z ruchem wskazówek zegara, a G3 w kierunku przeciwnym. W przypadku stosowania robotów przemysłowych istotny jest również punkt pośredni łuku. Z kolei w maszynach sterowanych układami Sinumerik można używać promienia łuku, który jest liczbą ujemną, gdy opisywany łuk ma kąt rozwarcia większy niż 180°. Z uwagi na różny zapis interpolacji kołowej program wylicza szereg jej paramentów, umożliwiając elastyczne dostosowania do konkretnej maszyny. Wszystkie dostępne parametry pokazano na rysunku poniżej.

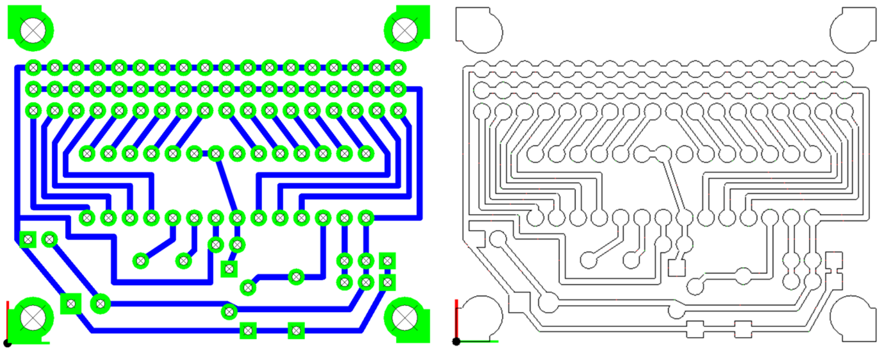
Wykonanie przejazdu roboczego po łuku - dostępne parametry interpolacji kołowej:
- @X@, @Y@ - wsp. punktu końcowego
- @AX@, @AY@ - wsp. punktu pośredniego
- @I@, @J@ - wsp. środka łuku względem punktu początkowego (G-code)
- @R@ - promień łuku
- @CR@ - promień łuku (Sinumerik - ujemny dla rozwarcia > 180*)
- @P@ - kąt rozwarcia łuku

Rysunek 1. Podpowiedź kreatora szablonu dot. interpolacji kołowej

Jak widać na powyższej ilustracji wszystkie parametry używane w polach szablonu muszą być zawarte pomiędzy znakami @. Aby użyć wybranego parametru wewnątrz bloku szablonu, należy wpisać: @nazwa parametru@. Podczas generowania pliku z kodem programu wszystkie miejsca użycia powyższej składni są zamieniane na dane liczbowe obliczone na podstawie modelu.

2.3. Tryb symulacji

Oprogramowanie umożliwia wygenerowanie podglądu ścieżki narzędzia oraz prześledzenie jego toru. Możliwe jest sterowania prędkością symulacji podając prędkość ruchów roboczych w m/s. Symulacja możliwa jest zarówno dla operacji grawerowania jak i wiercenia. W tym drugim przypadku pokazana jest kolejność wykonywania otworów. Użycie tego trybu pozwala zweryfikować poprawność wykonanych przez program obliczeń. Kolejność operacji widoczna na animacji jest całkowicie zgodna z tym co jest generowane do pliku wyjściowego. Poniżej przedstawiono przykładowy model oraz symulację grawerowania.



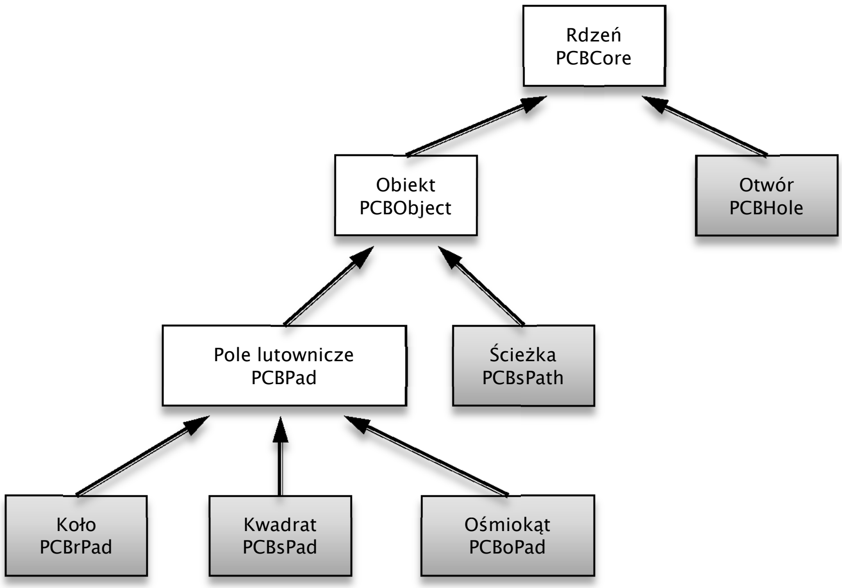
Rysunek 2. Przykładowy model oraz jego obliczony kontur

3. Opis modelu

Modele tworzone w prezentowanym oprogramowaniu składają się z elementów takich jak: prostoliniowy odcinek ścieżki, pola lutownicze w trzech możliwych kształtach (koło, kwadrat, ośmiokąt) oraz otwory. Elementy te są ze sobą powiązane za pomocą węzłów, które wyznaczają ich pozycję oraz wiążą je ze sobą. Otwory oraz pola lutownicze do swojego opisu wykorzystują jeden węzeł. Odcinki ścieżek potrzebują dwóch węzłów, po jednym dla każdego z końców. Zmiana pozycji węzła powoduje przemieszczenie wszystkich elementów do niego podłączonych.

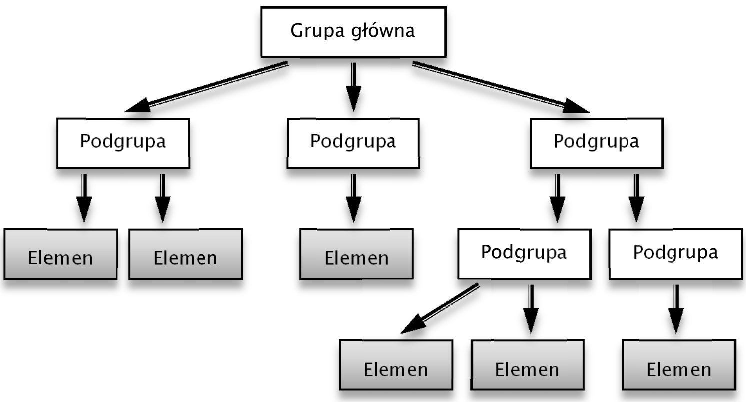
Wymienione powyżej elementy (z pominięciem otworów) posiadają pole ograniczone pewnym zamkniętym konturem. Kontur taki można opisać zbiorem linii i łuków zwanych dalej prymitywami. Wspomniane prymitywy opisujące kontur danego elementu są w sensie programistycznym obiektami i posiadają metody umożliwiające obliczanie m.in. punktów przecięć z innymi prymitywami.

Wszystkie elementy opisujące model należą, w sensie programistycznym, do różnych klas i są dynamicznie tworzone podczas pracy aplikacji. Wskaźniki na nowopowstające obiekty są zapisywane na listach dwukierunkowych. Dzięki zastosowaniu dziedziczenia pokazanego poniżej wszystkie obiekty mogą być wspólnie tablicowane.



Rysunek 3. Hierarchia klas stosowanych do opisu modelu

Klasy takie jak PCBCore, PCBObject czy PCBPad są abstrakcyjne. Oznacza to, że nie mogą istnieć obiekty tych typów. Klasy abstrakcyjne zawierają metody, które po odziedziczeniu przez klasy pochodne muszą być zdefiniowane, aby można było tworzyć instancje takich klas. Przykładem metody wirtualnej jest rysowanie. Każdy obiekt jest rysowany w inny sposób. Dzięki zastosowaniu dziedziczenia metod wirtualnych, można na rzecz każdego z nich wywołać metodę rysowania, używając wskaźników typu PCBCore i za każdym razem uzyskać inny wynik.
Widoczne na ekranie aplikacji elementy mogą być łączone w grupy. Grupa jest obiektem posiadającym listę podgrup oraz listę elementów. Dzięki takiemu podejściu możliwe jest zapisanie drzewa o dowolnej liczbie poziomów.

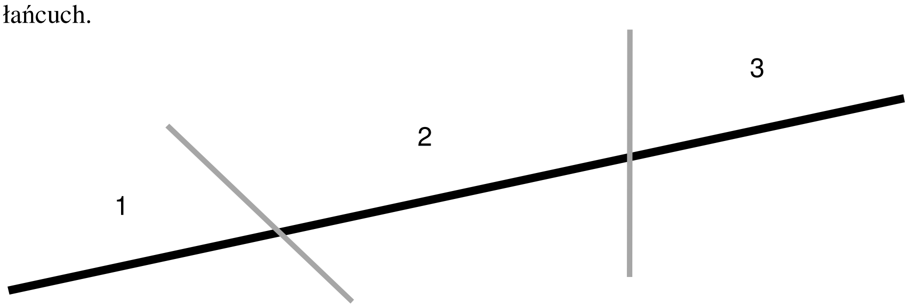


Rysunek 4. Schemat zapisu elementów z podziałem na grupy

4. Problematyka obliczeń

4.1. Wstęp

W poprzednim rozdziale pokazano wyniki pracy modułu CAM. Do obliczenia wspólnych konturów stosuje się wspomniane wcześniej prymitywy. Posiadają one nie tylko początek i koniec ale również zbiór punktów pośrednich powstających na skutek przecięć z innymi prymitywami. Po odpowiednim posortowaniu tych punktów prymityw może być podzielony na fragmenty, które łączą się ze sobą tworząc pewien łańcuch.



Rysunek 5. Przecinanie się prymitywów oraz podział na fragmenty

4.2. Opis linii

Linia do swojego opisu wymaga jedynie dwóch punktów które można interpretować jako początek i koniec. Kolejność tych punktów jest jednak dowolna. Dodatkowe punkty powstające na skutek przecięć z innymi prymitywami są sortowane wzdłuż kierunku linii i umieszczane na liście. W efekcie powstaje posortowany zbiór, w którym każde dwa kolejne punkty tworzą linię stanowiącą fragment pierwotnej. Zostało to pokazane na rysunku 5.

4.3. Opis łuku

Do opisu łuku, jak wspomniano wcześniej, można podejść na wiele sposobów. Do obliczeń zastosowano zapis, w którym znany jest środek łuku oraz jego promień. Punkty tworzące łuk można zapisać w postaci wektorowej, jako wektory łączące środek łuku z wybranym punktem. Każdy z takich wektorów tworzy pewien kąt z dodatnią półosią X. Zatem można zapisać jedynie zbiór wspomnianych kątów, ponieważ długości wektorów są równe promieniowi łuku. Stosując sortowanie zbioru kątów uzyskano analogiczny podział na fragmenty jak w przypadku linii.

Istotna jest tutaj kolejność zapisu początku i końca. Dwa punkty zapisane kątowo mogą reprezentować dwa różne łuki, dlatego trzeba zdecydować o kierunku łuku. W prezentowanym modelu obliczeniowym zastosowano kierunek przeciwny do ruchu wskazówek zegara, co jest zgodne z naturalnym pomiarem kąta względem dodatniej półosi X. Warto jeszcze zwrócić uwagę na fakt, że obliczane w tej metodzie kąty są z zakresu od -180 od +180, co podczas sortowania sprawia pewien problem. Przykładowo dla łuku znajdującego się w II i III ćwiartce układu współrzędnych, którego początek w zapisie kątowym wynosi 170°, a koniec -170° sortowanie w porządku rosnącym zamieniłoby miejscami początek i koniec. Powstałby w ten sposób łuk po przeciwnej stronie, którego kąt rozwarcia wyniósłby 340°. W związku z tym należało przyjąć, że w zapisie kątowym każdy punkt łuku musi posiadać wartość większą niż punkt początkowy, co wymaga dodania kąta pełnego w prezentowanym przykładzie. Wówczas opisywany łuk rozpoczyna się w kącie 170°, a kończy w 190°. W obliczeniach kąty te zapisane są oczywiście w radianach, stopnie zostały tu zastosowane dla lepszego zobrazowania.

4.4. Obliczanie wspólnego konturu

Mając już narzędzie w postaci prymitywów można przystąpić do kluczowej części obliczeń. Każdy zamknięty kontur posiada pewną liczbę punktów wspólnych z dowolnym prymitywem. Jeśli ta liczba jest większa od zera, prymityw zostaje podzielony na fragmenty, które mogą znaleźć się w całości wewnątrz albo na zewnątrz tego konturu. Można to zobrazować rysując linię na mapie. Granice państw podzielą ją na fragmenty, z których każdy znajdzie sie w całości w którymś z państw. Nie będzie takiego fragmentu który jednocześnie znajdzie się w dwóch państwach. Można zatem sprawdzić czy środkowy punkt fragmentu prymitywu należy do danego konturu. Jeśli należy, oznacza to, że powinien zostać usunięty, ponieważ przecina kontur. W przeciwnym wypadku fragment jest prawidłowy i powinien zostać uwzględniony w wyniku.

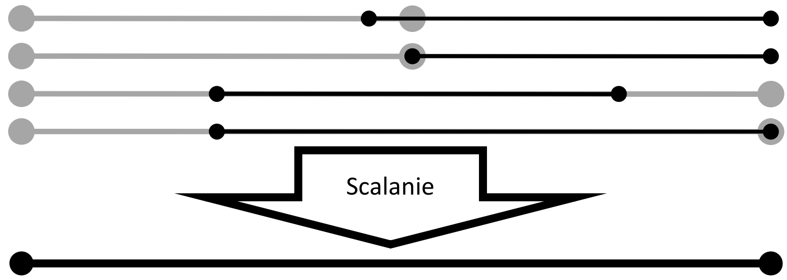
Po zastosowaniu powyższej metody dla wszystkich prymitywów tworzących model, powstaje pewien zbiór fragmentów. Aby można było wykonać grawerowanie potrzebne jest jeszcze ułożenie wspomnianych fragmentów w odpowiedniej kolejności, tak aby koniec poprzedniego pokrywał się z początkiem następnego. Jeśli odległość do kolejnego fragmentu jest zbyt duża oznacza to, że należy rozpocząć wykonywanie kolejnego konturu. Generator ścieżki narzędzia wyszukuje w takim przypadku pierwszy najbliższy niewykonany fragment i od niego rozpoczyna tworzenie kolejnego konturu.

4.5. Problem obliczeń zmienno-przecinkowych

Prowadząc obliczenia komputerowe należy mieć na uwadze fakt, że wyliczenie tej samej wartości dwiema różnymi drogami nie da nigdy identycznego wyniku. Nie można zatem bezpośrednio porównywać tych liczb. Twórcy różnego rodzaju algorytmów często zapominają o tym, pisząc warunki równościowe. Oczywiście w sensie matematycznym liczby te są równe, ale sprawdzenie tej równości w programie komputerowym nie jest takie oczywiste z uwagi na błędy zaokrągleń. Problem ten można łatwo rozwiązać badając różnicę liczb. Jeśli różnica dwóch liczb jest dostatecznie mała oznacza to, że można je uznać za równe. Przyjmując zatem pewnego rodzaju skalę podobieństwa S, można powiedzieć że dwie liczby są sobie równe gdy wartość bezwzględna ich różnicy jest mniejsza lub równa S. Stosując tą metodę dalej, można wyprowadzić zależności umożliwiające skonstruowanie pozostałych operatorów: mniejszy, większy, mniejszy lub równy oraz większy lub równy. Przykładowo jeśli $a < b$ oznacza to, że $a - b$ musi być mniejsze od S. Wartość skali podobieństwa można dobierać dowolnie, zależnie od wymaganej dokładności operatorów porównania. Obliczenia prowadzone w oprogramowaniu stosują zamiennie S na poziomie 10^{-9}, 10^{-6} oraz 10^{-3}. Zmiana S jest czasem wymagana aby ustalić pewną hierarchię warunków porównania.

4.6. Scalanie prymitywów

Scalanie prymitywów w końcowym etapie wyznaczania ścieżki narzędzia jest bardzo istotne. Mowa tu o sytuacji, w której dwie linie lub dwa łuki posiadają część wspólną. Nie można wówczas liczyć ich punktów przecięć, ponieważ jest ich nieskończenie wiele. Ponadto istnieje problem zbudowania z nich ścieżki narzędzia, gdyż nie można ich wykonać jeden po drugim. Narzędzie wykonałoby jeden ruch roboczy następnie musiałoby się cofnąć i wykonać ruch po tej samej ścieżce. W szczególnym przypadku takie współliniowe prymitywy tworzą łańcuch. Również tutaj narzędzie będzie wykonywać niepożądane ruchy. W przypadku obróbki prowadzonej na robocie przemysłowym, dla uzyskania większej dokładności, następuje zatrzymanie po osiągnięciu zadanego punktu. Zatem wykonanie prostego odcinka w postaci serii fragmentów z wielokrotnym zatrzymaniem się narzędzia jest również pewnego rodzaju błędem. Generuje to również zbędny kod programu obróbki.



Rysunek 6. Możliwe przypadki scalania

5. Podsumowanie

Rozwój własnego środowiska CAD/CAM daje nieograniczone możliwości, jest jednak bardzo pracochłonny i wymaga rozwiązywania wielu złożonych problemów. Warto wspomnieć, że przedstawiony pakiet oprogramowania jest systemem klasy 2,5D. Rozbudowa pakietu do klasy 3D, z możliwością generowania programów na 5-cio osiowe obrabiarki, wymagałaby pracy wieloosobowego zespołu. Zaletą zaprezentowanego pakietu oprogramowania jest elastyczność, prosty interfejs oraz wygoda użytkowania. Dostęp do kodu źródłowego oprogramowania umożliwia rozbudowę pakietu o nowe funkcje i postprocesory.

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INTELIGENTNY SYSTEM STEROWANIA ŚWIATŁAMI ULICZNYMI W MIEŚCIE

Streszczenie: W tym artykule omówiono możliwość zastosowania kanałów transmisji radiowej jako kanału komunikacyjnego do transmisji danych. Ponadto, zestawiono zasady budowy takiego system. Opisano implementację sprzętową (hardware'ową) takiego rozwiązania z zastosowaniem inteligentnego system zdalnego sterowania (ASDC) dla oświetlenia ulicznego w mieście – w oparciu o tzw. komputer personalny (PC).

Słowa kluczowe: zdalne sterowanie, radiowy kanał komunikacyjny, inteligentny system

INTELLECTUAL SYSTEM OF STREET LIGHTING CONTROL IN A CITY

Summary: this article studies the possibility of using radio channel as a communication channel for transaction data and construction principles and hardware implementation of intellectual automated system of dispatching control (ASDC) of street lighting in a city based on a personal electronic computer (PC)

Keywords: dispatching control, communication radio channel, intelligent system

1. Assignment of issues

Nowadays it is hardly to mention a sector of the economy, which wouldn't have used automation, including automated control systems and control itself. However, due to the economic crisis and lack of finances the implementation of automation in the field

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of municipal services is quite low. The same situation is concerning updating of technical equipments designed to control street lighting and control of lighting net parameters. Equipments developed for this purpose in the 60s, use outdated element base, they often break down, they are cumbersome and expensive to maintain, wasteful due to the energy consumption. Because of the increase in recent years the number of housing constructions and industrial projects, there is a need at street lighting equipment at newly built districts and adjacent areas of industrial facilities. [1].

The main disadvantages of street lighting control systems used nowadays are:

- Low information content (as information output devices are used indicator lights that do not allow the dispatcher to receive full information about lighting network);

- Use telephone communications for sharing information required large investments in the implementation and are expensive to maintain.

The practice of recent years has shown that the most appropriate is to build intellectual automated system of dispatching control (ASDC) based on electronic personal computer (PC) using a communication channel for data channel that enables to provide high information management system and allows to reduce investment in implementation and operation by eliminating the costly excavation during the laying of cables and reduce maintenance costs.

2. Analysis of recent researches and publications

According to our analysis, there are several types of automatic and industrial automatic control of street lighting, but each of them has some drawbacks such as:

- The most common systems are offered as a so-called technical facilities but not as a ready solution;
- Other systems offered as a ready solution for the full update lighting control system, with new channels, with modern switching equipment and so on. This integrated approach is certainly good, but in many cases it is unavailable because of economic reasons;
- Some systems come with simple software that provides only supply orders and obtaining evidence of their passage, without functions of receiving measurements and events in the database, reporting and etc. [2].

In addition, most of the systems use specialized rigidly established software (SW), its re-configuration is difficult and integration with other systems ASDC is not considered.

You can also select automated control system of external lighting (ACSEL) that allows you to manage outdoor lighting using 3 modes: automatic (offline) mode, manual mode and control mode. All information on the current status of outdoor lighting displays on a dispatcher’s working place. As a channel of communication with the central control point used high noise immunity digital channel GSM using GPRS technology. Disclaiming of landlines in favor of GSM, as well as an opportunity to control lighting provides significant economic benefits and lets you recover the system in a short time. [3]

Nowadays, the software of French company Streetlight Vision is used for street lighting, it is designed for collecting and processing intelligent lighting ballast resistance and allows you to control street lighting network LonWorks and to control the brightness and lighting. According to the electronic ballasts this software automatically identifies failures of street lighting and allows you to set the schedule for adjusting the brightness to reduce power consumption. Streetlight Vision Program includes a set of 6 Web-based applications (Web Portal) and a module to collect information and to fill in a content database (Data Collect). Using Streetlight Vision systems in urban street lighting brings for the city not only economic benefits, but also improves the environment and increases road safety [4].

3. Short description of main material

The proposed intelligent system dispatching control of street lighting in the city using radio air has been developed at the department of power consumption and computer technology in the electricity of Ternopil Ivan Puluj National Technical University together with Ternopil design bureau of radio communication "Strila".

Functionally, the system consists of a central controlled equipment control (CCEC) and equipment of controlled facilities [5].

The structure CCEC equipment includes:

- PC control with inbuilt coupler of the radio equipment, keyboard, display and manipulator "mouse";
- Set for channel equipment (modem, transceiver (GSM-modem) with antenna and power supply);
- The structure of the controlled object equipment includes:
- Set of radio equipment (transceiver (GSM-modem) with antenna);
- Control unit;
- Block of signals formation of signaling (serviceability fuses and contactors, presence of phases) and remote control (turn on and off contactors);
- Tolerance control node of current;
- Manipulator for technological radio negotiations.

CCEC provides efficient management of controlled items CI. A standard PC is used as a control element, you can see on screen the current state of the facilities at CI. Control signals that are generated by radio equipment CCEC go to controlled facilities. Reliability of information transmitted over the radio channel is provided by CRC - cyclic redundancy checksum (Cyclic Redundancy Checksum). A structural system and transfer exchange of data is represented on Fig. 1.

CI equipment designed to receive control signals from CCEC, transfer from them to the equipment remotely, removing information about the current state of the object and transfer it to CCEC.

Setting modes of inquiry and state facilities controlled items are carried by orders of remote radio control transmitted via radio with automatic confirmation of command execution of remote control by remote signaling.

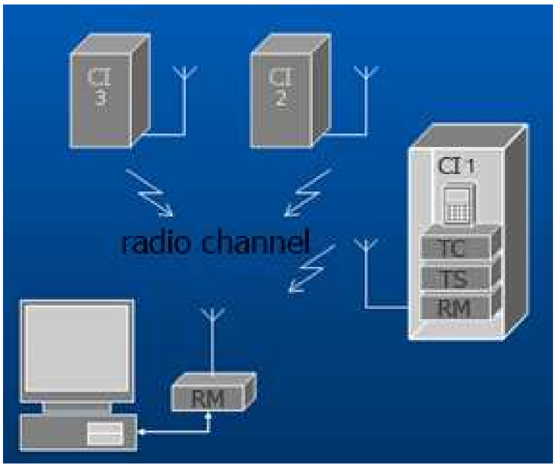

Figure 1. Structure of intellectual systems and data exchange

A message of troubleshooting is automatically transmitted to a central control room of control when unauthorized change of the controlled object happens.

Management of controlled items are made with keyboard control by PC of control station with displaying information about the current state of the objects on a screen of PC as a map of the city with symbols of controlled areas (Fig. 2) and mimic panels of controlled objects (Fig. 3).

Channels of communication are protected from external influences.

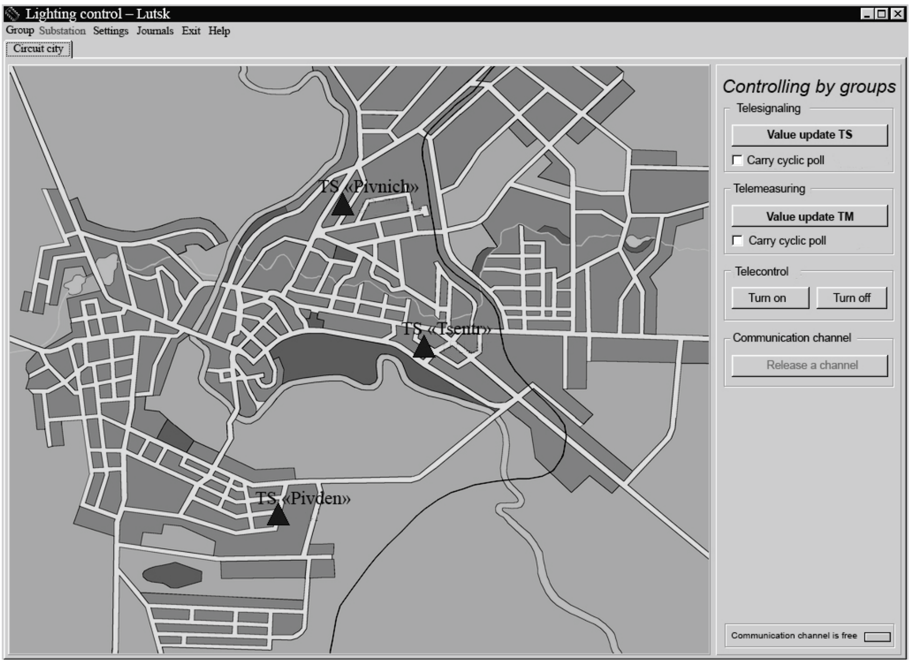

Figure 2. The main window of control center at the basis of "Lutskmisksvitlo"

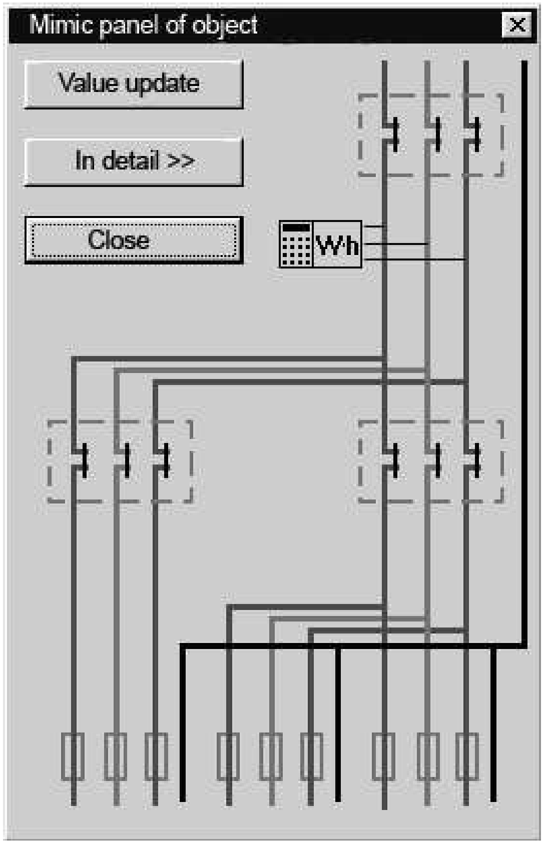

Figure 3. Mimic panel of the object

The software system automatically logs all activities of an operator in the operational log and all reports of abnormal and emergency situations in controlled facilities - in the emergency system log. Software system of lighting control provides registration of all events that occurred during the operation in the database file.
The program supports two types of journals:
• operational (all commands given by the operator and the orders made by the program automatically, query results and remote signaling remote measuring are registered);
• emergency (received of controlled object of codegrams about emergency situations are registered).
In journals are recorded date and time of the event and the object of the event.
To view the journal, a utility is developed that can be run from a menu of lighting control and from the start menu Windows.
In the program of viewing journals is a possibility to choose the type of journal (Fig. 4), and selective display of information (installation of filters on the name of the substation, feature type and date of recording).

The system provides the possibility for an operator to negotiate through the radio with support staff of CI.

The system provides the ability to perform remote monitoring of electrical parameters of the lighting network (instantaneous voltage, current, power, consumed electricity), which is implemented using modern electronic electricity meters.
To reduce the spent time for managing a group of objects system has the following features:

- perform a group of orders (switch on, switch off, request status), for this purpose a controller selects the objects on which a certain action must be performed, and selects the "Group order";
- switch on the cascade operation of controlled object, at the same time equipment independently performs cascading repetitions with following checking of an order. If there is a fault of a contractor, cutout, backing off – the equipment sends signal of emergency to CCEC with full description of all monitored signals.

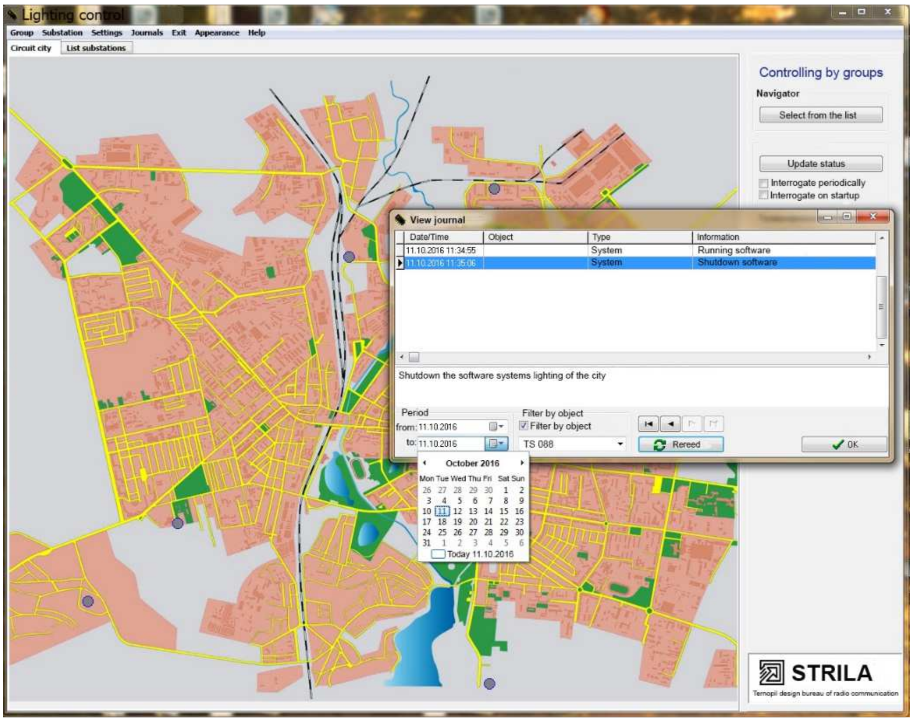

Figure 4. Utility for viewing journal and filter selection

4. Technical and operational characteristics of equipment

1. Active range (zone of steady reception) -up 20 km (using GSM - unlimited)
2. The range of radio frequency -148 ... 173 MHz (this system is based on radio frequency allocated to the customer by Telecommunication State Inspection or according to the contracts signed by national GSM-operators)
3. The number of controlled system objects -5000

4. Number of controlled signals for each CI:
   Remote signaling: functional testing of 9 fuses;
   Remote signaling: functional testing of contactors;
   Remote signaling: presence testing of phases;
   Deviation control of current concerning limits for each phase of the three-phase lines;
   Remote control:
   ON/OFF of lighting facilities 1/3;
   ON/OFF of lighting facilities 2/3;
   ON/OFF of all lighting objects.
5. The possibility to take data from smart meters (types EL should be agreed)
6. The possibility of technological radio negotiation
7. Sending massage about unauthorized access to equipment CI
8. Sending massage about switching on the power on CI after shutdown
9. Switching capacity of drive circuit – the current up to 5 A at alternating voltage 220 V
10. Baud Rate -1200, 2400, 4800, 9600 baud

5. Conclusions

The intellectual automated system of dispatching control of street lighting in a city based on a personal electronic computer using radio communication for data transmission has been developed. The system makes it possible to provide high information content of control system, can reduce investment in implementation and operation by eliminating the expensive excavation during the laying of cables, reduce maintenance costs, maintain the level and prestige of domestic developments at the levels of world's standards, to be competitive capable in this field.

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WŁAŚCIWOŚCI MECHANICZNE POLIMEROWYCH RUSZTOWAŃ WYTWORZONYCH METODĄ DRUKU 3D

Streszczenie: Artykuł prezentuje wyniki badań właściwości mechanicznych próbek o różnej gęstości wypełnienia wewnętrznego (porowatości) wytworzonych metodą druku 3D. Wykazano, wpływ gęstości wypełnienia próbki. na własności mechaniczne drukowanego elementu.

Słowa kluczowe: Druk 3D, właściwości mechaniczne, polimerowe rusztowania, inżynieria tkankowa

MECHANICAL PROPERTIES OF POLYMER SCAFFOLDS PRODUCED BY 3D PRINTING

Summary: Preliminary results of mechanical properties of samples with different internal density (porosity) produced by 3D printing are presented in this article. The effect of internal structure on mechanical properties was confirmed.

Keywords: 3D printing, mechanical properties, polymer scaffolds, tissue engineering

1. Wprowadzenie

Metoda wytwarzania zaprojektowanych wcześniej elementów przy wykorzystaniu drukarki 3D jest obecnie jedną z nowatorskich metod umożliwiającą formowanie porowatych, przestrzennych podłoży dla inżynierii tkankowej. Możliwość łatwego sterowania porowatością podłoży, wielkością porów, ich kształtem i rozmieszczeniem w materiale sprawia, że na całym świecie w laboratoriach trwają

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intensywne badania nad opracowaniem nowych materiałów dla zastosowań w technologii warstwowego kształtowania przyrostowego [1]. Jednym z wymagań stawianych materiałom dla inżynierii tkankowej jest zaprojektowanie rusztowania (będącego w przyszłości nośnikiem komórek i rusztowaniem dla tkanek), które stanowiłoby podłoże o odpowiednich parametrach mechanicznych. W ramach niniejszej pracy, wykorzystując technikę druku przestrzennego oraz stosując komercyjnie dostępne materiały do drukarki 3D, zbadano parametry mechaniczne, próbek polimerowych o różnym zagęszczeniu wewnętrznym. Różnice w zagęszczeniu (porowatości materiału) osiągnięto stosując różne odległościami pomiędzy drukowanymi liniami.

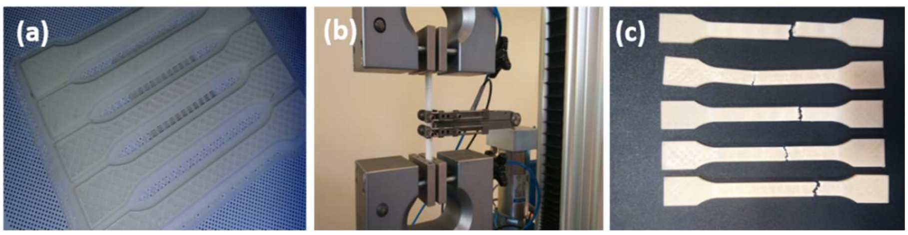
2. Opis próbek

Do badań własności mechanicznych użyto próbek o geometrii wynikającej z wymogów stawianych w normie dotyczącej polimerów EN ISO 527-2. Wymiary pola poprzecznego próbek przedstawiono w Tabeli 1.

Tabela 1. Wymiary pola przekroju poprzecznego próbek:

Próbka	Przekrój A [mm^2]
LOW	19,54
MEDIUM	20,64
HIGH	23,78
MAXIMUM	27,32

Próbki charakteryzowały się różną gęstością wypełnienia wewnętrznego tj. różną porowatością (Rys. 1a). Wykonano je na drukarce Zortrax M200 z dwóch materiałów Z-Ultrat oraz Z-PCABS. Użyte oprogramowanie Z-Suite pozwoliło na wybranie jednego z czterech zagęszczeń wypełnienia drukowanego elementu są to: rzadkie (oznaczane dalej jako low), średnie (medium), gęste (high) i bardzo gęste (maximum) [2]. Wykonano po pięć próbek dla każdego zagęszczenia wypełnienia dla obu materiałów. Drukowanie odbywało się w pomieszczeniu o temperaturze 20°C, a grubość nakładanej warstwy wynosiła 140 µm. Każda próbka składała się z czterech warstw dolnych i czterech warstw górnych, grubość ścianek bocznych, generowana automatycznie przez program, wynosiła 800 µm.



Rysunek 1. (a) Próbki w trakcie drukowania – pokazane przykładowe zagęszczenie wypełnienia próbek. (b)Próbka z zamocowanym ekstensometrem. (c) Próbki Z-PCABS(low) po rozerwaniu.

3. Metodyka badań

Badania właściwości mechanicznych wytworzonych metodą druku 3D próbek, przeprowadzone zostały na uniwersalnej maszynie wytrzymałościowej firmy Hegewald und Peschke typu Inspekt Table Blue 5kN. Próbki wytworzonych materiałów w kształcie wiosełek zamocowano w szczękach pneumatycznych (rozstaw 80 mm) maszyny wytrzymałościowej (Rys. 1b) i poddano badaniom wytrzymałości Badania przeprowadzono z wykorzystaniem ekstensometru. Przy pomocy tego urządzenia zostały zarejestrowane takie wielkości jak: moduł sprężystości podłużnej E, umowna granica plastyczności $R_{0,2\%}$, wytrzymałość na rozciąganie R_m oraz wydłużenie εM odpowiadające R_m. Założony ekstensometr zdejmowano po osiągnięciu wydłużenia pryzm równym 1 mm. Procedura ulegała zakończeniu po osiągnięciu spadku siły o 3%. Takie ustawienia zastosowano, aby chronić ekstensometr przed uszkodzeniem, wynikającym z rozerwania próbki między pryzmami ekstensometru. Procedura realizująca próbę rozciągania ułożona została w programie Labmaster. Próby przeprowadzano z prędkością 5 mm/min.

4. Wyniki i dyskusja

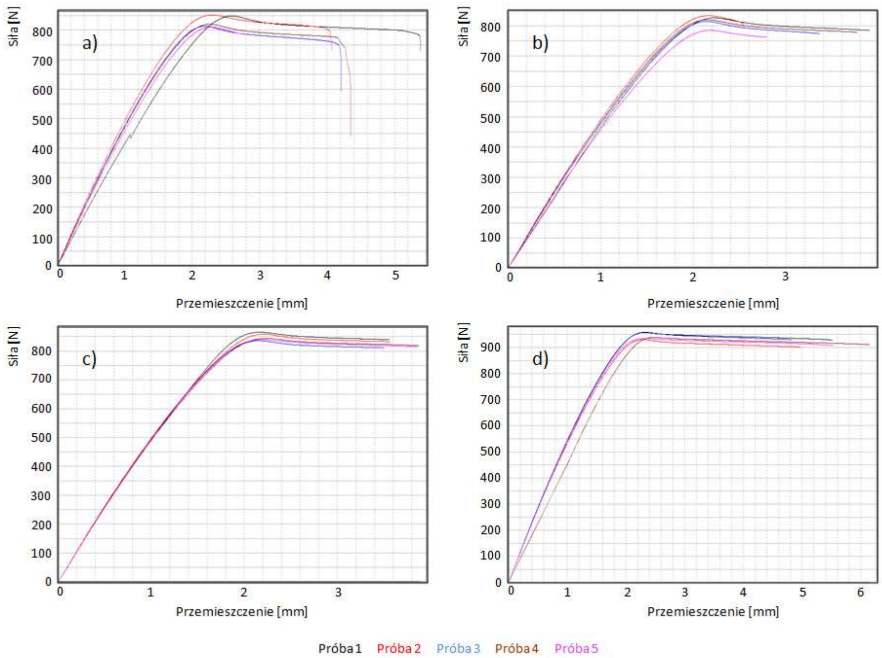
4.1. Właściwości mechaniczne próbek wykonanych z materiału Z-Ultrat

Wyniki uzyskane podczas statycznej próby rozciągania próbek o różnym zagęszczeniu wykonanych z materiału Z –Ultrat przedstawiono w Tabeli 2 oraz na wykresach siła-przemieszczenie (Rys.2). Na podstawie otrzymanych wyników można zaobserwować, że wraz ze wzrostem zagęszczenia wypełnienia próbek wzrasta moduł sprężystości E. Próbki o średnim wypełnieniu (Medium) cechują się największą wartością $R_{0,02\%}$. Próbki z serii o rzadkim zagęszczeniu (LOW) wykazują znacznie większe wydłużenie εM przy R_m, niż pozostałe serie próbek.

Tabela 2. Wyniki badań mechanicznych dla próbek z materiału Z-Ultrat.

Nr	E [MPa]				$R_{0,2\%}$[MPa]			
	LOW	MED	HIGH	MAX	LOW	MED	HIGH	MAX
1.	2161,9	3301,8	2592,9	2882,2	17,42	39,73	35,29	34,44
2.	2093,9	2502,9	2572,6	2863,8	18,87	-	35,48	33,47
3.	2393,8	2368,9	2513,1	2996,3	18,55	39,11	34,82	34,77
4.	2213,8	2440,4	2576,3	5750,1	18,92	39,44	35,04	24,08
5.	2257,5	2401,8	2529,7	2811,8	41,37	37,71	34,95	33,91
M ±SD	2224,2 ±112,7	2603,2 ±393,7	2556,9 ±33,8	3460,8 ±1281,5	23,03 ±10,27	39,00 ±0,89	35,12 ±0,26	32,13 ±4,53
	R_m [MPa]				εM [%]			
	LOW	MED	HIGH	MAX	LOW	MED	HIGH	MAX
1.	43,42	40,02	36,38	35,05	2,82	0,87	0,12	1,16
2.	43,56	40,37	36,10	34,06	2,60	0,49	1,14	1,13
3.	41,64	39,46	35,14	35,11	2,39	0,95	1,12	0,83
4.	41,99	39,71	35,49	34,38	2,50	1,10	1,11	0,90
5.	41,49	38,04	35,31	34,25	1,14	1,09	1,13	1,15
M ±SD	42,42 ±0,99	39,52 ±0,89	35,68 ±0,53	34,57 ±0,48	2,29 ±0,66	0,90 ±0,25	0,92 ±0,45	1,03 ±0,16

W próbie nr 2 dla serii Z-Ultrat MED nie została obliczona wartość umownej granicy plastyczność prawdopodobnie przez zbyt wczesne zdjęcie ekstensometru.



Rysunek 2. Wykresy rozciągania próbek wykonanych z materiału Z-Ultrat o zagęszczeniach: a)LOW b)MEDIUM c)HIGH d)MAXIMUM

4.2. Właściwości mechaniczne próbek wykonanych z materiału Z-PCABS

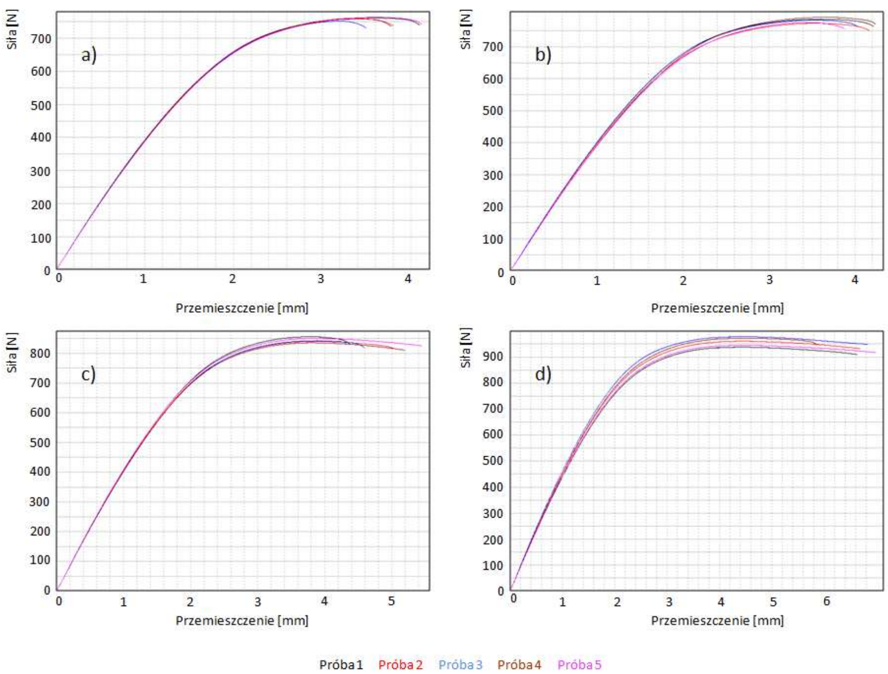
Seria próbek z materiału Z-PCABS również została wykonana w czterech różnych zagęszczeniach. Wyniki badań właściwości mechanicznych dla tej serii próbek zostały przedstawione w Tabeli 3 oraz na wykresach siła-przemieszczenie (Rys. 3). Na podstawie otrzymanych wyników badań wyników można zaobserwować, że wraz ze wzrostem zagęszczenia wzrasta wartość modułu Younga. Największą wartość εM wykazują próbki o wypełnieniu MAX. Wraz ze wzrostem zagęszczenia zmniejsza się wartość wytrzymałości na rozciąganie.

Tabela 3. Wyniki badań mechanicznych dla próbek z materiału Z-PCABS

Nr	E [MPa]				$R_{0,2\%}$[MPa]			
	LOW	MED	HIGH	MAX	LOW	MED	HIGH	MAX
1.	1915,1	1974,2	2097,9	2342,3	33,40	33,80	31,15	28,81
2.	1835,9	1979,4	2144,4	2431,7	33,30	31,98	30,50	29,41
3.	1919,8	1964,2	2184,9	2497,7	34,21	33,31	30,18	30,26
4.	1934,6	1964,6	1979,8	2442,6	34,23	34,09	31,47	29,66
5.	1942,7	2001,5	2161,9	2434,8	33,64	32,67	30,56	28,71
M ±SD	1909,6 ±42,4	1976,8 ±15,3	2113,8 ±81,4	2429,8 ±55,8	33,76 ±0,44	33,17 ±0,86	30,77 ±0,53	29,37 ±0,64

Tabela 3c.d. Wyniki badań mechanicznych dla próbek z materiału Z-PCABS

	R_m [MPa]				εM [%]			
	LOW	MED	HIGH	MAX	LOW	MED	HIGH	MAX
1.	39,00	38,10	35,98	34,32	2,00	1,88	2,19	2,87
2.	38,94	37,46	35,32	35,15	2,19	2,23	2,19	1,52
3.	38,51	37,95	35,41	35,80	1,61	1,96	2,08	2,85
4.	38,81	38,37	35,12	35,58	1,89	1,92	2,23	2,89
5.	39,08	37,60	35,74	34,58	1,99	1,89	2,19	2,85
M ±SD	38,87 ±0,22	37,90 ±0,37	35,52 ±0,34	35,09 ±0,63	1,94 ±0,21	1,98 ±0,15	2,18 ±0,06	2,60 ±0,60



Rysunek 3. Wykresy siła-przemieszczenie dla próbek z materiału Z-PCABS o zagęszczeniach: a)LOW b)MEDIUM c)HIGH d)MAX

5. Wnioski

W wyniku przeprowadzonych badań określono wpływ gęstości wypełnienia modelu. na własności mechaniczne drukowanego elementu. Wykazano, że niezależnie od zastosowanego rodzaju materiału serie próbek o rzadszym zagęszczeniu charakteryzują się niższą sztywnością (modułem Younga) i wyższą wytrzymałością na rozciąganie. Wraz ze wzrostem zagęszczenia w próbce rośnie moduł E oraz maleje wytrzymałość próbek. Z-Ultrat jest materiałem charakteryzującym się lepszymi parametrami mechanicznymi niż Z-PCABS, natomiast próbki, niezależnie od materiału, wykazują podobny, opisany wcześniej, wzrost lub spadek właściwości wraz ze wzrostem zagęszczenia. Jedyną różnicę w zachowaniu próbek zaobserwowano w przypadku próbek z materiału Z-Ultrat. W tym przypadku próbki o rzadkim zagęszczeniu charakteryzują znacznie większym wydłużeniem niż pozostałe serie próbek oraz niż próbki z materiału Z-PCABS. Prawdopodobnie różnice w wynikach były rezultatem poślizgu pryzm ekstensometru. Inną przyczyną mogą być nieciągłości ścianek wypełnienia powstające podczas drukowania, zaburzające jednorodność wydruku.

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WPŁYW STĘŻENIA ROZTWORU ŻELATYNY NA WYTRZYMAŁOŚĆ WŁÓKNIN WYTWORZONYCH METODĄ ELEKTROPRZĘDZENIA

Streszczenie: W ramach niniejszej pracy badano wpływ stężenia roztworu na właściwości mechaniczne nanowłókien z żelatyny wytworzonych metodą elektroprzędzenia. Wytrzymałość na rozciąganie R_m wyznaczono w statycznej próbie rozciągania włóknin. Wykazano, że niższe stężenie procentowe roztworu żelatyny umożliwia wytworzenie metodą elektroprzędzenia nanowłóknistych włóknin o wyższej wytrzymałości na rozciąganie.

Słowa kluczowe: wytrzymałość, elektroprzędzenie, inżynieria tkankowa, żelatyna

EFFECT OF GELATIN CONCENTRATION ON TENSILE PROPERTIES OF ELECTROSPUN NONWOVENS

Summary: In the present study the effect of solution concentration on the mechanical properties of gelatin nanofibers produced using electrospinning process was investigated. Tensile strength R_m was determined in a static tensile test. It has been shown that lower concentration of gelatin solution permits formation of nanofibrous nonwovens with higher tensile strength.

Keywords: tensile strength, electrospinning, tissue engineering, gelatin

1. Wprowadzenie

Proces elektroprzędzenia jest obecnie jedną z najczęściej wykorzystywanych metod wytwarzania podłoży zbudowanych z nanowłókien do zastosowań w inżynierii tkankowej [1]. Inżynieria tkankowa zajmuje się odbudową i przywróceniem funkcji tkanek i narządów, uszkodzonych lub usuniętych w wyniku urazu czy choroby.

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Podłoża dla hodowli tkanek, czyli materiały w obrębie których powinna się odbudowywać tkanka, konstruuje się z polimerów resorbowalnych, bioaktywnej ceramiki jak również z niektórych stopów metali i polimerów biostabilnych [2]. Biomateriał stosowany jako rusztowanie musi posiadać odpowiednie, zbliżone do zastępowanych tkanek właściwości mechaniczne, które nie ulegną zmianie do czasu wygojenia tkanki. W pracy do wytworzenia podłoży zastosowano żelatynę. Żelatyna jest biopolimerem, pochodną kolagenu – polimeru naturalnie występującego w tkankach w postaci włókien. Zaletą wytworzonych metodą elektroprzędzenia nanowłókien z żelatyny, jest ich podobieństwo (średnica włókien) do włókien kolagenowych tworzących matrycę zewnątrzkomórkową (ECM) tkanek. Dzięki temu w przyszłości podłoża takie będą sprzyjać szybszej odbudowie tkanki. Proces elektroprzędzenia zależny jest od wzajemnie powiązanych ze sobą parametrów, które bezpośrednio wpływają na morfologię oraz średnicę wytworzonych włókien a przez to również na właściwości mechaniczne wytworzonych podłoży [3]. W ramach niniejszej pracy badano wpływ stężenia roztworu na właściwości mechaniczne nanowłóknistych włóknin z żelatyny wytworzonych metodą elektroprzędzenia.

2. Materiały i metody

2.1. Materiały

W badaniach wykorzystano żelatynę wieprzową typu A firmy POCH. Nanowłókna formowano metodą elektroprzędzenia z roztworu, na urządzeniu TIC 1092012 (ATH, Bielsko-Biała). Rozpuszczalnikiem użytym do sporządzenia roztworów był Trifluoroetanol (TFE, ARCOS). Przygotowano dwa roztwory żelatyna/TFE o zawartości żelatyny 6 i 9 % wt. Przygotowane roztwory umieszczano w jednorazowej strzykawce zakończonej igłą o średnicy 0,22 mm. Doprowadzone do igły napięcie wynosiło 20 kV. Odległość między kapilarą a kolektorem wynosiła 200 mm. Wał obrotowy, został owinięty papierem do pieczenia w celu łatwiejszego oderwania próbek od kolektora. W rezultacie z roztworów o różnym stężeniu otrzymano dwie włókniny oznaczone odpowiednio GEL6 i GEL9. Próbki wytworzonych materiałów pocięto na pięć pasków o szerokości 20 mm i długości 100 mm.

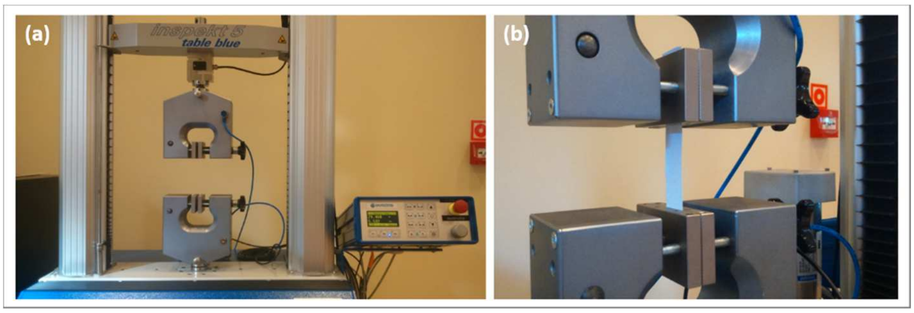
Tabela 1. Zestawienie średnich grubości włóknin wytworzonych metodą elektroprzędzenia

nr	GEL9	GEL6
	grubość [mm]	grubość [mm]
1.	0,154 ± 0,008	0,070 ± 0,014
2.	0,161 ± 0,011	0,060 ± 0,014
3.	0,144 ± 0,017	0,060 ± 0,014
4.	0,164 ± 0,011	0,060 ± 0,014
5.	0,155 ± 0,016	0,065 ± 0,007

Przed przystąpieniem do badań wytrzymałościowych zmierzono grubość otrzymanych włóknin. Pomiary grubości przeprowadzone zostały na grubościomierzu firmy Mitutoyo w dziesięciu miejscach, po długości próbki, dla każdej z pięciu próbek danej serii. W tabeli 1 zamieszczono średnie wartości tych pomiarów oraz ich odchylenie standardowe.

2.2. Metodyka badań

Badania właściwości mechanicznych wytworzonych próbek przeprowadzone zostały na uniwersalnej maszynie wytrzymałościowej firmy Hegewald und Peschke typu Inspekt Table Blue 5kN (Rys. 1a).



Rysunek 1. Uniwersalna maszyna wytrzymałościowa Hegewald und Peschke (a); przykładowa próbka zamocowana w szczękach maszyny (b)

Próbki wytworzonych materiałów o szerokości 20 mm i długości 100 mm zamocowano w szczękach pneumatycznych (rozstaw 50 mm) maszyny wytrzymałościowej (Rys. 1b) i poddano badaniom wytrzymałości. Dla każdego rodzaju włókniny wykonano badania na serii 5 próbek. Właściwości mechaniczne włóknin określono w statycznej próbie rozciągania (procedura badawcza utworzona w systemie Labmaster). Próbki do badań zostały rozciągnięte wzdłuż ich głównej osi wzdłużnej, przy stałej prędkości 5 mm/min, W trakcie badań zmierzono siłę maksymalną oraz towarzyszące jej wydłużenie próbki. Wyniki przedstawiono w postaci wykresu siła - przemieszczenie. Wytrzymałość na rozciąganie wyrażoną jako maksymalne naprężenie (nominalne), jakie włóknina przenosiła podczas statycznego rozciągania wyliczono ze wzoru:

$$R_m = \frac{F_m}{A} \qquad (1)$$

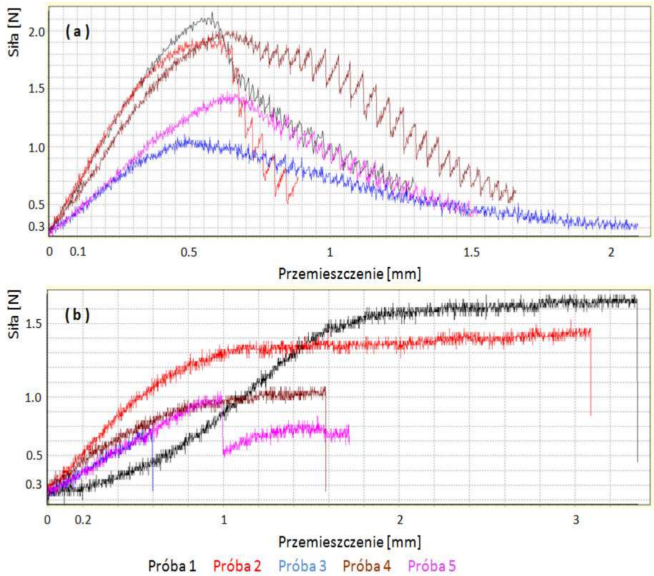
gdzie:

R_m- wytrzymałość na rozciąganie, MPa
F_m – maksymalna siła, N
A – początkowy przekrój poprzeczny włókniny, m^2

Obserwacje mikrostruktury wytworzonych próbek przeprowadzono przy użyciu skaningowego mikroskopu elektronowego NOVA NANO SEM 200 (producent FEI EUROPE COMPANY).

3. Wyniki i dyskusja

Otrzymane w wyniku próby rozciągania zależności siła - przemieszczenie dla próbek żelatyny przedstawiono na rysunku 2. Na wykresach badanych materiałów polimerowych można zauważyć znaczne różnice w przebiegach krzywych rozciągania.



Rysunek 2. Przykładowe wykresy zależności siła – przemieszczenie dla próbek: (a) GEL9 i (b)GEL6

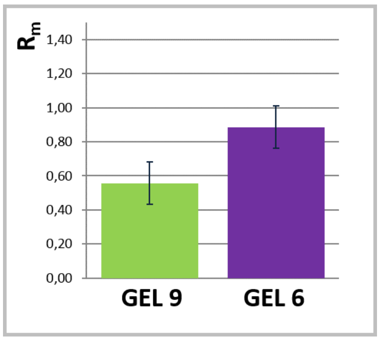
Przejawiają się one różnymi wartościami siły F_m oraz odmiennym wydłużeniem przy tych siłach. Właściwości mechaniczne próbek oznaczone w wyniku próby rozciągania zebrano w Tabeli 2. Rozbieżność wyników w serii przeprowadzonej dla danej włókniny wynika z niejednorodności mikrostruktury danego materiału (mamy do czynienia z porowatą włókniną o nierównomiernym rozmieszczeniu włókien).

Tabela 2. Właściwości mechaniczne próbek GEL9 i GEL6wyznaczone w statycznej próbie rozciągania

Nr	εM [%]		F_m [N]		A [mm^2]		R_m [MPa]	
	GEL9	GEL6	GEL9	GEL6	GEL9	GEL6	GEL9	GEL6
1.	1.16	4.98	2.17	1.60	3.08	1.40	0.70	1.14
2.	1.13	5.89	1.97	1.43	3.22	1.20	0.61	1.19
3.	0.96	1.01	1.11	0.69	2.88	1.20	0.39	0.57
4.	1.16	2.46	2.00	0.97	3.28	1.20	0.61	0.81
5.	1.26	1.89	1.48	0.94	3.10	1.30	0.48	0.72
M ± SD	1.13 ± 0.11	3.25 ± 2.09	1.74 ± 0.44	1.12 ± 0.38	3.11 ± 0.15	1.26 ± 0.09	0.56 ± 0.13	0.89 ± 0.27

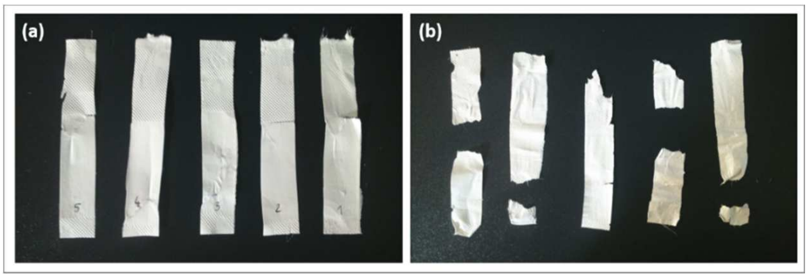
εM – wydłużenie przy R_m, F_m – maksymalna siła, A – przekrój poprzeczny, R_m – wytrzymałość na rozciąganie

Natomiast sam przebieg krzywych jest charakterystyczny dla danego rodzaju włókniny. Próbki otrzymane z roztworu żelatyny o większym stężeniu procentowym (9% wt.) charakteryzują się większą sztywnością próbek, a tym samym mniejszą odkształcalnością (Rys.2a). Włóknina, otrzymana z 6% wt. roztworu żelatyny wykazuje większą tendencję do odkształcania się (Rys. 2b). Korzystając z otrzymanych wyników badań zebranych w tabelach 1 i 2, obliczono pole przekroju poprzecznego każdej z próbek oraz wytrzymałość na rozciąganie wyrażoną jako naprężenie (Rys. 3).



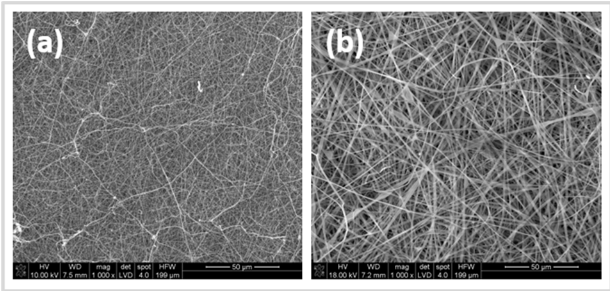
Rysunek 3. Wytrzymałość włóknin z żelatyny wytworzonych metodą elektroprzędzenia

Wyższą, średnią wartość naprężenia wynoszącą 0,89 ± 0,27 MPa otrzymano dla próbki GEL6, dla której zarejestrowano również największą średnią wartość wydłużenia wynoszącą 3,25 ± 2,09. Zdjęcia próbek po próbie rozciągania przedstawiono na rysunku 4.



Rysunek 4. Zdjęcie próbek po próbie rozciągania: (a) GEL9 i (b)GEL6

Na rysunku 5 przedstawiono mikrostrukturę obu włóknin z żelatyny po procesie elektroprzędzenia. Próbka GEL 6 posiada włókna o znacznie drobniejszych średnicach (obliczona na podstawie zdjęć mikroskopowych średnia średnica włókien w próbkach wynosi: 222±37nm dla próbki GEL6 i 782±327nm dla GEL9). Podobne zależności zaobserwowano przeprowadzając doświadczenia na otrzymanych metodą elektroprzędzenia włóknach z polikaprolaktonu. Wraz ze zmniejszeniem się średnicy włókien wytrzymałość na rozciąganie rosła [5].



Rysunek 5. Mikrostruktura wytworzonych metodą elektroprzędzenia próbek: (a) GEL6 i (b)GEL9

4. Wnioski

Z przeprowadzonych badań wynika, że wytworzona metodą elektroprzędzenia włóknina otrzymana z roztworu o mniejszym stężeniu procentowym żelatyny (6% wt.) charakteryzuje się większą wytrzymałością na rozciąganie oraz większą wartością wydłużenia przy R_m.. Włóknina ta posiada również znacznie mniejsze średnice nanowłókien w porównaniu z włókniną o większej zawartości procentowej żelatyny. Wyciągnięte na podstawie przeprowadzonych eksperymentów wnioski znajdują potwierdzenie w doniesieniach literaturowych opisujących badania właściwości mechanicznych innych polimerów wytwarzanych metodą elektroprzędzenia. Zaobserwowano, że wraz ze zmniejszeniem się średnicy włókien wytrzymałość na rozciąganie rośnie.

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Sylwia TRAGARZ[1]

Opiekun naukowy: Marcin ZEMCZAK[2]

ZARZĄDZANIE ZAPASAMI PRZY UŻYCIU SYSTEMU KANBAN

Streszczenie: Praca przedstawia racjonalizację zarządzania zapasami w przedsiębiorstwie produkcyjnymi z branży automotive. Pierwsza część teoretyczna polega na badaniach literaturowych związanych z system kanban. Druga część praktyczna przedstawia badania własne prowadzone w przedsiębiorstwie polegające na analizie stanu obecnego i wprowadzeniu projektu racjonalizacji. Artykuł ukazuje usprawnienie przepływu materiałowego przez zastosowaniu elektrycznego systemu kanban.

Słowa kluczowe: zarządzanie zapasami, system kanban

INVENTORY MANAGEMENT BY USE KANBAN SYSTEM

Summary: The thesis presents the rationalization of inventory management in the enterprise production of the automotive industry. The first part consists of theoretical studies concerning system kanban. The second practical part presents own research conducted in the company involving the analysis of the current state and the introduction of the project rationalization. The article shows streamline the flow of material through the use of an electrical system kanban.

Keywords: inventory management, kanban system

1. Kanban w przedsiębiorstwie produkcyjnym

Kanban, czyli technika magazynowania używająca pojemników, kart czy elektronicznych sygnałów, gdzie system produkcyjny sterowany jest rzeczywistymi potrzebami, a nie prognozami. Podstawowym jej elementem są karty kanban, służące do sterowania zarówno czasem jak i ilością przepływu materiałów oraz części. Karty te krążą między magazynem materiałów, stanowiskami produkcyjnymi oraz magazynem wyrobów gotowych. Kanban jako prosty i szybki system komunikacji umożliwia wizualną kontrolę przepływu wytwarzania.[3]

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[3] Hammarberg M., Sunden J.: Kanban in Action.Manning Publications Co, Greenwich 2014.

1.1. Tradycyjny kanban

Na każdej karcie kanban powinny zostać zawarte informacje o pozycji kartotekowej (indeksu), której ona dotyczy. Dodatkowo zwykle podaje się ilość danego pojemnika bądź opakowania. Możliwe jest również umieszczenie nazwy oraz opisu indeksu bądź wydziału. Jeśli karta wisi na pełnym pojemniku, opisuje ona jego zawartość. W przypadku pobierania do wysyłki opakowania z wyrobami gotowymi pracownik przygotowujący wysyłkę ściąga kartę z pojemnika oraz przekazuje ją na stanowisko produkcyjne, gdzie realizowana jest ostatnia operacja lub wiesza na tablicy kart kanban.[4]Podstawą technik Kanban są formularze, które powinny zawierać:[5]

- plan produkcji oparty na prognozowaniu popytu zapisany na karcie;
- odpowiednie zlecenie produkcyjne dotyczące partii elementów określające potrzebne zasoby do wytworzenia;

1.2. Nowoczesny system kanban

W niektórych implementacjach elektroniczne systemy śledzą wirtualne obiekty kanban i wysyłają sygnał, gdy można rozpocząć nową pracę. Sygnał może być wizualny lub w formie alertu, takiego jak wiadomość e-mail. Ponadto można wykorzystać kody kreskowe dla tzw. elektronicznego kanbana. Techniki te wykorzystują możliwości technologii informacyjnej w celu usprawnienia komunikacji w całym łańcuchu dostaw, a co za tym idzie bardziej efektywnego sterowania przepływem informacyjnym oraz materiałowym. Dzięki czytnikom kodu kreskowego wyposażonym w interfejs, możliwe jest natychmiastowe wysyłanie sygnałów o kończących się zasobach niezbędne do dalszej produkcji. W odchudzonym wytwarzaniu obiekty kanban są wirtualne i często śledzone przez ustawienie maksymalnej liczby dla danego etapu w przepływie pracy dla typu elementu pracy. [6]Nowoczesny system sterowany jest zdarzeniami występującymi bezpośrednio na produkcji (nie jest oparty o prognozy). Dodatkowym atutem jest możliwość automatycznego generowania dokumentacji obrotowej tj:

- dokumenty pobrań materiałowych (RW);
- dokumenty przekazania wyrobów na magazyn (PW);
- dokumenty związanych z przesuwaniem detali między magazynami (MM);
- dokumenty wydawania indeksów do obróbki w kooperacji (WZ);
- dokumenty zwrotnego przyjmowania (PZ).

System kanban umożliwia lepszą wymianę danych oraz informacji między pracownikami działów i samym magazynem. Przykładem jest rozpoczęcie produkcji (system posiada tą informację na podstawie odczytanego przez pracownika kodu kreskowego z karty), gdzie magazynier automatycznie otrzymuje taką informację, jakich konkretnie materiałów oraz półproduktów brakuje. W jego szczegółowej specyfikacji system wyświetla poszczególne magazyny oraz lokalizacje, skąd powinny zostać pobrane komponenty oraz na jakie wydziały należy je dostarczyć.[7]

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[4] Serwis internetowy Erp info: *http://erp.info.pl/kanbanmrpii/,* 01.10.2016
[5] Serwis internetowy Governica: *https://www.governica.com/Kanban,* 01.10.2016
[6] Hammarberg M., Sunden J.: Kanban in Action.Manning Publications Co, Greenwich, 2014.
[7] Serwis internetowy Erp info: *http://erp.info.pl/kanbanmrpii/,* 01.10.2016

2. Analiza stanu obecnego w przedsiębiorstwie automotive

Przepływ materiałów z magazynu na produkcję poprzedzony jest zamawianiem konkretnego materiału za pomocą kart kanban. Karta ta pokazuje numer materiału potrzebnego na produkcję oraz numer wydziału magazynowego, gdzie można znaleźć komponent. Rysunek 1 przedstawia przykład takiej karty.

Rysunek 1. Obecna karta kanban[8]

Karta trafia do tzw. tablicy pobrań, skąd magazynier pobiera ją na początku każdej zmiany. Po zakończeniu przerwy na wydziałach produkcyjnych również następuje sprawdzenie przez magazynierów czy nie pojawiły się nowe kanbany do wydania. Jedna karta oznacza wydanie jednego pudełka komponentów. Gdy magazynier zbierze wszystkie karty z poszczególnych wydziałów udaje się na magazyn w celu znalezienia materiału. Każdy przedział na magazynie ma przypisany numer porządkowy, po którym identyfikowane jest miejsce przechowywania danego materiału np. klipsy RC1, inserty RC2. Kod kreskowy na karcie umożliwia z czytanie miejsca składowania przy użyciu skanera. Materiały wydawane są zgodnie z zasadą FIFO, dlatego magazynier wydaje w pierwszej kolejność materiały

[8] Opracowanie własne

z najstarszą datą przyjęcia. Gdy już magazynier zlokalizuje pudło, które zarazem jest zgodne z FIFO, wydaje go na produkcję bezpośrednio do leadera wydziału, gdyż na wydziałach nie ma określonych miejsc, gdzie magazynier mógłby wydać bezpośrednio materiał bez angażowania leadera.

2.1. Wprowadzenie nowoczesnego systemu kanban

W przypadku, kiedy nastąpi opróżnienie przez pracownika pojemnika z zapasami, ten natychmiast powinien wygenerować zgłoszenie do systemu kanban poprzez wybranie pozycji zawierającej numer części. System sam analizuje potrzeby fabryki dotyczące danego materiału, planując kolejne dostawy oraz zlecając dostarczenie przez kierowcę wózka widłowego materiału do pracownika. Będzie to realizowane za pomocą terminali przemysłowych umieszczonych na wydziałach. Rysunek 2 przedstawia przykład takiego terminala.

Rysunek 2. Terminal wydziałowy[9]

Natomiast terminal odpowiedzialny za pobieranie danych z wydziałów będzie umieszczony na wózku widłowym w widocznym miejscu dla magazyniera, wówczas magazynier będzie na bieżąco informowany o potrzebnej ilości wydania materiału. Po wprowadzeniu systemu kanban pracownicy zobowiązani są, by zamówić materiał przez panel z ich stacji pracy. Dane transmituje system ERP do głównego komputera, który równocześnie wywołuje utworzenie zlecenia. Zlecenie ukazuje się na panelu graficznym kierowcy wózka, który jedzie i dopełnia materiał

[9]https://www.google.pl/search?q=dlog&safe=active&biw=1342&bih=658&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjkkbaNt6bJAhWIbBoKHT19CM8Q_AUIBigB, 23.11.2015, 12:22

bezpośrednio w poszczególnej stacji montażowej, zabierając puste opakowania zbiorcze. Umożliwia to pozbycie się dużych, niepotrzebnych miejsc składowania. Tabela 1 przedstawia porównanie tradycyjnego kanbana z nowym systemem.

Tabela 1. Porównanie tradycyjnego kanbana z nowym systemem kanban

NOWY KANBAN	STARY KANBAN
skrócenie czasu przejścia	wydłużony czas przejścia
skrócenie dróg transportowych	wydłużona droga transportowa między operacjami
spadek zapotrzebowania na powierzchnię	duża powierzchnia utrzymująca duże zapasy
mniej przemieszczania materiału	ciągłe dostarczanie towarów
90% redukcji nakładu pracy na transport wewnętrzny	ciągłe dostarczanie komponentów
redukcji kosztów logistyki	ciągłe monitorowanie stanów magazynowych
wzrost produktywności	umiarkowana produktywność
spadek materiałów wip	utrzymanie wip w celu realizacji zamówień
wzrasta jakość produktów	brak skupienia operatorów
maleje czas realizacji zamówienia z tygodni do dni	wydłużony czas realizacji ze względu na organizację przepływu

W projekcie racjonalizacji postanowiono wdrożyć elektroniczne kanbany, na całym wydziale, które wspomagane są przez system na bazie ERP. Wdrożenie systemu nałożyło na przedsiębiorstwo konieczność przemyślenia oraz zmian prawie całego procesu produkcyjnego. Najważniejszym elementem była rekonstrukcja infrastruktury fabryki dla utworzenia ciągłego strumienia informacji pomiędzy produkcją, a łańcuchem dostaw. System zaoszczędza czas, przesyłając wszelkie informacje przez sieć - zdejmując materiały z magazynu głównego oraz wydając rozkazy transportowe kierowcom. W przypadku konieczności uzupełnienia zapasów towaru, system planując dostawę po potwierdzeniu jej możliwości przesyła pracownikowi informacje dotyczące terminu dostawy. Oszczędza on też czas potrzebny przy dostarczeniu materiału od dostawcy do stacji pracy. Kierowca wózka widłowego otrzymuje (w przypadku wydania rozkazu transportu przez system) czerwony monit i po wybraniu go na swoim terminalu blokuje możliwość realizacji tego zlecenia przez pozostałe wózki. Po wykonaniu rozkazu również potwierdza

czynność, umożliwiając śledzenie na bieżąco wszystkich czynności logistycznych odbywających się na terenie firmy. Wszystkie funkcje graficzne terminala są łatwe do aktualizacji z centralnego serwera plików.
Wdrożenie systemu oraz wprowadzenie elektronicznych kanbanów pozwoli na uzyskanie spójnych informacji o tym, co działa prawidłowo i nieprawidłowo, zamianę przeczuć na fakty (czyli to, co nam się wydaje, jest potwierdzone liczbami), identyfikację źródła problemów. Dzięki systemowi ERP, kierownik produkcji jest w stanie zobaczyć, co dzieje się w danym momencie na hali, nie musząc jej kontrolować osobiście.

3. Podsumowanie

Przedsiębiorstwo dzięki wdrożeniu systemu uzyska widoczne przyspieszenie strumienia materiału oraz zapewnienie solidnej i pewnej gospodarki magazynowej. Zmniejszona zostanie ilość przechowywanego materiału. Zautomatyzowano też sposób gospodarowania dostawami i kontrolowania aktualnych zapasów. Zaobserwowano przy tym powiększenie wolnej przestrzeni poprzez racjonalne gospodarowanie systemu kanban. Duże oszczędności przyniesie wyeliminowanie konieczności wypełniania stosów papierów oraz stałej obserwacji stanów materiałowych. W efekcie system oparty na terminalach przemysłowych pozwoli obniżyć koszty logistyczne fabryki o 20 %. Natomiast dla pracowników praca stanie się łatwiejsza, szybsza, bez konieczności długiego oczekiwania na komponenty.

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Matej URBANSKÝ[1], Jaroslav HOMIŠIN[2]

Supervisor: Jaroslav HOMIŠIN

PREZENTACJA SYSTEMU REGULACJI DRGAŃ SKRĘTNYCH MOBILNEGO UKŁADU MECHANICZNEGO

Streszczenie: W naszym artykule opisano problem ciągłego strojenia/sterowania układów mechanicznych drgających skrętnie podczas ich pracy zwłaszcza w zakresie amplitudy drgań skrętnych. Artykuł prezentuje aktualne wyniki dotyczące funkcji regulacji ekstremalnej dla mobilnego układu mechanicznego, który był zbudowany dla celów badań oraz prezentacji. Ten układ mechaniczny działa w trybie pracy ciągłej będąc zabezpieczony przed uszkodzeniami i przeciążeniami.

Słowa kluczowe: drganie skrętne, ciągłe strojenie, regulacja extremalna.

PRESENTATION OF TORSIONAL VIBRATION CONTROL ON MOBILE MECHANICAL SYSTEM

Summary: At our department we deal with continuous tuning of torsionally oscillating mechanical systems during their operation mainly in terms of torsional vibration size. This paper presents current results of extremal control function on a mobile mechanical system, which was built for presentation purposes. The mechanical system operates at failure-free stable state.

Keywords: torsional vibration, continuous tuning, extremal control method.

1. Introduction

In the laboratory of our workplace, we attend to a tuning of torsionally oscillating mechanical systems (TOMS) and mainly we focus on continuous tuning of TOMS during their operation, i.a. publications [1, 2, 3, 4, 5, 6, 7, 8, 9], mainly in terms of torsional vibration magnitude (but also in terms of magnitude of rectilinear vibration or noise arising from torsional vibration). As means of this continuous tuning we use

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pneumatic flexible shaft couplings (pneumatic torsional vibrations tuners, hereafter „pneumatic tuners“) developed by us.
The torsional stiffness of given pneumatic tuners and so the natural frequencies of torsional systems can be changed by adjusting the gaseous media pressure in their pneumatic flexible elements (most commonly air).
The application of extremal control – experimental optimization is one of the methods of continuous tuning. The extremal control gives us the possibility to minimize a magnitude of dangerous torsional vibration in torsionally oscillating mechanical systems during their operation directly by adapting the dynamic properties of TOMS to actual operating parameters and failures. The main advantage of the extremal control is that we don't need to know exact mathematical model of mechanical system. We only have to know that the objective function of mechanical system has an extreme i.a. [3, 4, 5, 6, 7, 8, 9] and [1].

2. The aim of paper

The aim of this paper is to present the current results of extremal control function on a mobile mechanical system, which was built for presentation purposes [1, 8, 10, 11]. In this case, the extremal control function will be presented only when the mechanical system (Fig.1) operates at various failure-free stable states. In this case, the failure state under consideration is mainly the state, when compressor valve(s) is out of action or it works strongly unequally compared to the others.

3. The newly build mobile torsional oscillating mechanical system

In Fig.1 we can see that the TOMS is made up of the 3-phase asynchronous electromotor MEZ 4AP132M-4 (7,5 kW, 1450 min^{-1}) (1), whose rotation speed is continuously vector-controlled by the frequency converter Sinamics G120C.

Figure 1. The newly build mobile torsional oscillating mechanical system

The electromotor drives the 3-cylinder piston compressor ORLIK 3JSK-75 (3) through the pneumatic tuner of type 4-2/70-T-C (2). Next component situated on the mobile platform (5) is the electronic extremal control system called ESLER (4) and its accessories (sensors, actuators, etc.). Function of ESLER is in detail described in [8] and the whole process of torsional oscillation data measuring and evaluation using optical sensors is in detail described in [10]. The mobile platform's design and functions are in detail described in [11].

4. Measured objective functions of the mechanical system

It were measured the resonant curves (in our case the dependences of the effective value RMS of dynamic component of load torque M_k on the rotation speed) of the mechanical system at various constant air overpressure values in the pneumatic tuner p_{pS} (Fig.3.a). The constant air overpressure value in the pressure tank was 400 kPa. The resonance peaks in Fig.3.a arise from coincidence of the main – 3rd harmonic component of the excitation with the 1st natural frequencies of the mechanical system. We can see that with increasing the pressure in the pneumatic tuner the resonant curve of the mechanical system moves to the right. It occurs because the dynamic torsional stiffness of the tuner k_{dyn} increases with increase of air pressure in the tuner (Fig.3.b). When we use data from the measured resonant curves and plot the dependences of the RMS M_k on the p_{pS} in the pneumatic tuner at various stable states of operation of the mechanical system (In our case, this stable operating state of given mechanical system will be characterized at constant rotation speed, compressor delivery pressure and disturbing variables values), we get the objective functions of the mechanical system (Fig.2).We can see that the objective functions are in whole p_{pS} range monotonic, concave or convex.

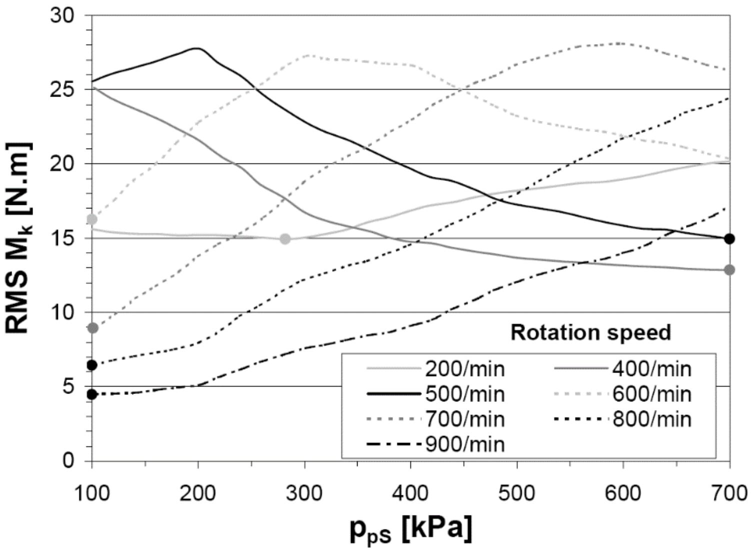

Figure 2. The objective functions at various stable operating states of the system

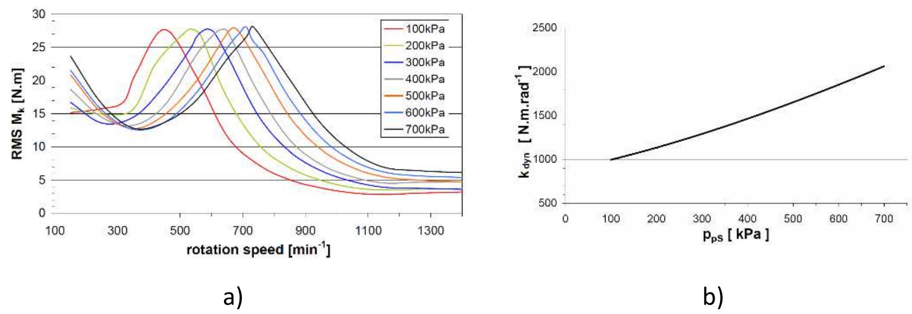

Figure 3. a) The resonant curves of the mechanical system at various air overpressure in the tuner p_{pS} = 100 ÷ 700 kPa; b) The dependence of the dynamic torsional stiffness of the tuner k_{dyn} on the overpressure p_{pS} in the tuner

5. Description of current function of the extremal control

The result of our extremal control should be finding the global minimum of objective function = minimum of dynamic load torque at certain stable state of mechanical system operation, as soon as possible. Or else air pressure in the pneumatic tuner needs to be adjusted so that dynamic load torque descends to acceptable level. Previous function of our extremal control was in detail described in [8]:

- The air overpressure p_{pS} in the pneumatic tuner was changed step by step in whole p_{pS} range from $p_{pS\,\min}$ to $p_{pS\,\max}$ (defined in advance) or reversely (the constant step width value was defined in advance).
- When operating parameters of the mechanical system were changed or a failure (e.g. cylinder fall-out) occurred, we had to wait for the stabilization of operating state of the mechanical system and then manually start the objective function extreme searching process.

The main disadvantage of above mentioned extremal control function is too long time of searching for objective function extreme and non-automatic response to change of mechanical system operating parameters or to occurrence of failures.
Therefore, the new extremal control algorithm was developed, which already allows automatic response to change of mechanical system operating parameters, even during searching for an extreme of objective function. The extreme searching time is significantly shorter, because we make use of the fact that the objective functions at failure-free stable operating states of given system are in the whole p_{pS} range monotonic, concave or convex.

The principle of current function of our extremal control is shown in Fig.4. We can see that three different stable operating states of given mechanical system are chosen for the explanation. For example, the operation of the mechanical system begins in the point “A” (rotation speed 200 min^{-1}, p_{pS} = 100 kPa). The extremal control begin its work with increase of p_{pS} step by step (the step width value was defined in advance, it is constant) up to the point “C”, wherein the RMS M_k value increases by the value ΔRMS (defined in advance) over the until then lowest measured value RMS M_k of given objective function in the point “B”. The RMS M_k value will be even checked in this case at upper limit of p_{pS} range (defined in advance) due to possible concave shape of the objective function. Because it is searched the minimum of RMS M_k of the objective function, the p_{pS} value in the pneumatic tuner will be finally set to point “E=B”. If it comes to the change of the mechanical system operating state, where the rotation speed changes from 200 min^{-1} to 600 min^{-1}, then the objective function of the mechanical system acquires the new shape, according to Fig.4. The electronic system ESLER evaluates this change, waits for stabilization of the mechanical system operating state and subsequently continues with the extremal control from the point “F” with increase of p_{pS} up to the point “G”, because in this section the until then lowest measured value RMS M_k of given objective function increases not by the value ΔRMS. The extremal control continues with decrease of p_{pS} from the point “F” up to the point “H”, wherein is also the global minimum of RMS M_k of given objective function. If it comes to the change of the mechanical system operating state again, where the rotation speed changes from 600 min^{-1} to 900 min^{-1}, then the objective function acquires the new shape again, according to Fig.4. The electronic system ESLER evaluates this change again, waits for stabilization of the mechanical system operating state and subsequently continues with the extremal control from the point “I” with increase of p_{pS} up to the point “J”, wherein the RMS M_k value increases by the value ΔRMS over the until then lowest measured value RMS M_k of given objective function in the point “I”. The RMS M_k value will be even checked in this case at upper limit of p_{pS} range due to possible concave shape of the objective function. Because it is searched the minimum of RMS M_k of the objective function, the p_{pS} value in the pneumatic tuner will be finally set to point “L=I”. It is necessary to say that we can suitably change all the above mentioned variables, defined in advance, during the extremal control process.

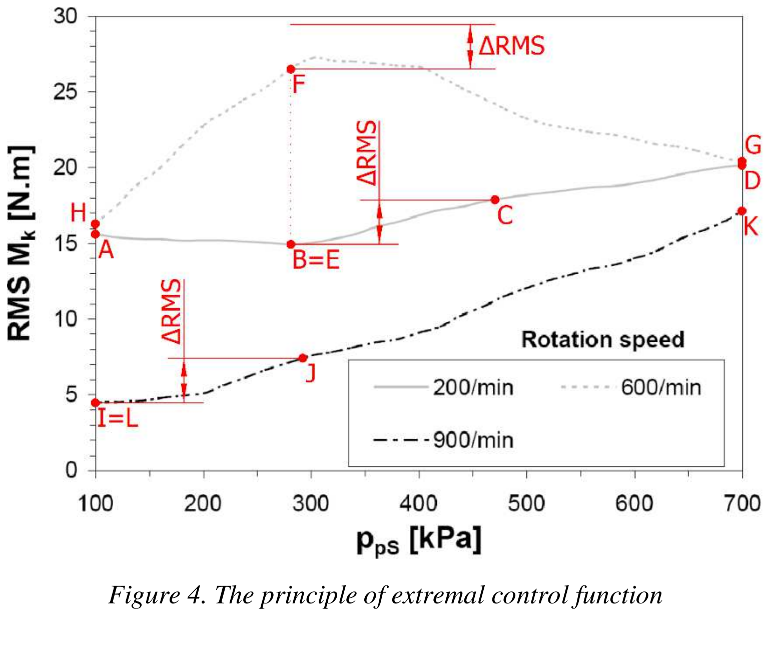

Figure 4. The principle of extremal control function

6. Conclusion

The time, necessary for finding of objective function extreme using the new extremal control algorithm, is significantly shorter, as we can see in the Fig.4. However, this new algorithm is suitable only when the objective functions of the mechanical system are in whole p_{pS} range monotonic, concave or convex. When a cylinder(s) fall-out or another failure causes that the shape of the objective functions will be more complex with more local minima and maxima [9], searching of the objective function global extreme must be realized according to another algorithm. This algorithm operates with various p_{pS} step width due to short time of extreme searching process and nowadays we are focused on its development and testing.

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This paper was written in the framework of Grant Project VEGA: „*1/0197/14 Research of the new methods and innovative design solutions to increase efficiency and to reduce emissions of a vehicle drive unit with an assessment of the potential operational risks.*"

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MODUŁOWA KONSTRUKCJA TYPOSZEREGU WOLNOOBROTOWYCH MIESZADEŁ ZANURZALNYCH Z SILNIKIEM PRZECIWWYBUCHOWYM I PRZEKŁADNIĄ PLANETARNĄ

Streszczenie: Niniejszy artykuł przedstawia problematykę poświęconą tematowi wolnoobrotowych mieszadeł zanurzalnych dla oczyszczalni ścieków i biogazowni. Przedstawiono problematykę związaną z kosztami zakupu mieszadeł z importu i ich późniejszą eksploatacją, w odniesieniu do mieszadeł polskiej produkcji. W dokumencie przedstawiono koncepcję modułowej konstrukcji urządzenia, z punktu widzenia wytwarzania i eksploatacji.

Słowa kluczowe: konstrukcja modułowa, mieszadła zanurzalne, silnik przeciwwybuchowy, przekładnia planetarna

MODULAR DESIGN SERIES OF TYPES LOW-SPEED SUBMERSIBLE MIXERS WITH EXPLOSION-PROOF MOTOR AND PLANETARY GEARBOX

Summary: This article presents problems dedicated to the low-speed submersible mixers for wastewater treatment plants and biogas plants. Presents the problems associated with the purchase costs of imported agitators and their subsequent use, in relation to the mixers Polish production. The document presents the concept of modular construction of the device, from the point of view of manufacturing and exploitation.

Keywords: modular construction, submersible mixers, explosion-proof motor, planetary gear

1. Wprowadzenie

Zastosowanie konstrukcji modułowych to metoda upraszczania złożonego systemu, zaczyniając od podstawowych, aż po złożone i obszerne obiekty, znajdująca coraz

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szersze zastosowanie we współczesnym projektowaniu obiektów technicznych. Zastosowanie tej metody pozwala na produkowanie dużej liczby mniej złożonych komponentów, zamiast małej liczby złożonych urządzeń. Prostsza konstrukcja daje możliwość większej automatyzacji procesu wytwarzania, co skutkuje lepszą jakością wytwarzanych produktów i niższymi kosztami procesów produkcyjnych i eksploatacyjnych. Konstruowanie modułowe jest efektem dążenia w rozwoju systemów wytwórczych w kierunku wzrostu wydajności i elastyczności, jak również łatwości eksploatacji, niezawodność konstruowanych obiektów technicznych [8].

Wyróżniającą cechą konstruowania modułowego jest możliwość tworzenia wariantów konstrukcji dostosowanych do określonych wymogów (wytwarzania, eksploatacji itp.). Istnieje kilka wariantów tworzenia zbiorów wariantów konstrukcji: podziału na sekcje, budowy składanej, zespołu podstawowego [3].

Konstruowanie modułowe ma wiele zalet. Pozwala ono na [3,8]:

- konstruowanie wariantów w oparciu konstrukcje poszczególnych modułów jak również ich typoszeregów,
- wykorzystanie w procesie konstruowania parametrycznych modeli CAD.

Na etapie wytwarzania modułowość konstrukcji daje możliwość zastosowania modułu wytwarzanego przez jednego z wielu konkurujących ze sobą zewnętrznych, wyspecjalizowanych dostawców [8].

W procesie eksploatacji umożliwia [4,7]:

- poprzez wymianę modułów
    - rozszerzenie funkcjonalności obiektu (np. maszyny),
    - dostosowanie parametrów obiektu do potrzeb eksploatacyjnych,
    - łatwe usuwanie awarii.
- z punktu widzenia diagnostyki można prowadzić pomiary stanu maszyny na poziomie modułu.

2. Obiekt badań

Mieszadła zanurzalne są to urządzenia, których postać konstrukcyjna pozwala na nieprzerwaną pracę w pełnym zanurzeniu w otaczającej cieczy. Z uwagi na swoje możliwości pracy, mieszadła zanurzalne znalazły szerokie zastosowanie w wielu gałęziach przemysłu, a w szczególności w sektorze gospodarki odpadami, gdzie doskonale sprawdzają się jako urządzenia wspomagające różnego rodzaju procesy technologiczne [5].

Obecnie brakuje krajowych producentów urządzeń, a mieszadła zanurzalne produkowane są przez duże firmy zagraniczne m.in. na potrzeby oczyszczalni ścieków. Biorąc pod uwagę polskie realia gospodarowania odpadami są to urządzenia drogie w zakupie, eksploatacji oraz serwisie. Często są to rozwiązania kompaktowe, gdzie zwartość budowy w razie awarii wyklucza remont, generuje duże koszty lub zmusza użytkownika do kupna kompletnego nowego urządzenia. Postać ta ma swoje

uzasadnienie z uwagi na podobieństwo konstrukcyjne, zamienność części w wielu modelach urządzeniach, ale w szczególności we względach ekonomicznych produkcji wielkoseryjnej. Z tych samych względów biorąc pod uwagę produkcję jednostkową lub pod specjalne wymagania odbiorcy jest to rozwiązanie nieekonomiczne, niekonkurencyjne. Aby spełnić wymagania odbiorcy krajowego, urządzenia powinny być projektowane tak aby jego koszty wytworzenia, a tym samym cena rynkowa były akceptowalne przez rodzimego odbiorcę. Ponadto rozwiązanie konstrukcyjne powinno być opracowane tak, aby umożliwić wymianę części. Rozwiązaniem, które spełnia te wymagania jest budowa modułowa urządzenia.
Wolnoobrotowe mieszadła zanurzalne stosowane są głównie w komunalnych i przemysłowych oczyszczalniach ścieków, a także biogazowniach i stacjach uzdatniania wody. Ponadto urządzenia te wykorzystywane są w wielu innych gałęziach przemysłu, gdzie wymagana jest wymiana objętościowa cieczy pod jej powierzchnią z uwagi na uwarunkowania zabudowy (np. chłodziwa w wannach hartowniczych, zbiorniki magazynowe tłuszczy, zbiorniki popłuczyn budowlanych). Urządzenia te przeznaczone są do wprawiania w ruch wirowy cieczy z określoną prędkością potrzebną dla prawidłowego przebiegu, założonego procesu technologicznego, ujednorodniania jej składu, zapobiegania sedymentacji osadu na dnie zbiornika oraz nadawania jej określonego kierunku przepływu w otwartych zbiornikach, rowach czy kanałach recyrkulacyjnych. Innym zastosowaniem mieszadeł zanurzalnych jest intensyfikowanie zachodzących w cieczach procesów fizyko – chemicznych, w szczególności rozpuszczanie ciał stałych oraz gazów [2].

3. Przykład modułowej konstrukcji typoszeregu wolnoobrotowych mieszadeł zanurzalnych

3.1. Kryteria konstrukcji mieszadeł modułowych

Głównym czynnikiem decydującym o możliwości konkurowania z innymi producentami zagranicznymi jest podzielenie konstrukcji na moduły. Rozwiązanie takie pozwala wyeliminować omawiane wcześniej problemy dotyczące dostosowania do potrzeb klienta, wytwarzania i eksploatacji.

Podstawowe założenia konstrukcyjne:

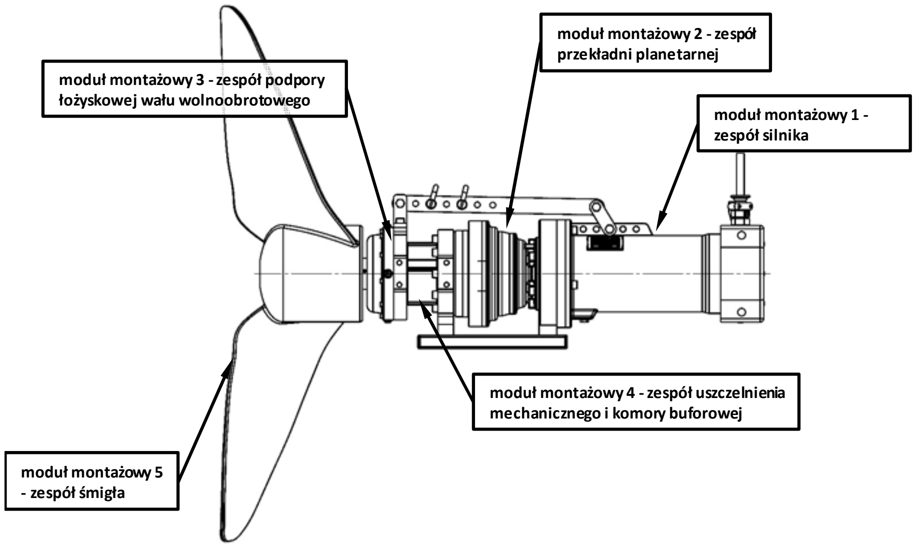
- budowa modułowa wg struktury wyrobu zgodnej z kryterium technologiczności montażu, przeprowadzania serwisu, przeglądów i remontów;
- wariantowość budowy uwzględniająca możliwość zabudowy silnika elektrycznego przeznaczonego do pracy w strefie zagrożenia wybuchem jak i do pracy poza strefą;
- możliwość remontowania wybranych modułów urządzenia;
- zastosowanie komory olejowej z zabudowanym uszczelnieniem czołowym mechanicznym oraz czujnikiem zawilgocenia chroniące część mechaniczną przed przeciekami i uszkodzeniem.

Według przedstawionych założeń zaproponowano konstrukcję modułową w której wyodrębniono 5 modułów:

1. moduł montażowy 1 -zespół silnika;

2. moduł montażowy 2 - zespół przekładni planetarnej;
3. moduł montażowy 3 - zespół podpory łożyskowej wału wolnoobrotowego;
4. moduł montażowy 4 - zespół uszczelnienia mechanicznego i komory buforowej;
5. moduł montażowy 5 - zespół śmigła;

Zaproponowane rozwiązanie struktury modułowej dla typoszeregu mieszadeł przedstawiono na rys. 1.

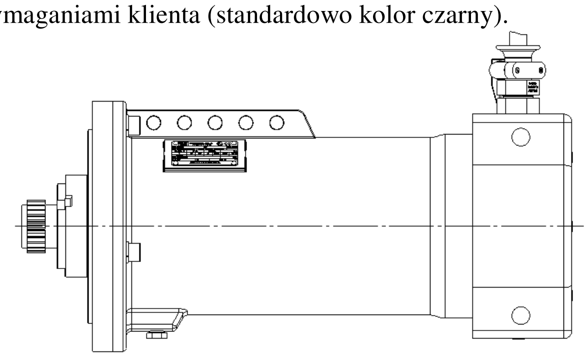


Rysunek 1. Rysunek poglądowy mieszadła wolnoobrotowego z przekładnią planetarną produkcji REDOR z podziałem na moduły konstrukcyjne (opracowanie własne)

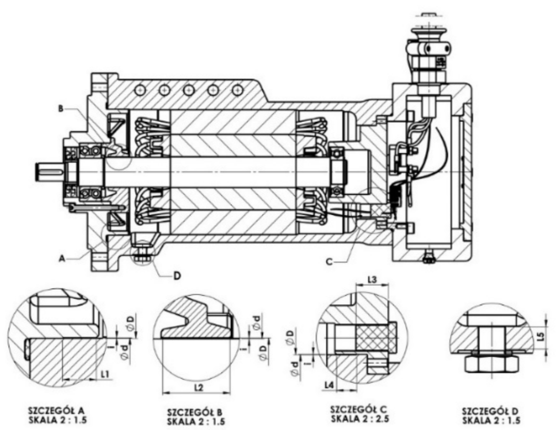
3.2. Moduł montażowy 1 - zespół silnika

Zanurzalne silniki przeciwwybuchowe typu EXS100L-…(wyk.) przeznaczone są do napędu mieszadeł zanurzalnych przeznaczonych do ujednorodniania zawartości komór fermentacyjnych biogazowni oraz w reaktorach biologicznych oczyszczalni ścieków. Przykład rozwiązania konstrukcyjnego na rys. 2. Są przewidziane wyłącznie do zabudowy w urządzeniach (mieszadłach zanurzalnych) i pracy w zanurzeniu. Silniki przeznaczone są do napędu urządzeń instalowanych w przestrzeniach zagrożonych wybuchem (strefach 1 lub 2), w których mogą powstać mieszaniny palnych gazów z powietrzem zaliczane do grupy IIB, klasy temperatury T4 lub niższej (maksymalna temperatura powierzchni silnika nie przekracza 135°C). Zapewniają wysoki stopień bezpieczeństwa – są urządzeniami kategorii 2G wg Dyrektywy 94/9/WE (ATEX). Silniki posiadają obudowę o stopniu ochrony IP68 wg PN-IEC 64-5:1998 i przeznaczone są do pracy ciągłej S1, w zanurzeniu do 10m w medium o temperaturze do 50°C [6].
Budowa i parametry eksploatacyjne

Kadłub, tarcza silnika, skrzynka zaciskowa dla wielkości mechanicznej 100, wykonane są z żeliwa szarego EN-GJL-200. Gniazdo łożyskowe strony przeciwnapędowej wykonane jest z żeliwa sferoidalnego EN-GJS-400-15. Uzwojenie stojana wykonane jest z miedzianego przewodu nawojowego w emalii. Elementy układu izolacyjnego odpowiadają klasie ciepło odporności F. Uzwojenia stojana są połączone w gwiazdę. W każdym z uzwojeniu zabudowano bimetaliczne czujniki temperatury typu S01 1505 (styki normalnie zamknięte, temperatura przełączania 150+/-5^{o}C). Czujniki połączono szeregowo. Klatka wirnika odlewana jest pod ciśnieniem z czystego aluminium. Wirnik jest dynamicznie wyważony łącznie z wpustem na wolnym czopie końcowym wału i osadzony w tarczy silnika (tarcza z gniazdem łożyskowym strony napędowej) i gnieździe łożyskowym tylnym (strona przeciwnapędowa) za pomocą dwóch łożysk kulkowych. Skrzynka zaciskowa posiada jeden otwór do zamontowania certyfikowanej dławnicy kablowej, tabliczkę zaciskową 6-cio torową z bezobrotowym złączem śrubowym, (do której podłączone są wyprowadzenia faz uzwojenia), zacisk uziemiający, bezobrotową listwę zaciskową do podłączenia czujników temperatury oraz dwa izolatory przepustowe wielożyłowe w gnieździe tylnym (rys. 3). Podczas pracy silnik chłodzony jest otaczającą go cieczą. Silniki zabezpieczone są antykorozyjnie wg instrukcji technologicznej farbą podkładową, a następnie farbą wierzchnią (EPINOX 77, lub odpowiednik) w kolorze zgodnym z wymaganiami klienta (standardowo kolor czarny).



Rysunek 2. Moduł silnika elektrycznego (opracowanie własne)



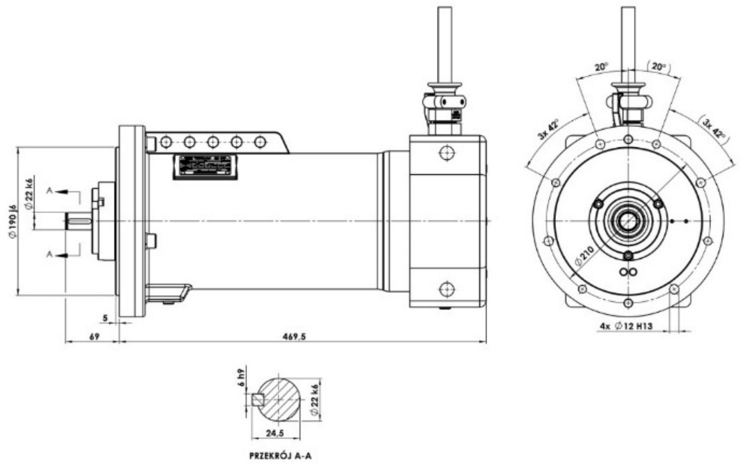
Rysunek 3. Rozmieszczenie złączy ognioszczelnych (opracowanie własne)

Tabela 1. Parametry eksploatacyjne silników [6]

Typ silnika	P_n	M_n	n_n	η_n	$\cos\varphi_n$	I_{1n} Przy nap. znam.		m_{rn}	i_{rn}	m_{maxn}	J
	kW	Nm	min^{-1}	%	-	A_{380V}	A_{400V}	%	%	%	kgm^2
2p=4, ns=1500 obr/min											
EXS100L-4A	1,1	7,3	1435	78,1	0,82	2,6	2,5	265	680	340	0,0058
EXS100L-4B	1,5	10,0	1430	79,4	0,83	3,5	3,3	245	625	275	0,0065
EXS100L-4P	2,2	14,7	1430	81,7	0,84	4,9	4,6	240	635	280	0,0067
EXS100L-P4A	3,5	23,6	1415	80,0	0,82	8,1	7,7	250	600	270	0,0067
EXS100L-P4B	**4,0**	**26,8**	**1425**	**80,8**	**0,80**	**9,4**	**8,9**	**285**	**660**	**320**	**0,0067**
2p=6, ns=1000obr/min											
EXS100L-6	1,1	10,9	960	73,3	0,69	3,3	3,1	190	520	290	0,0090
EXS100L-6 P	**1,5**	**15,2**	**945**	**76,7**	**0,73**	**4,1**	**3,9**	**190**	**460**	**230**	**0,0090**
EXS100L-P6A	2,2	22,6	930	72,4	0,74	6,2	5,9	190	420	220	0,0090
EXS100L-P6B	3,0	30,6	935	74,9	0,72	8,5	8,0	220	470	250	0,0142
2p=8, ns=750obr/min											
EXS100L-8B	1,1	14,9	705	72,2	0,65	3,6	3,4	160	360	190	0,0100

Tabela 2. Charakterystyka wykonania silników EXS100L [6]

Rodzaj pracy	S1
Klasa izolacji	F
Stopień ochrony	IP68
Zakres temperatury	0-50°C
Głębokość instalowania	10m (ciśnienie hydrostatyczne 1bar)
Materiał kadłuba	Żeliwo szare
Wielkość mechaniczna	100
Materiał tarcz łożyskowych	Żeliwo sferoidalne
Zabezpieczenie termiczne	3 termokontakty w każdym z uzwojeń
System chłodzenia	Własny (opływająca ciecz)
Tabliczka zaciskowa	6 zacisków do podłączenia uzwojeń, zacisk ochronny i 2 zaciski czujników temperatury
Łożyska	kulkowe kryte
Ilość wpustów kablowych	1
Malowanie	EPINOX 77 kolor czarny



Rysunek 4. Wymiary przyłączeniowe silnika EXS100L, wykonanie dla mieszadeł z przekładnią (opracowanie własne)

3.3. Moduł montażowy 2. - zespół przekładni planetarnej

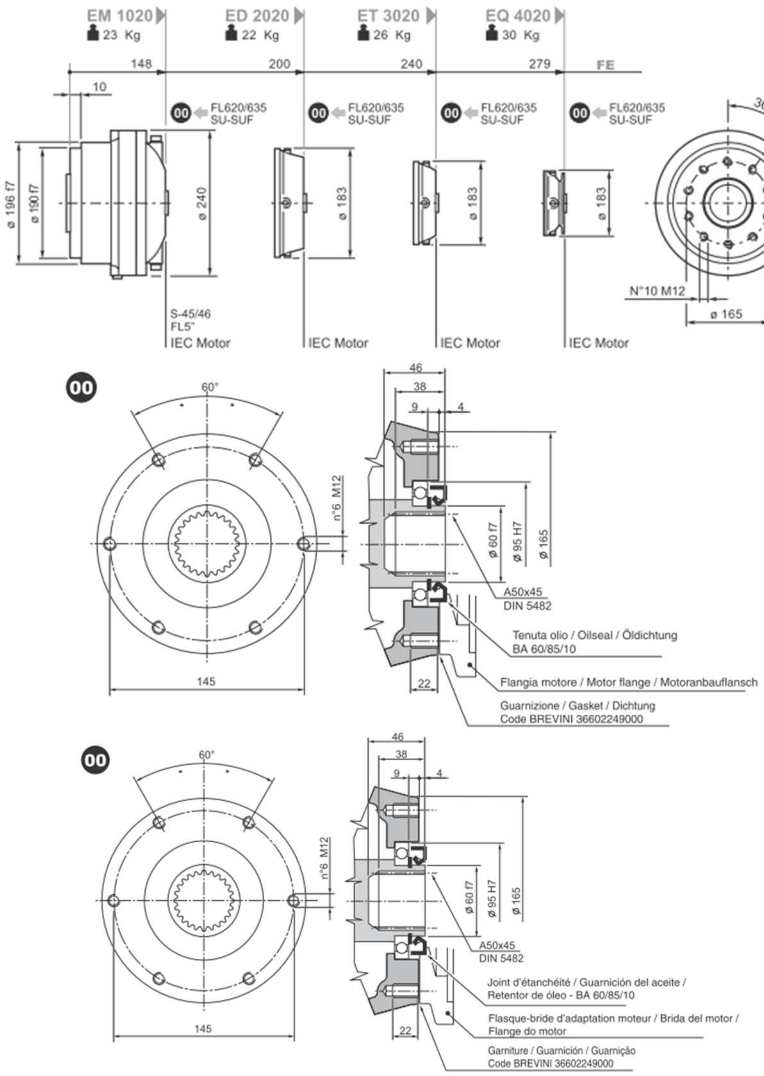
Adaptacja katalogowej przekładni planetarnej do warunków pracy w zanurzeniu polega na wymianie elementów złącznych typu śruby na wykonane ze stali kwasoodpornej typu 18/10, zastąpienie oleju mineralnego specjalnym olejem syntetycznym niewymagającym odpowietrzenia przekładni oraz zastąpienie odpowietrzników i korków, korkami ze stali kwasoodpornej typu 18/10. Każda przekładnia po adaptacji powinna być sprawdzona na szczelność w zbiorniku z wodą poprzez doprowadzenie do jej wnętrza ciśnieni 0,5 bar. Przekładnie planetarną można dobrać na z rozwiązań katalogowych różnych firm. Przykład wariantów konstrukcyjnych tego modułu przedstawiono na rys. 5.

3.4. Moduł montażowy 3 - zespół podpory łożyskowej wału wolnoobrotowego, 4 – zespół uszczelnienia mechanicznego i komory buforowej

Budowa podpory łożyskowej z komorą buforową zapewnia przeniesienie wszystkich sił generowanych przez zespół śmigła i na przekładnię planetarną przenoszony jest tylko moment obrotowy. Komora buforowa zabezpiecza przekładnię planetarną i pośrednio silnik przed przedostaniem się wody a pojawienie się wody w komorze buforowej jest sygnalizowane poprzez zabudowany w niej czujnik wilgotności. Rysunek 6 przedstawia schemat tych modułów.

3.5. Moduł montażowy 5 - zespół śmigła

Śmigło stosowane w 2 wariantach: ze śmigłami ze stali kwasoodpornej oraz z tworzywa sztucznego.



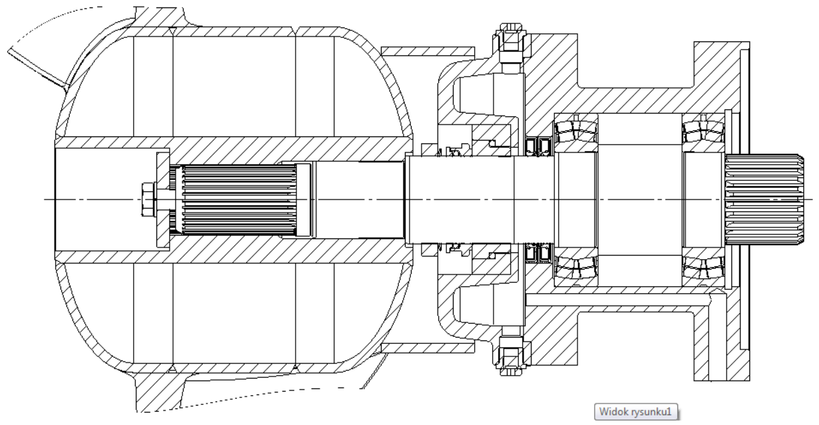
Rysunek 5. Moduł przekładni planetarnej [1]

4. Podsumowanie

Zalety opracowanego i wdrożonego do produkcji rozwiązania konstrukcyjnego

1. Poprzez możliwość zabudowy silnika przeciwwybuchowego, możliwość aplikacji do pracy w strefach zagrożonych wybuchem np. niektóre zastosowania w biogazowniach.

2. Budowa modułowa umożliwia zakup przez klienta zespołów zapasowych w postaci modułów do samodzielnego montażu (np. w przypadku awarii łożysk w podporze łożyskowej można wymienić cały moduł podpory a uszkodzony oddać do remontu.
3. Zgodnie z punktem 2 zostały zminimalizowane czasy przestojów mieszadeł w przypadku awarii.
4. Możliwość produkcji „na magazyn” zespołów w postaci modułów serwisowo – montażowych a nie tylko pojedynczych części lub zespołów niższego rzędu.
5. Skrócenie i ułatwienie montażu poprzez montaż końcowy bazujący na pobieraniu z magazynu całych modułów.



Rysunek 6. Moduły (od lewej) połączenie wielowypustowe wirnika z wałem, komora olejowa, korpus łożyskowy wału wolnoobrotowego (opracowanie własne)

Na podstawie założonych kryteriów konstrukcyjnych powstała modułowa konstrukcja spełniająca wymogi stawiane przez odbiorców jak założenia produkcyjno-eksploatacyjne (rys. 7).

Dalszym etapem badań będzie analiza kosztowa wariantów wytwarzania np. na podstawie analizy make-or-buy, która narzuci konieczność predykcji kosztów wytwarzania różnych wariantów rozwiązań konstrukcyjnych dla tego wyrobu.

Metoda ta może odpowiedzieć na pytanie czy w danej sytuacji przedsiębiorstwo dysponuje odpowiednimi zasobami wytwórczymi czy finansowymi, aby podjąć produkcję danego modułu czy znaleźć odpowiednik na rynku. Przykładami takich modułów są moduł silnika czy przekładni planetarnej, gdzie analizowane przedsiębiorstwo ma potencjał wytwórczy, ale ze względu na skale produkcji jego wyroby mogą być dużo bardziej kosztochłonne niż zakupione u wyspecjalizowanych wytwórców.

Rysunek 7. Wolnoobrotowe mieszadło zanurzalne – wyrób gotowy (opracowanie własne)

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BADANIA NIENISZCZĄCE ODLEWÓW ZE STOPÓW ALUMINIUM

Streszczenie: W pracy przedstawiono wybrane metody badań nieniszczących odlewów ze stopów aluminium, które umożliwiają już na wczesnym etapie produkcyjnym wykrywanie i identyfikowanie wad kształtu, struktury czy też ciągłości odlewów. Przedstawiono wyniki badań odlewów korpusów silnika metodą wizualną z wykorzystaniem penetrantów, jak również defektoskopię rentgenowską RTG oraz pomiar zgodności wymiarowej z wykorzystaniem skanera 3D.

Słowa kluczowe: wady odlewnicze, badania nieniszczące odlewów, metoda penetracyjna, defektoskopia rentgenowska, skanowanie 3D

NON-DESTRUCTIVE TESTING OF CASTINGS MADE OF ALUMINUM ALLOYS

Summary: The research presents selected methods of non-destructive testing for castings made of aluminum alloys, which allow for detection and identification defects in shape, structure or continuity of castings, on early production stage. In the paper showed results of examining engine blocks with use of visual method with application of penetrants, as well as X-ray flaw detection and measurement of dimensional conformity according to 3D scan.

1. Wprowadzenie

Producenci samochodów optymalizując swoje konstrukcje pod kątem masy i wytrzymałości, już na etapie projektowania decydują się coraz częściej na zastąpienie stali jako materiału wyjściowego stopami aluminium. Metal ten, w połączeniu z innymi pierwiastkami tworzy stopy charakteryzujące się wysoką wytrzymałością, małą gęstością oraz dużą odpornością na korozję. Te cechy

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sprawiają, że aluminium to materiał idealnie nadający się na odlewy niektórych części samochodów [1].
Obecnie ze stopów aluminium nie wykonuje się jedynie bloków i głowic silników, obudów skrzyń biegów czy sprzęgieł, lecz również obudowy amortyzatorów, podłużnice, wsporniki czy elementy pośrednie. Coraz częściej spotyka się również duże fragmenty karoserii w całości wykonane ze stopów aluminium. Części te za sprawą swojej wysokiej podatności na pękanie, a także stopień skomplikowania kształtu nie mogą być uzyskiwane w procesach tłoczenia. Wykonuje się w procesach grawitacyjnego lub wysokociśnieniowego odlewania. W przyszłości przewiduje się utrzymanie trendu dalszego wypierania stali z konstrukcji samochodów na rzecz elementów wykonywanych ze stopów aluminium oraz kompozytów z jego udziałem. Jako, że sektor „automotive" jest jedną z najprężniej rozwijających się gałęzi przemysłu, odlewy należą obecnie do najliczniej spotykanych elementów wyjściowych i półfabrykatów dla produkcji małoseryjnej, wielkoseryjnej i masowej. Ciągły wzrost produkcji, a także coraz bardziej restrykcyjne wymagania związane z mechanicznymi oraz technologicznymi właściwościami wymuszają prowadzenie badań nad rozwojem nie tylko technologii samego odlewania, ale i nowoczesnych metod szybkiej weryfikacji jakości wyrobów. Główny nacisk kładzie się w tym przypadku na badania nieniszczące [4, 8].

2. Wymagania stawiane odlewom

Ciągłe „odchudzanie" konstrukcji samochodów przez ich producentów powoduje wzrost oczekiwań w stosunku do odlewów i koniecznych do spełnienia norm. Normy te wyznacza się na podstawie porozumienia pomiędzy dostawcą i odbiorcą odlewów. Dotyczą one przede wszystkim części bardzo wytężonych, pracujących pod dużym obciążeniem, lub też narażonych na działanie wysokich temperatur takich jak głowice czy korpusy silników. Wymagania specjalnych norm muszą również spełniać elementy podatne na zmianę kształtu nawet przy niedużych obciążeniach mechanicznych jak choćby podłużnice i fragmenty karoserii [9, 14].
Niezależnie jednak od typu części, funkcji i jej przeznaczenia, każdy odlew wykonany ze stopu aluminium musi spełniać przede wszystkim normy jakościowe dotyczące parametrów wytrzymałościowych, takich jak: wytrzymałość na rozciąganie Rm, wytrzymałość na ściskanie Rc, oraz zginanie Rg, a także udarność Kc [11].
Normami określony jest również stan powierzchni i ciągłości struktury odlewu. Niedopuszczalne są widoczne na powierzchni zewnętrznej zawirowania strugi metalu oraz pęknięcia. Bardzo ważne jest również zachowanie odpowiedniej tolerancji kształtu profilu, a także innych tolerancji rysunkowych zawartych w dokumentacji odlewu surowego, w szczególności dotyczących naddatków na późniejszą obróbkę.
Wymaganiom klienta podlega również wykorzystywany stop odlewniczy, choć ten w większości przypadków założony jest odgórnie i dopuszcza się jedynie niewielką ingerencję jego skład, jego modyfikacja musi być niezwłocznie zgłoszona. Normami określa się również dopuszczalną ilość złomu odlewniczego zawartego w przetopionym stopie. Wykorzystane dodatki stopowe, ich udział procentowy oraz parametry procesu odlewania stanowią o know-how odlewni i są objęte tajemnicą [9, 13].

Każdy produkt ma także określoną ilość dopuszczalnych wtrąceń niemetalicznych, wielkość porowatości i skurczy. Niedopuszczalna jest jednak ich obecność w strefach poddawanych późniejszej obróbce skrawaniem.
Warto również nadmienić, że w zależności od klienta odlewni, norm i wymogów koniecznych do spełnienia jest mniej lub więcej, są one również w mniejszym lub większym stopniu restrykcyjne.

3. Badania własne typowych wad odlewniczych

Najczęściej napotykane wady odlewnicze można podzielić na kilka zasadniczych grup.
Pierwszą z nich jest grupa wad powierzchniowych. Zalicza się do niej przede wszystkim fałdy (rys. 1), nadmierną chropowatość (rys.2), wżery, rysy, porowatość, fałdy, zawirowania i „zagotowania", wgniecenia oraz różnego rodzaju naloty pochodzenia metalicznego lub organicznego.

Rysunek 1. Fałdy na powierzchni odlewu [9]

Rysunek 2. Nadmierna chropowatość [9]

Wady odlewnicze z tej grupy wykrywa się w większości praktycznie już na etapie kontroli wstępnej, gdzie wizualnej weryfikacji dokonuje odlewnik w asyście

kontrolera jakości. Do oceny stanu powierzchni wykorzystuje się również mikroskopy oraz sprawdziany kontrolno-pomiarowe.
Kolejną grupę wad odlewniczych stanowią wady ciągłości, a wśród nich pęknięcia powierzchniowe (rys. 3) i wewnętrzne lub też naderwania. Podobnie jak w przypadku wad powierzchniowych, powodem ich powstawania przede wszystkim jest częściowe lub całkowite zużycie formy wtryskowej, a w szczególności wkładów formujących profil, brak lub nieprawidłowe wykonanie pasowania wkładów, nieprawidłowe odprowadzenie powietrza z wolnej przestrzeni przez pompy próżniowe, źle dobrane parametry chłodzenia lub wtrysku, a także pozostałości smaru na elementach profilowych w trakcie cyklu wtrysku. Wady te możliwe są do wykrycia również przez kontrolę wizualną bez, lub z wykorzystaniem środków penetrujących [2, 11].

Rysunek 3. Pęknięcia na powierzchni odlewu [9]

Producent musi zadbać również o spełnienie norm dotyczących kształtu profilu i jakości jego odwzorowania, a także o jego zgodność z modelem wzorcowym.

Rysunek 4. Wyraźny niedolew w obrębie otworu [9]

Do najczęściej spotykanych wad kształtu zalicza się wystąpienie uszkodzenia mechanicznego, brak zachowania tolerancji kształtu i zgodności wymiarowej z modelem, powstawanie zalewek na podziałach elementów formujących, obecność niedolewów (rys. 4), czy też przestawienie osiowe elementów formujących. Wady te

w większości są trudne do oceny wizualnej, dlatego do wykrywania tych defektów wykorzystuje się pomiary na maszynach współrzędnościowych, pomiary skanerami 3D, czy też sprawdziany kontrolno-pomiarowe. Stosuje się również wyrywkowe kontrole szczelności odlewu poprzez zanurzanie odlewów w wodzie i ocenę ewentualnych nieszczelności poprzez przepuszczanie przez odlew strumienia powietrza [13, 14].
Najważniejszą grupą wad odlewniczych spotykanych w odlewach aluminiowych są tzw. defekty wewnętrzne. Zalicza się do nich przede wszystkich pęcherze i bąble powietrzne, sitowatość, obecność jam skurczowych (rys. 5) oraz porowatość (rys. 6)

Rysunek 5. Widoczny wyraźny skurcz odlewniczy [9]

Rysunek 6. Znaczna porowatość [9]

Ilość wad wewnętrznych odlewu zależy w głównej mierze od czynników takich jak parametry wtrysku, szybkość krzepnięcia, chłodzenia, prędkości przepływu strugi, sekwencji pracy formy, zastosowanego typu i ilości smaru, pracy pompy próżniowej, charakterystyki pracy tłoka oraz wielu innych parametrów. Wady te możliwe są do identyfikacji między innymi przez zastosowanie inspekcji promieniami rentgenowskimi wykonywanej wyrywkowo lub dla każdej wyprodukowanego odlewu, a także dzięki analizie makrostruktury prowadzonej na zgładach metalograficznych [1, 4].

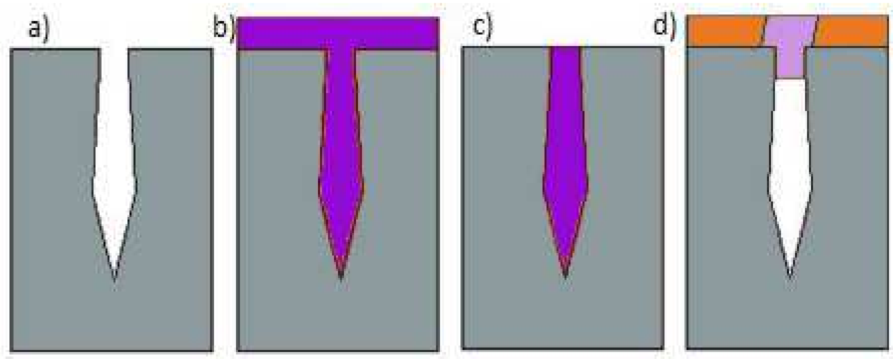
Celem przeprowadzonych badań było przeprowadzeniu testów i ocena jakości odlewu bloku silnika, wykonanego ze stopu AlSi9Cu3(Fe), pod kątem wystąpienia w nim typowych wad odlewniczych. W niniejszej pracy szczególną uwagę poświęcono wykrywaniu wad z grup powierzchniowych oraz wewnętrznych z wykorzystaniem defektoskopii rentgenowskiej, skanowania 3D oraz metody wizualnej z wykorzystaniem penetrantów.

4. Badania nieniszczące odlewu bloku silnika ze stopu aluminium

Obecnie najczęściej do oceny jakości wytworzonego produktu, o ile pozwalają na to warunki badań i charakter oraz postać spodziewanego defektu, stosuje się tak zwane badania nieniszczące.
Można je stosować w kilku obszarach produkcji - od fazy projektowej na prototypach i podczas produkcji próbnej, poprzez kontrole międzyoperacyjne i ostateczne a także weryfikację materiałów wyjściowych, aż po okresowe przeglądy i remonty.
Dzięki swoim licznym zaletom, badania nieniszczące (NDT) znalazły szerokie zastosowanie w produkcji masowej, w tym w branży odlewnictwa ciśnieniowego i kokilowego stopów aluminium. Umożliwiają one szybką i precyzyjną weryfikację jakości odlewów dając tym samym możliwość szybkiej interwencji w przypadku wykrycia defektu, co minimalizuje tym samym ryzyko wysłania wadliwej sztuki odlewu do klienta [7].
W ramach badań wykonano testy korpusu silnika benzynowego metodą penetracyjną, radiologiczną oraz najbardziej nowoczesną – pomiarem z wykorzystaniem skanera 3D.

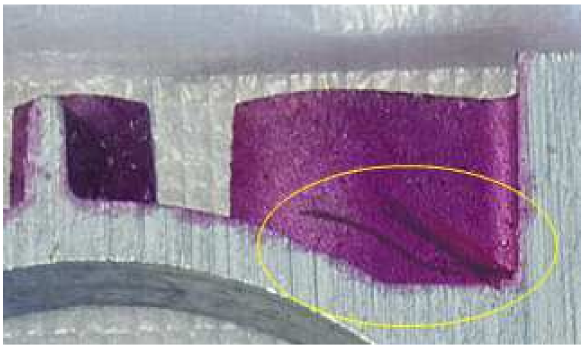
4.1. Metoda wizualna z wykorzystaniem penetrantów

Badania penetracyjne są najstarszą metodą badań NDT. Podstawową zaletą przeprowadzania tego typu badań jest prosty, lekki i niewymagający dużego wysiłku w zastosowaniu sprzęt, a także skuteczność oceny wskazań. Metoda ta umożliwia wykrywanie wad szczelinowych o małych wymiarach nawet do 0,001mm. Do zalet należy również zaliczyć możliwość jej stosowania nawet w warunkach warsztatowych, czyli na przykład w pobliżu maszyny odlewniczej. Do wad tej metody zaliczyć trzeba jednak konieczność wcześniejszego przygotowania powierzchni, a także ograniczenia zastosowania w podwyższonej temperaturze. Należy zadbać, by temperatura badanego przedmiotu była zbliżona do temperatury otoczenia [6, 8].
Badanie metodą penetracyjną przeprowadza się według schematu przedstawionego na rys. 7. Pierwszy etap polega na oczyszczeniu powierzchni oraz wnikaniu w głąb materiału płynu, tzw. penetrantu, który charakteryzuje się wysoką zwilżalnością względem badanego materiału. Kolejnym etapem jest użycie zmywacza, który stosujemy w celu usunięcia nadmiaru penetrantu i tym samym przygotowania podłoża do przeprowadzenia ostatniego etapu, którym jest naniesienie wywoływacza. Jest to płyn, który kontrastowo ujawnia usytuowanie i wielkość nieciągłości [6, 7].



Rysunek 7. Schemat przebiegu badań penetracyjnych [7]

W ramach pracy przeprowadzono badanie metodą penetracyjną na fragmencie wycinku przekrojonego odlewu korpusu silnika. Na rysunku 8 przedstawiono wadę powierzchniową w formie rys występujących na powierzchni analizowanego elementu. Jak można zauważyć, penetrant w miejscach rys ma znacznie ciemniejszą barwę.

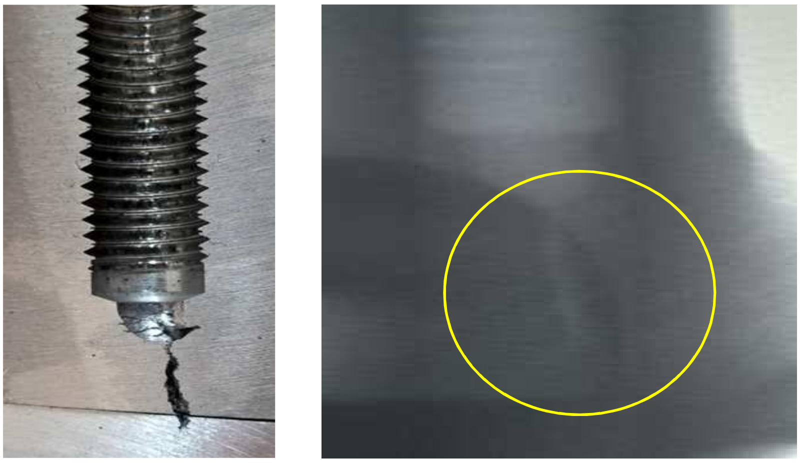


Rysunek 8. Rysa powierzchniowa ujawniona w wyniku badań penetracyjnych [9]

Do badania wykorzystano technikę barwną, ponieważ pozwala ona na osiągnięcie bardzo dużej czułości, a same wady są bardzo dobrze widoczne.

4.2. Defektoskopia rentgenowska

osłabienia promieniowania jonizującego przechodzącego przez badany materiał. Powszechnie w przemyśle odlewniczym stosuje się promieniowanie rentgenowskie (zwane również promieniami X) [15].
Metoda ta jest obecnie bardzo powszechnie stosowana w odlewniach aluminium, ponieważ pozwala nie tylko na bardzo skuteczne wykrywanie nawet najmniejszych wad na powierzchni odlewu, lecz przede wszystkim wszelkich wewnętrznych nieciągłości materiału takich jak: pory, sitowatość, zawirowania metalu oraz jamy skurczowe [5, 10, 11, 12].



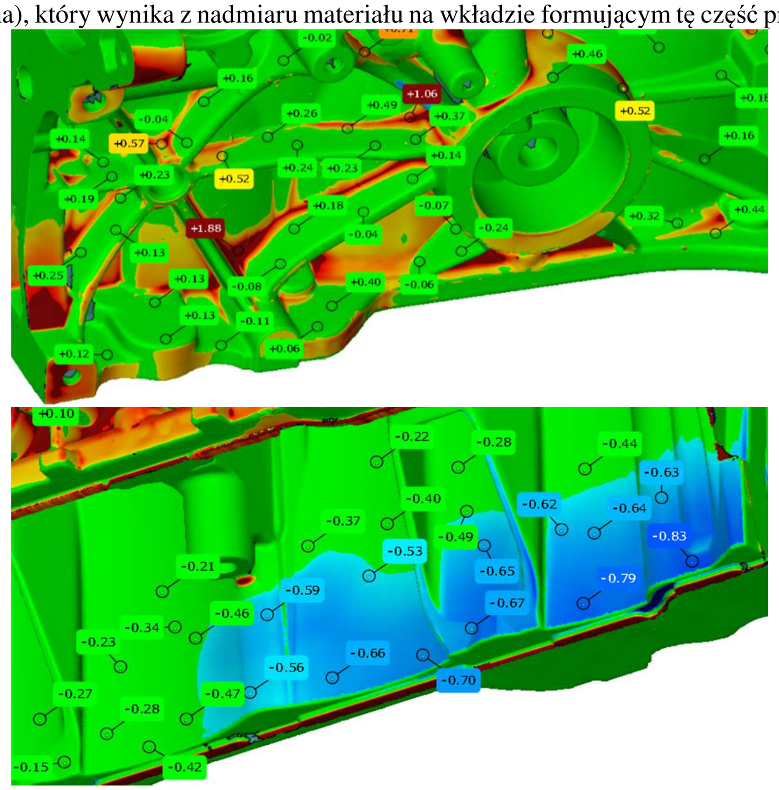
Rysunek 9. Wada w postaci jamy skurczowej: a) analizowany element, b) obraz uzyskany podczas inspekcji rentgenowskiej z zaznaczonym obszarem występowania wady [9]

Przykładowa jama skurczowa wykryta dzięki badaniu promieniami rentgena przedstawiono na rys. 9a. Na zdjęciu z prawej strony (rys. 9b) widać wyraźnie, że jama skurczowa stanowi ciemniejszy obszar na obrazie. Mamy tutaj do czynienia z dość dużą jamą skurczową o długości około 10mm a szerokości 3mm. Metoda rentgenowska pozwala jednak na wykrywanie nawet znacznie mniejszych defektów materiałów.

4.3. Metoda pomiaru kształtu z wykorzystaniem skanera 3D

Ostatnią z zastosowanych metod badań jest metoda pomiaru tolerancji kształtu z wykorzystaniem nowoczesnego skanera 3D.
Metoda ta wymaga, aby przed przystąpieniem do pomiaru odpowiednio przygotować badany element. Najpierw należy dokładnie osuszyć obiekt i pokryć go specjalnym środkiem, którego głównym zadaniem jest zmatowienie skanowanych powierzchni, a przez to zniwelowanie wpływu rozproszenia promieni świetlnych na wynik pomiaru. Następnie na badany obiekt nakleja się szereg punktowych znaczników, których położenie w przestrzeni trójwymiarowej mierzy skaner. Im więcej punktów pomiarowych, tym uzyskany obraz jest dokładniejszy ale czas pomiaru znacznie się wydłuża. Dlatego ważna jest intuicja operatora, ponieważ pozwala ona na uzyskanie kompromisu pomiędzy dokładnością uzyskanych wyników a czasem wykonywania pomiaru. Po określeniu położenia wszystkich punktów charakterystycznych z powierzchni obiektu badanego, następuje przesłanie zebranych danych do komputera gdzie specjalne oprogramowanie tworzy na ich podstawie model trójwymiarowy przedmiotu. Po nałożeniu zmierzonego elementu na wzorcowy model przestrzenny, program pozwala na uzyskanie mapy tolerancji kształtu (rys. 10). Odpowiednie wartości różnic wymiarowych są oznaczane kolorami [3, 6, 8].
Przyjmuje się, że jeżeli fragment odlewu mieści się w zakresie tolerancji kształtu (±0,5mm), to obszar ten jest oznaczany kolorem zielonym. Odcieniami barwy

niebieskiej oznaczone są miejsca, gdzie występuje ubytek materiału (odchyłka ujemna), który wynika z nadmiaru materiału na wkładzie formującym tę część profilu.



Rysunek 10. Mapa tolerancji kształtu z zaznaczonymi odchyłkami wymiarowymi pomiędzy odlewem rzeczywistym a modelem matematycznym [9]

Kolorami pomarańczowym, czerwonym oraz brązowym o różnym nasyceniu, oznaczane są z kolei odchyłki dodatnie, które są na przykład wynikiem niedostatku materiału na części formującej te fragmenty odlewu. Wady kształtu, zarówno ujemne jak i dodatnie, mogą też być powodowane złą sekwencją zamykania i otwierania formy odlewniczej, a także źle dobranymi parametrami wtrysku i krzepnięcia metalu. Obecnie w przemyśle odlewniczym pomiarom 3D poddaje się nie tylko same odlewy ale i części formujące profil, wspomagające lub też elementy, które uległy uszkodzeniu w eksploatacji, w celu odtworzenia ich pierwotnych kształtów i funkcji.

5. Podsumowanie

Na potrzeby badawcze przeprowadzono analizę kilku odlewów ciśnieniowych korpusu silnika benzynowego, wykonanych ze stopu odlewniczego aluminium AlSi9Cu3(Fe), pod kątem ewentualnego wystąpienia w nich typowych wad odlewniczych takich jak: niezgodność wymiarowa z modelem matematycznym, porowatość, obecność jam skurczowych czy też pęknięć i rys na powierzchni zewnętrznej, a także nadmiernej chropowatości i zawirowań strugi metalu.

Do oceny jakości i stanu odlewów zastosowano kilka metod, a w tym: metodę penetracyjną używając penetrantu w barwie fioletu wraz z wywoływaczem, metodę radiograficzną przy pomocy aparatu rentgenowskiego, a także dokonano weryfikacji zgodności profilu odlewu, wykorzystując w tym celu nowoczesny skaner 3D.
Dzięki zastosowanym metodom udało się wykryć w badanych odlewach kilka rys oraz pęknięć powierzchniowych, głównie w zagłębieniach i wnękach. Ponadto dzięki zastosowaniu aparatu rentgenowskiego udało się zidentyfikować parę znacznych jam skurczowych w niektórych z badanych sztuk. Badanie skanerem trójwymiarowym potwierdziło z kolei niewielkie błędy wymiarowe na profilach odlewów, które przekroczyły założoną, dopuszczalną tolerancję kształtu.

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ALGORYTM ANALIZY CZASOWO-CZĘSTOTLIWOŚCIOWEJ SYGNAŁÓW Z WYKORZYSTANIEM ORTONORMALNYCH BAZ FALKOWYCH DAUBECHIES

Streszczenie: W artykule opisano algorytm dekompozycji sygnałów niestacjonarnych pod kątem analizy czasowo-częstotliwościowej, w którym wykorzystano ortonormalne bazy falkowe Daubechies. Przedstawiono krótko problem analizy czasowo-częstotliwościowej oraz konstrukcję ortonormalnych baz falkowych i zależności wykorzystane przy tworzeniu algorytmu. Na końcu zaprezentowano sam algorytm i wynik dekompozycji przykładowych sygnałów.

Słowa kluczowe: Analiza czasowo-częstotliwościowa, dyskretna transformacja falkowa, falki Daubechies

ALGORITHM OF TIME-FREQUENCY ANALYSIS USING DAUBECHIES ORTHONORMAL WAVELET BASES

Summary: In this paper, the algorithm of decomposition of non-stationary signals in terms of time-frequency analysis using Daubechies orthonormal wavelet bases was presented. The time-frequency analysis problem and construction of orthonormal wavelet bases was shortly discussed as well as some mathematical dependencies, used during projecting of the algorithm. At the end, the algorithm was described and results of decomposition of some sample signals were presented.

Keywords: Time-frequency analysis, discrete wavelet transform, Daubechies wavelets

1. Wstęp

W niniejszym artykule przedstawiono projekt algorytmu analizy czasowo-częstotliwościowej sygnałów o charakterze niestacjonarnym, mający w zamierzeniu stanowić element składowy bardziej złożonego automatycznego systemu detekcji wad w połączeniach spawanych, z pomiarów wykonywanych za pomocą skanera ultradźwiękowego. W systemach diagnostycznych tego rodzaju, oprócz wykrywania

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nieprawidłowości, objawiających się fluktuacjami bądź skokowymi zmianami częstotliwości, istotne znaczenie ma także lokalizacja czasowa.
Większość metod analizy sygnałów opiera się na ich reprezentacji jako kombinacji liniowej odpowiednich sygnałów bazowych, tworzących bazę przestrzeni sygnałów danego typu. W istocie, każdy sygnał rzeczywisty x można interpretować jako funkcję rzeczywistą (mierzalną, całkowalną z kwadratem) na pewnym podzbiorze $A \subseteq \mathbb{R}$, czyli $x \in L_2(A)$ [1]. Można więc go zapisać jako kombinację liniową sygnłów bazowych e_k (1).

$$x(t) = \sum_k a_k e_k(t), \quad a_k \in \mathbb{R} \tag{1}$$

Najczęściej stosowaną metodą analizy sygnałów jest oczywiście analiza częstotliwościowa, w której wykorzystuje się bazę Fouriera zbudowaną z funkcji $\cos(k\omega_0 t)$ i $\sin(k\omega_0 t)$, gdzie ω_0 jest pewną pulsacją bazową. Jest to baza ortonormalna przestrzeni funkcji okresowych o okresie $T = 2\pi/\omega_0$. Uogólniając na przestrzeń zespoloną jego graniczny przypadek otrzymuje się całkowe przekształcenie zwane transformacją Fouriera (2), przypisujące sygnałowi x, jego widmo częstotliwościowe.

$$\mathcal{F}\{x\}(j\omega) = X(j\omega) = \int_A x(t)\exp(-j\omega t)\mathrm{d}t \tag{2}$$

Baza ta jest optymalna pod kątem badania sygnałów stacjonarnych, z uwagi na dobrą lokalizację częstotliwościową, nie jest jednak zlokalizowana w czasie [2]. W istocie, widmo częstotliwościowe sygnału nie dostarcza informacji na temat charakteru zmian częstotliwości w czasie. Aby taką informację uzyskać, konieczne jest stosowanie baz zlokalizowanych zarówno w czasie jak i częstotliwości. Spośród różnych baz zapewniających lokalizację czasowo-częstotliwościową, wyjątkowo korzystne własności mają bazy falkowe, złożone z funkcji postaci (3) [2].

$$\Psi_{a,k} = |a|^{-\frac{1}{2}}\Psi\left(\frac{t-k}{a}\right), \quad j,k \in \mathbb{Z} \tag{3}$$

Funkcje $\Psi(t)$, dla których rodzina (3) tworzy bazę $L_2(\mathbb{R})$ nazywa się właśnie falkami [2], $a \in \mathbb{R}$ jest współczynnikiem skali. Dla bazy falkowej, wraz ze wzrostem częstotliwości, maleje rozdzielczość częstotliwościowa, rośnie natomiast rozdzielczość czasowa. Dzięki temu możliwa jest zarówno dobra rozróżnialność składowych niskoczęstotliwościowych, jak i dobra lokalizacja czasowa składowych wysokoczęstotliwościowych badanych sygnałów [1]. Z bazą falkową związane jest przekształcenie całkowe nazywane ciągłą transformacją falkową (4) [2,3].

$$CWT\{x\}(a,k) = \tilde{x}(a,k) = \int_{\mathbb{R}} x(t)\overline{\Psi_{a,k}(t)}\mathrm{d}t \tag{4}$$

W kolejnych rozdziałach zostanie przedstawiony efektywny algorytm dekompozycji sygnałów dla falek generujących bazy ortonormalne $L_2(\mathbb{R})$, nie wykorzystujący wprost ogólnej postaci (5). Opiera się on na konstrukcji tzw. analizy wieloskalowej, związanej z falkami ortonormalnymi.

2. Konstrukcja ortonormalnych baz falkowych metodą analizy wieloskalowej

Formalnie analizę wieloskalową definiuje się jako ciąg domkniętych podprzestrzeni $V_j < L_2(\mathbb{R})$, spełniający warunki [1]:

a) $(V_j)_{j\in\mathbb{Z}}$ jest rosnącym ciągiem zbiorów, czyli ... $\subset V_{-1} \subset V_0 \subset V_1 \subset_{...}$
b) $\operatorname{span} \bigcup_{j\in\mathbb{Z}} V_j = L_2(\mathbb{R})$
c) $\bigcap_{j\in\mathbb{Z}} V_j = \{0\}$
d) $f(t) \in V_j \Leftrightarrow f(2^{-j}t) \in V_0$
e) $f(t) \in V_0 \Leftrightarrow \forall_{m\in\mathbb{Z}}\, f(t-m) \in V_0$
f) Istnieje funkcja $\Phi \in V_0$ nazywana funkcją skalującą taka, że zbiór $\{\Phi(t-k)\}_{k\in\mathbb{Z}}$ tworzy bazę ortonormalną V_0.

Korzystając z warunków d, e i f, dowodzi się [1], że jeśli układ $\{\Phi(t-k)\}_{k\in\mathbb{Z}}$ jest bazą ortonormalną V_0, to układ:

$$\left\{2^{j/2}\Phi(2^j t - k)\right\}_{k\in\mathbb{Z}} \tag{5}$$

jest bazą ortonormalną podprzestrzeni V_j. Stąd widać, że znalazłszy funkcję skalującą Φ, można skonstruować bazy kolejnych podprzestrzeni $V_j < L_2(\mathbb{R})$. Wprowadzając operator diadycznej dylatacji J_s: $L_2(\mathbb{R}) \to L_2(\mathbb{R})$ zadany wzorem (6)

$$J_s(f)(t) = f(2^s t) \tag{6}$$

można zapisać warunek d w alternatywnej postaci: $V_j = 2^{-j/2} J_{-j}(V_0)$.
Operator $2^{s/2}J_s$ jest unitarny (co więcej, jest izometrą na $L_2(\mathbb{R})$ [1], zatem zachowuje iloczyn skalarny w $L_2(\mathbb{R})$. W praktyce, dla sygnałów dyskretnych, jego działanie można interpretować jako decymację sygnału, w przypadku $s < 0$ i interpolację sygnału, gdy $s > 0$ (odpowiednio usuwanie co drugiej próbki i dublowanie każdej próbki sygnału). Oznacza to, że począwszy od pewnej podprzestrzeni V_k, można otrzymać bazy podprzestrzeni o niższych indeksach, poprzez decymację funkcji bazowych V_k. Z teorii przetwarzania sygnałów wiadomo, że decymacja ciągu próbek sygnału zdyskretyzowanego jest tożsama ze zmniejszeniem częstotliwości próbkowania tego sygnału, a co za tym idzie zawężeniem jego pasma częstotliwościowego [1]. Można więc wywnioskować, że podprzestrzenie V_j o wyższych indeksach będą zawierały sygnały o coraz szerszym zakresie częstotliwości.
Należy zauważyć, że podprzestrzenie V_j nie są wzajemnie ortonormalne ($V_j \subset V_{j+1}$), rodzina $\left\{\Phi_{j,k}\right\}_{j,k\in\mathbb{Z}}$ nie tworzy więc bazy ortonormalnej $L_2(\mathbb{R})$. Co więcej jest to baza nadmiarowa tej przestrzeni. Celem uzyskania bazy ortonormalnej wprowadza się ciąg podprzestrzeni (W_j) przestrzeni $L_2(\mathbb{R})$, spełniających warunek (7).

$$V_j \oplus W_j = V_{j+1} \tag{7}$$

Z warunków a i b definicji analizy wieloskalowej wynikają równości (8) i (9).

$$\bigoplus_{j\in\mathbb{Z}} W_j = L_2(\mathbb{R}) \tag{8}$$

$$\left(\bigoplus_{j=l}^{+\infty} W_j\right) \oplus V_l = L_2(\mathbb{R}) \tag{9}$$

Pozostaje teraz znaleźć funkcję $\Psi \in W_0$ taką, aby zbiór $\{\Psi(t-k)\}_{k\in\mathbb{Z}}$ był bazą ortonormalną podprzestrzeni W_0. Wtedy, na mocy równości (9) i warunku d z definicji analizy wieloskalowej, Ψ będzie falką, gdyż zbiór $\left\{\Psi_{j,k}\right\}_{j,k\in\mathbb{Z}}$ będzie bazą ortonormalną $L_2(\mathbb{R})$. Dodatkowo, z równości (9) wynika, że zbiór funkcji zadany wzorem (10) także będzie bazą ortonormalną $L_2(\mathbb{R})$.

$$\{\Psi_{jk}\}_{\substack{j\geq l, j\in\mathbb{Z} \\ k\in\mathbb{Z}}} \cup \{\Phi_{lk}\}_{k\in\mathbb{Z}} \tag{10}$$

Falka Ψ dla przyjętej analizy wieloskalowej jest zadana wyłącznie przez funkcję skalującą, zgodnie ze wzorem (11).

$$\begin{gathered} \Psi(t) = \sum_{k\in\mathbb{Z}} \overline{a_k}(-1)^k \Phi(2t+k+1) \\ a_k = \langle \Phi(t/2), \Phi(t-k) \rangle = \int_{\mathbb{R}} \Phi(t/2)\overline{\Phi(t-k)}\mathrm{d}t \end{gathered} \tag{11}$$

Wyprowadzenie wzoru (11) jest w całości przeprowadzone w książce [1] i z powodu jego znacznej złożoności zostało pominięte.

Pierwszą poznaną funkcją generującą ortonormalną bazę falkową była falka Haara zadana wzorem (12) [3].

$$H(t) = \begin{cases} 1 & \text{dla } t \in \left[0, \frac{1}{2}\right) \\ -1 & \text{dla } t \in \left[\frac{1}{2}, 1\right] \\ 0 & \text{poza tym} \end{cases} \tag{12}$$

Łatwo pokazać, że funkcją skalującą dla $H(t)$ jest funkcją okna prostokątnego (13).

$$\Phi^H(t) = \begin{cases} 1 & \text{dla } t \in [0,1] \\ 0 & \text{poza tym} \end{cases} \tag{13}$$

3. Interpretacja dyskretnych falek jako filtrów

Przyjmijmy bazę ortonormalną zadaną wzorem (10). Rozważmy rzeczywisty, mierzalny sygnał $x(t)$ zdyskretyzowany z okresem próbkowania T_p w postaci ciągu próbek $\left(x(nT_p)\right)_{n=0}^{N-1}$ o długości N. Współczynniki szeregu falkowego dla falek Ψ_{jk} i funkcji skalujących Φ_{0k} można otrzymać ze wzorów (14) i (15).

$$d^{j,k} = 2^{\frac{j}{2}} \sum_{n=0}^{N-1} x(nT_p)\Psi(2^j(nT_p - k)) \quad (j \geq l) \tag{14}$$

$$a^{l,k} = 2^{\frac{l}{2}} \sum_{n=0}^{N-1} x(nT_p)\Phi(2^l(nT_p - k)) \tag{15}$$

Współczynniki $d^{j,k}$ nazywa się detalami j-tego poziomu, natomiast $a^{l,k}$, aproksymacją l-tego poziomu. Sygnał x można zrekonstruować przy użyciu współczynników $d^{j,k}$ i $a^{l,k}$, według wzoru (16).

$$x(nT_p) = \sum_{j=l}^{+\infty} \sum_{k\in\mathbb{Z}} d^{j,k}\, \Psi_{j,k}(nT_p) + \sum_{k\in\mathbb{Z}} a^{l,k} \Phi_{l,k}(nT_p) \tag{16}$$

Sumy w równaniach (14) i (15) wyrażają sploty dyskretne sygnału x z sygnałami uzyskanymi przez odwrócenie kolejności próbek w ciągach $(\Psi_{j,k}(nT_p))_{n=0}^{N-1}$ i $(\Phi_{l,k}(nT_p))_{n=0}^{N-1}$. Tak otrzymane sygnały nazywamy falkami analizującymi i funkcjami skalującymi analizującymi i oznaczamy przez Ψ^{jk} i Φ^{lk}. Wtedy sygnały

Ψ_{jk} i Φ_{lk} określa się mianem falek i funkcji skalujących syntezujących [2]. Stosując powyższe oznaczenia można równania (14) i (15) zapisać w postaci (17) i (18).

$$d^{j,k} = x(nT_p) * \Psi^{j,k}(nT_p) \ \ (j \geq l) \tag{17}$$

$$a^{l,k} = x(nT_p) * \Phi^{l,k}(nT_p) \tag{18}$$

Analizujące falki i funkcje skalujące można zatem interpretować jako filtry o współczynnikach równych odpowiednio $\Psi^{jk}(nT_p)$ i $\Phi^{lk}(nT_p)$ [4]. Funkcja skalująca powinna mieć właściwości filtra dolnoprzepustowego – wzmacniać niskie częstotliwości i składową stałą oraz tłumić wyższe częstotliwości. Natomiast falki powinny wykazywać właściwości filtrów górnoprzepustowych. Dodatkowo, najlepszą lokalizację czasową bazy falkowej uzyskuje się, gdy są to filtry o skończonej odpowiedzi impulsowej (typu FIR) [3], czyli takie, których prawie wszystkie współczynniki są równe 0 [1]. Jedynymi, opisanymi w dostępnej literaturze, ortonormalnymi bazami falkowymi spełniającymi ten warunek są bazy generowane przez tzw. falki Daubechies [2, 3]. Szczególnym przypadkiem falki Daubechies jest falka Haara [2].

Przyjmijmy teraz bazę postaci (10) generowaną przez falkę Haara $H(t)$ (12) i związaną z nią funkcję skalującą $\Phi^H(t)$ (13). Współczynniki filtra falkowego można wyznaczyć, korzystając z faktu, że $\{\Phi^H{}_{(j+1),k}\}_{k\in\mathbb{Z}}$ jest bazą ortonormalną podprzestrzeni V_{j+1} oraz $W_j \subset V_{j+1}$. Każdą funkcję $W_j \ni H_{j,k}(t) = 2^{j/2}H(2^j t - k)$ można przedstawić jako kombinację liniową funkcji bazowych V_{j+1}:

$$\begin{aligned} H_{j,k}(t) &= \sum_{m\in\mathbb{Z}} h_m \Phi^H{}_{(j+1),m}(t) \\ &= 2^{-\frac{j+1}{2}} \sum_{m\in\mathbb{Z}} h_m \Phi^H(2^{j+1}t - 2k - m) \end{aligned} \tag{19}$$

Funkcja $H(t)$ przyjmuje wartości rzeczywiste jedynie wewnątrz przedziału [0,1], zatem jedynie dwa współczynniki h_0 i h_1 są niezerowe. Stąd:

$$\begin{aligned} H_{j,k}(t) = 2^{-\frac{j+1}{2}} \Big(& h_0 \Phi^H(2^{j+1}t - 2k) \\ & + h_1 \Phi^H(2^{j+1}t - 2k - 1) \Big) \end{aligned} \tag{20}$$

Falki powinny mieć cechę filtrów górnoprzepustowych, czyli ich wartości średnie powinny wynosić 0.

$$\int_{\mathbb{R}} H_{j,k}(t)\,\mathrm{d}t = 0 \tag{21}$$

Podstawiając do równania (21) równość (20), otrzymujemy (22).

$$\begin{aligned} \int_{\mathbb{R}} H_{j,k}(t)\,\mathrm{d}t = \int_{\mathbb{R}} \big(h_0 \Phi^H{}_{(j+1),2k}(t) + h_1 \Phi^H{}_{(j+1),(2k-1)}(t) \big)\,\mathrm{d}t = \\ = h_0 + h_1 = 0 \end{aligned} \tag{22}$$

Dochodzi jeszcze warunek ortonormalności falek $H_{j,k}$ (G., 1994):

$$\begin{aligned} \langle H_{j,0}, H_{j,k} \rangle &= \sum_{m\in\mathbb{Z}} h_m \sum_{p\in\mathbb{Z}} h_{2k+p} \langle \Phi_{(j+1),m}, \Phi_{(j+1),(2k+p)} \rangle = \\ &= \sum_{m\in\mathbb{Z}} \sum_{p\in\mathbb{Z}} h_m h_{2k+p} \delta_{m-2k-p} = \sum_{m\in\mathbb{Z}} h_m h_{m-2k} = \delta_{2k,0} \end{aligned} \tag{23}$$

Układ równań (22) i (23) zadaje współczynniki filtra górnoprzepustowego odpowiadającego syntezującym falkom $\mathrm{H}_{j,k}(t)$. Jego rozwiązaniem są liczby $\left\{\frac{1}{\sqrt{2}}, -\frac{1}{\sqrt{2}}\right\}$. Filtr analizujący dla tej falki ma natomiast wagi $\left\{-\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}\right\}$. Współczynniki filtra syntezującego związanego z funkcjami skalującymi ${\Phi^H}_{j,k}$ oblicza się korzystając z wyznaczonych już wag h_0 i h_1, podstawiając do wzoru (11). Szukanymi wagami są $g_k = a_k = \langle \Phi(t/2), \Phi(t-k) \rangle$.

$$h_k = g_{2N-1-k}(-1)^k, \qquad k = 0{,}1 \tag{24}$$

Syntezujący filtr związany z funkcjami skalującymi zadany jest więc współczynnikami $\left\{\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}\right\}$. Są to także współczynniki filtra analizującego.

Wyznaczone współczynniki filtrów nie zależą od j, czyli na każdym poziomie dekompozycji są jednakowe.

Ogromną zaletą falki Haara jest jej bardzo dobra lokalizacja czasowa, z uwagi na jej szybkie zanikanie [3]. Jest to jednak funkcja nieciągła, przez co nie stanowi dobrego narzędzia do analizy funkcji ciągłych, czy tym bardziej gładkich [1]. Dążono więc do konstrukcji falek podobnych do falki Haara pod kątem szybkości zanikania, lecz będących funkcjami gładkimi. Konstrukcję takich falek jako pierwsza zaproponowała Ingrid Daubechies w roku 1992 [4] i od jej nazwiska nadano im miano falek Daubechies. Falka Haara jest ich szczególnym przypadkiem (nazywana jest falką Daubechies pierwszego rzędu). Falki te reprezentowane są przez związane z nimi filtry [4]. Współczynniki filtrów odpowiadających falkom i funkcjom skalującym z nimi związanym wyznacza się, podobnie jak w przypadku falki Haara, korzystając z warunków ortonormalności oraz właściwości filtrów. Uogólniając warunki (22) i (23) dla filtra długości $2N$, otrzymujemy układ równań:

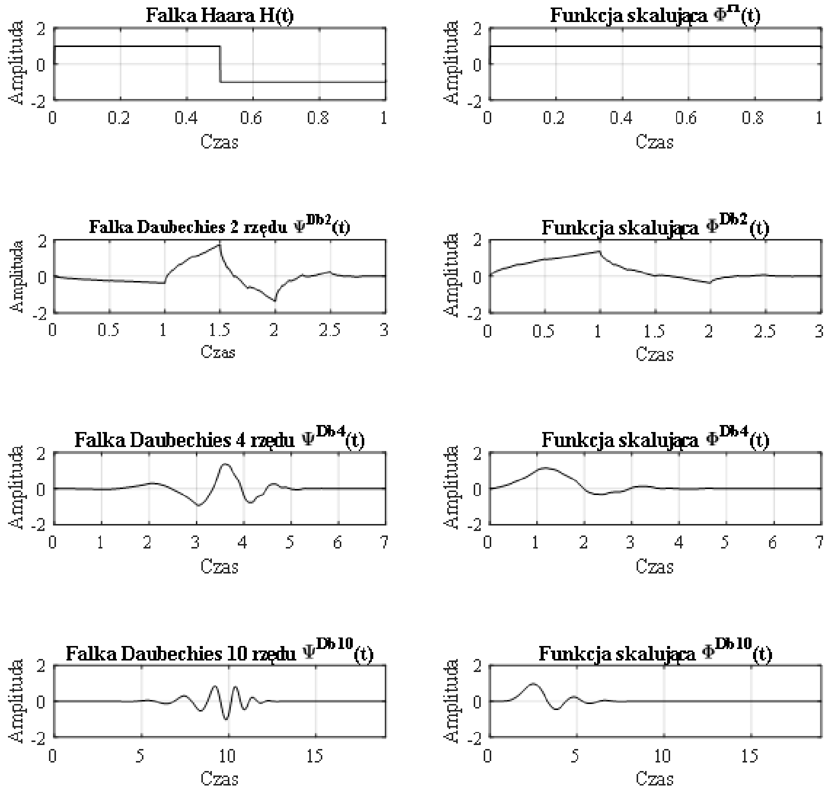
$$\begin{cases} \displaystyle\sum_{m=0}^{N-1} h_m = 0 \\ \displaystyle\sum_{m=1}^{N-1} h_m h_{m-2k} = \delta_{2k} \end{cases} \tag{25}$$

(25) jest układem $N+1$ równań o $2N$ niewiadomych. W przypadku falki Haara, gdy $N=1$ układ ten jednoznacznie zadawał współczynniki filtra. Dla $N>1$, brakujące $N-1$ równań można zadać tak, by poprawić określone właściwości falki, na przykład wymusić zanikanie jej $N-1$ pierwszych momentów. Efektywna metoda wyznaczenia współczynników filtra falkowego dla $N>1$ opiera się na wykorzystaniu transformacji Z i doborze odpowiedniego wielomianu zespolonego. Dowodzi się, że dla spełnienia zarówno warunków danych równaniem (25) jak i dotyczących momentów falki, powinien on spełniać równość (26) [3].

$$|W(z)|^2 = \sum_{n=0}^{2N-1} \binom{2N-1}{n} \left(\frac{(\bar{z})^{\frac{1}{2}} + z^{\frac{1}{2}}}{2} \right)^{2N-2-2k} \left(\frac{(\bar{z})^{\frac{1}{2}} - z^{\frac{1}{2}}}{2i} \right)^{2k} \tag{26}$$

Na podstawie wielomianu $W(z)$ można wyznaczyć współczynniki filtra falkowego, a na ich podstawie obliczyć współczynniki filtra związanego z funkcjami skalującymi, korzystając z zależności (24). Ciekawym faktem jest, że dla tak wyznaczonych falek, poza trywialnym przypadkiem $N=1$ (falka Haara), funkcja skalująca nie jest symetryczna względem środka przedziału [3].

Na rys. 1 przedstawiono wykresy falek i funkcji skalujących dla wybranych falek Daubechies.



Rysunek 1. Przebiegi wybranych falek Daubechies i odpowiadających im funkcji skalujących

4. Konstrukcja algorytmu dekompozycji sygnału i analiza przykładowego sygnału

Ponownie przyjmujemy bazę ortonormalną postaci (10), tym razem generowaną jednak przez falkę Daubechies dowolnego poziomu. Jeszcze raz wykorzystamy fakt, że każdą funkcję $V_j \ni \Phi_{jk}(t) = 2^{j/2}\Phi(2^j t - k)$ oraz każdą funkcję $W_j \ni \Psi_{jk}(t) = 2^{j/2}\Psi(2^j t - k)$ można przedstawić jako kombinacje liniowe funkcji bazowych V_{j+1} (gdyż $V_j \subset V_{j+1}$ i $W_j \subset V_{j+1}$). Zachodzą więc równości (27) i (28) [4].

$$\begin{aligned}\Phi_{j,k}(t) &= 2^{\frac{j}{2}}\Phi(2^j t - k) = 2^{\frac{j+1}{2}}\sum_{m\in\mathbb{Z}} g_m \Phi(2^{j+1}t - 2k - m) \\ &= \sum_{m\in\mathbb{Z}} g_{m-2k}\Phi_{(j+1),m}(t)\end{aligned} \tag{27}$$

$$\begin{aligned}\Psi_{j,k}(t) &= 2^{\frac{j}{2}}\Psi\big(2^j t - k\big) = 2^{\frac{j+1}{2}}\sum_{m\in\mathbb{Z}} h_m \Phi\big(2^{j+1}t - 2k - m\big) = \\ &= \sum_{m\in\mathbb{Z}} h_{m-2k}\Phi_{(j+1),m}(t)\end{aligned} \tag{28}$$

Jeżeli w równaniu (17) zapiszemy $\Psi_{j,k}$ w postaci (28) otrzymamy zależność (29).

$$\begin{aligned} d^{j,k} &= 2^{\frac{j+1}{2}} \sum_{n=0}^{N-1} x(nT_p) \sum_{m\in\mathbb{Z}} h_{m-2k} \Phi^{H}{}_{(j+1),m}(nT_p) = \\ &= \sum_{m\in\mathbb{Z}} h_{m-2k} \left(x(nT_p) * \Phi^{H\,(j+1),(2k+m)}(nT_p) \right) = \\ &= \sum_{m\in\mathbb{Z}} h_{m-2k} a^{(j+1),(2k+m)} \end{aligned} \tag{29}$$

Ostatnia suma w zależności (29) jest oczywiście równaniem splotu dyskretnego sygnału uzyskanego poprzez decymację (usunięcie co drugiej próbki) aproksymacji poziomu $(j+1)$ analizowanego sygnału z analizującym filtrem falkowym. Zależność (29) można zatem przepisać w postaci (30).

$$d^{j,k} = J_{-1} a^{(j+1),k} * \Psi^{j,k} \tag{30}$$

Przeprowadzając analogiczne rozumowanie dla aproksymacji j-tego poziomu, wykorzystując zależność (27) otrzymujemy (31).

$$a^{j,k} = J_{-1} a^{(j+1),k} * \Phi^{j,k} \tag{31}$$

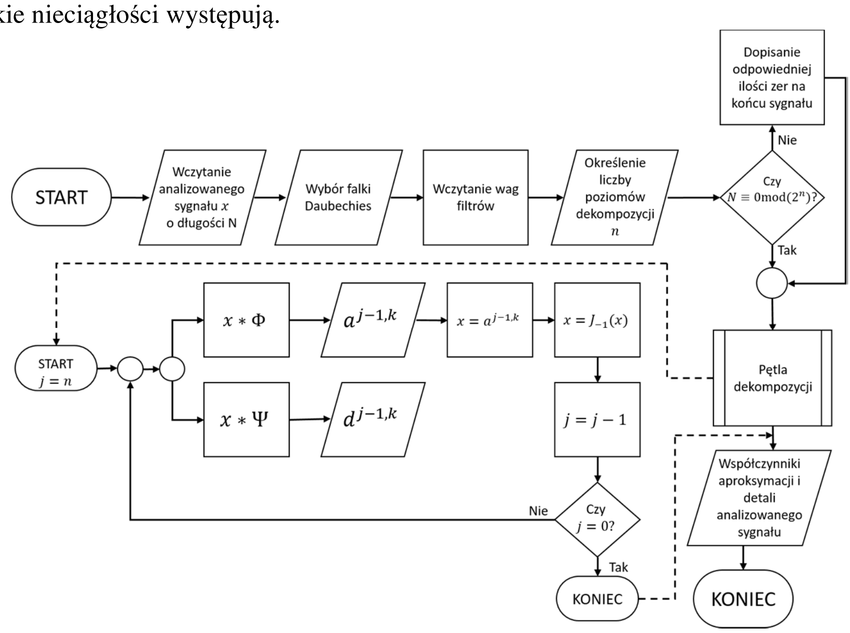
Obie zależności (30) i (31) są niezwykle istotne z punktu widzenia tworzenia algorytmu. Wynika z nich bowiem, że wyznaczywszy aproksymację $a^{(j+1),k}$ sygnału na poziomie $(j+1)$ można łatwo obliczyć zarówno aproksymację jak i detale j-tego poziomu, wykonując splot sygnału uzyskanego przez usunięcie co drugiej próbki z $a^{(j+1),k}$ z filtrami analizującymi funkcji skalujących $\Phi^{j,k}$ i falek $\Psi^{j,k}$.

Uzyskane powyżej zależności umożliwiają zaprojektowanie efektywnego algorytmu dekompozycji sygnału. Na rysunku 2 przedstawiono schemat blokowy zaprojektowanego algorytmu w oparciu o [4].

Algorytm został zaimplementowany w środowisku Matlab. Dużym ułatwieniem podczas korzystania z tego środowiska jest możliwość wczytania współczynników filtrów związanych z falkami Daubechies bezpośrednio z bibliotek przy użyciu funkcji *wfilters*. Dobierając liczbę poziomów dekompozycji n, będącej zarazem liczbą iteracji w pętli dekompozycji należy mieć na uwadze długość sygnału N. Jeżeli bowiem $N < 2^n$, to w wyniku kolejno wykonywanych decymacji, po pewnym kroku dekompozycji długość sygnału może zostać zmniejszona do 0. Dodatkowo, by nie utracić części sygnału w wyniku decymacji należy przed rozpoczęciem dekompozycji sprawdzić, czy długość sygnału jest całkowitą wielokrotnością 2^n. Jeżeli tak nie jest, należy sygnał sztucznie wydłużyć, dopisując na końcu odpowiednią ilość zer, tak by warunek ten był spełniony.

Na wyjściu pętli dekompozycji otrzymywany jest ciąg współczynników aproksymacji zerowego poziomu (odpowiadającej składowym o najniższej częstotliwości) oraz detali poziomów 0,1,…,N-1. Na rys. 3 przedstawiono wynik dekompozycji przykładowego sygnału sinusoidalnego o zmieniającej się skokowo częstotliwości, spróbkowanego z częstotliwością $f_p = 200$ Hz, dla falek Haara i Daubechies rzędu 5.

Jak widać na rysunku 3, analiza współczynników odpowiadających detalom i aproksymacji badanego sygnału umożliwia określenie przebiegu zmian częstotliwości w czasie oraz lokalizacji chwil czasowych, w których te zmiany następują. Widać również, że lokalizacja częstotliwościowa jest znacząco lepsza w przypadku falek Daubechies wyższych rzędów, niż w przypadku falki Haara. Składowa sinusoidalna o częstotliwości około 10 herców występująca w sygnale do 1 sekundy, jest w przypadku falki Haara reprezentowana przez falki bazowe do podprzestrzeni W_3 włącznie. W przypadku falki Daubechies 5 rzędu falki z tej podprzestrzeni odtwarzają już jedynie nieciągłości w dziedzinie częstotliwości. Jest to korzystne, gdyż umożliwia dokładne zlokalizowanie czasowe chwil, w których takie nieciągłości występują.



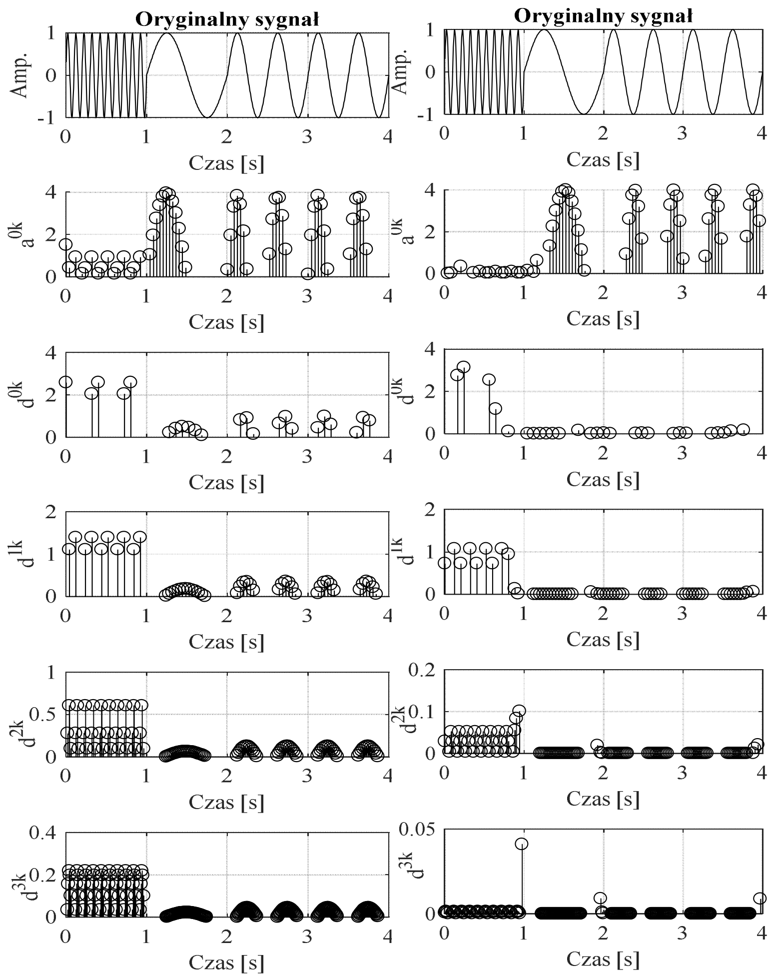
Rysunek 2. Schemat blokowy algorytmu dekompozycji sygnału z wykorzystaniem ortonormalnej bazy falkowej generowanej przez falki Daubechies

5. Podsumowanie

Zaprojektowany algorytm umożliwił efektywną dekompozycję próbnego sygnału sinusoidalnego o skokowo zmieniającej się częstotliwości. Wykorzystanie pewnych zależności między falkami ortonormalnymi i funkcjami skalującymi z nimi związanymi, umożliwiło stworzenie algorytmu w pełni rekurencyjnego i opierającego się na stosunkowo prostych operacjach, jak sploty i decymacje.

Analiza ciągu współczynników aproksymacji a^{jk} i detali d^{jk} na wszystkich poziomach dekompozycji umożliwia zarówno wykrycie zmian częstotliwości w sygnale, jak również chwil czasowych, w których one wystąpiły. Pozwala to mieć spore nadzieje, że zarówno wybrana metoda analizy czasowo-częstotliwościowej jak również sam algorytm umożliwią sprawne funkcjonowanie systemu detekcji wad w połączeniach spawanych, którego mają być częścią.

Porównanie wyników dekompozycji uzyskanych dla falek różnych falek Daubechies potwierdziło lepszą lokalizację częstotliwościową falek wyższych rzędów. Niemniej zaobserwowano pewne problemy z dekomponowaniem sygnałów, w których występują nieciągłości w postaci nagłych, znacznych skoków amplitudy, co może być spowodowane wzmocnioną gładkością falek Daubechies wyższych rzędów.



Rysunek 3. Wyniki dekompozycji przykładowego sygnału sinusoidalnego o zmieniającej się skokowo częstotliwości dla falki Haara (po lewej) i falki Daubechies rzędu 5 (po prawej)

Artykuł powstał w ramach projektu *pt. „Kryteria i metodyka określania jakości złączy zgrzewanych łukiem wirującym" współfinansowanym przez Narodowe Centrum Badań i Rozwoju w ramach III Programu Badań Stosowanych.*

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OPRACOWANIE PROCESU TECHNOLOGICZNEGO WYTWARZANIA ELEMENTU Z WYSOKOWYTRZYMAŁEJ BLACHY STALOWEJ TYPU AHSS

Streszczenie: W artykule przedstawiono proces technologiczny, wytwarzania przykładowej części struktury samochodowej z wysokowytrzymałej blachy stalowej typu AHSS (Advanced High-Strength Steels) Przeprowadzono badania wytrzymałościowe stali DP600 i na ich podstawie wykonano symulacje procesu kształtowania tłoczonego elementu nadwozia w programie AutoForm 6.0.1. Opracowany proces stanowi ekonomicznie uzasadnioną alternatywę dla kosztownych procesów obróbki plastycznej na gorąco czy hydroformowania.

Słowa kluczowe: tłocznictwo, materiały wysokowytrzymałe, AHSS,

TECHNOLOGICAL PROCESS DEVELOPMENT OF COMPONENT MANUFACTURING FROM ADVANCED HIGH STRENGTH STEEL SHEET

Summary: The article presents technological process, production of sample car structure part made from advanced high strength steel sheet (AHSS). Conducted research tensile strength of DP600 steel and based on them forming simulations of body component in AutoForm 6.0.1. Developed process is an economically viable alternative to the costly hot forming and hydroforming.

Keywords: sheet metal forming, modern high strength steels, AHSS,

1. Wstęp

Wybór materiałów przeznaczonych na części struktur karoseryjnych jest jednym z najważniejszych etapów podczas projektowania nadwozia samochodu. Kryteria

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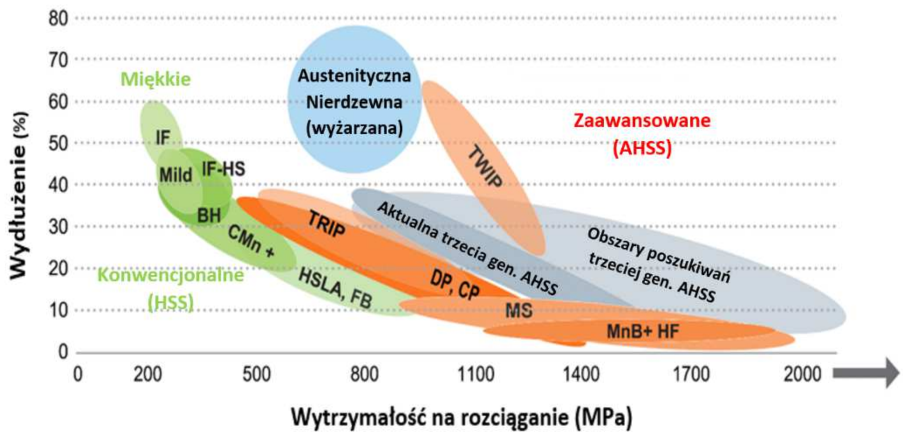
jakie powinny spełniać te materiały to: niska gęstość, odpowiednia wytrzymałość, akceptowalna cena oraz możliwości ich recyklingu. To właśnie te czynniki spowodowały powstanie w 1994 roku konsorcjum składającego się z 35 producentów blach stalowych. Celem tego konsorcjum było wspólne zaprojektowanie lekkiej stalowej struktury karoseryjnej zapewniającej bezpieczeństwo przy zachowaniu wymagań jakościowych. W 1998 roku zaprezentowano pierwszy prototyp, wykonany z nowego rodzaju materiału, który był lekkim i stosunkowo niedrogim rozwiązaniem w porównaniu do stosowanych w tego rodzaju konstrukcjach stali. Ze względu na wyjątkowo wysokie parametry wytrzymałościowe (wytrzymałość na rozciąganie Rm > 700 MPa) nowy rodzaj blachy stalowej nazwano AHSS (Advanced High-Strength Steels) [5].

2. Podział i zastosowanie stali typu AHSS

Współcześnie używane w przemyśle motoryzacyjnym stale można sklasyfikować w trzech kategoriach [2]:

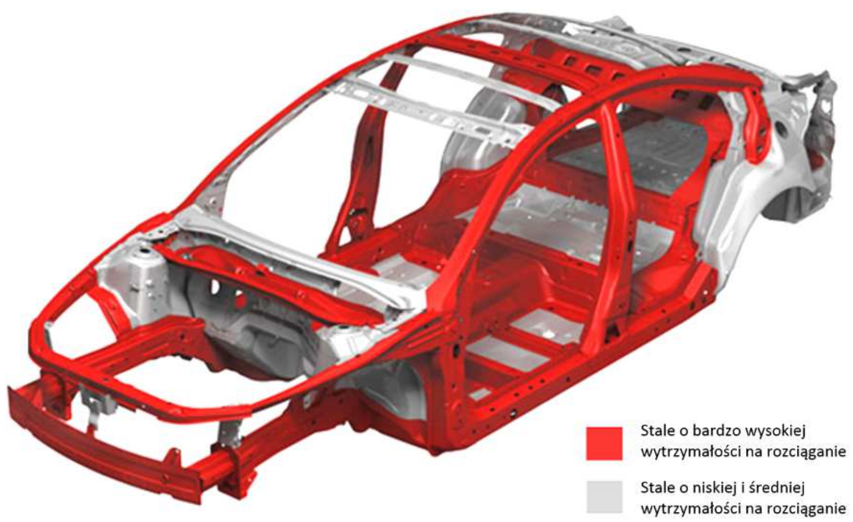
- <u>miękkie</u>, o wytrzymałości na rozciąganie R_m poniżej 300 MPa i wydłużeniu A_{80} powyżej 30%, niskowęglowe, plastyczne (IF, MILD),
- <u>konwencjonalne</u>, o wytrzymałości na rozciąganie R_m mieszczącej się w zakresie od 300 do 700 MPa i wydłużeniu A_{80} od 10% do 30% (HSS: IF-HS, BH, CMn, HSLA, FB),
- <u>zaawansowane,</u> o bardzo wysokiej wytrzymałości na rozciąganie R_m powyżej 700 MPa i wydłużeniu A_{80} w zakresie 5% - 30% (AHSS: TRIP, DP, CP, MS),

Na rysunku 1 przedstawiono porównanie właściwości stali obecnie używanych w przemyśle motoryzacyjnym.



Rysunek 1. Właściwości stali przeznaczonych na elementy nadwozia [5]

Dwie pierwsze grupy wymienionych stali są już klasycznymi. Stale miękkie, plastyczne stosowane są przede wszystkim do głęboko tłoczonych paneli zewnętrznych, natomiast stale konwencjonalne na bardziej odpowiedzialne części, np. wsporniki. Zaawansowane stale o bardzo wysokiej wytrzymałości są umacniane poprzez transformację fazową, a nie jak to miało miejsce dla stali klasycznych i konwencjonalnych przez umocnienie dyspersyjne lub roztworowe. W przypadku stali z gatunku DP, CP, MS materiał umacnia się na etapie jego przygotowania, natomiast w przypadku gatunków stali TRIP/TWIP podczas jego formowania oraz w trakcie ewentualnych kolizji drogowych [2]. Bardzo wysokie parametry wytrzymałościowe oraz zdolność do pochłaniania dużej ilości energii sprawiły, że stal typu AHSS znalazła szerokie zastosowanie w przemyśle motoryzacyjnym (rysunek 2). Wykonywane są z niej elementy strukturalne, części zawieszenia, siedzeń, a także felgi samochodowe.



Rysunek 2. Zastosowanie stali typu AHSS w przemyśle motoryzacyjnym [6]

To właśnie potrzeba stosowania materiałów o coraz wyższych parametrach wytrzymałościowych oraz skomplikowanie kształtu części nadwozia powoduje znaczne problemy w projektowaniu procesów technologicznych wytwarzania. W celu identyfikacji miejsc zagrożonych pękaniem lub nadmiernym fałdowaniem wytłoczki, już na etapie koncepcji stosowane są programy wykorzystujące metodę elementów skończonych. W dalszej części artykułu opisano przykładowy proces technologiczny wytwarzania wzmocnienia słupka typu B oraz przedstawiono wyniki wykonanych symulacji tłoczenia.

3. Proces technologiczny wytwarzania wzmocnienia słupka typu B

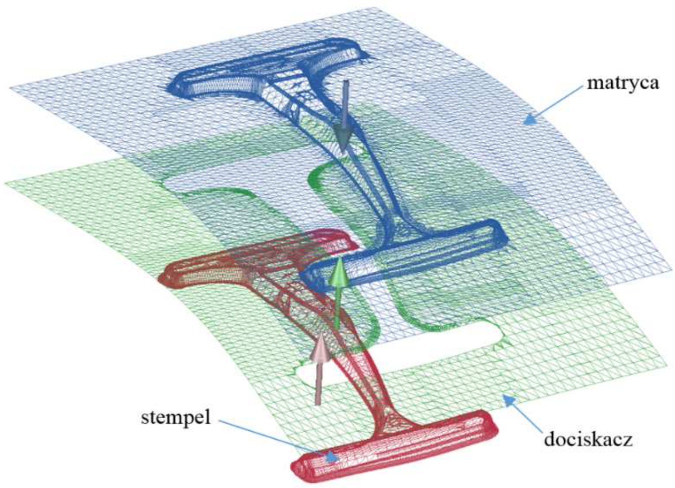
Proces technologiczny opracowano na podstawie modelu geometrycznego części, który wynika bezpośrednio z budowy nadwozia samochodowego. Model ten może być przygotowany w dowolnym oprogramowaniu 3D np. Siemens NX lub CATIA. Koncepcja procesu technologicznego w znacznym stopniu zależy od doświadczenia konstruktora oraz warunków ograniczających takich jak wielkość stołu prasy lub jej maksymalny nacisk. Dla wstępnej koncepcji procesu technologicznego wzmocnienia słupka typu B założono 6 operacji:

- wykrawanie formatki w dwóch operacjach,
- wytłaczanie,
- okrawanie I,
- okrawanie II,
- dziurkowanie.

Ze względu na kluczowość procesu kształtowania części w dalszej kolejności skupiono się na badaniach materiału DP 600 oraz symulacji operacji wytłaczania. Na rysunku 3 przedstawiono model 3D części po operacji wytłaczania.

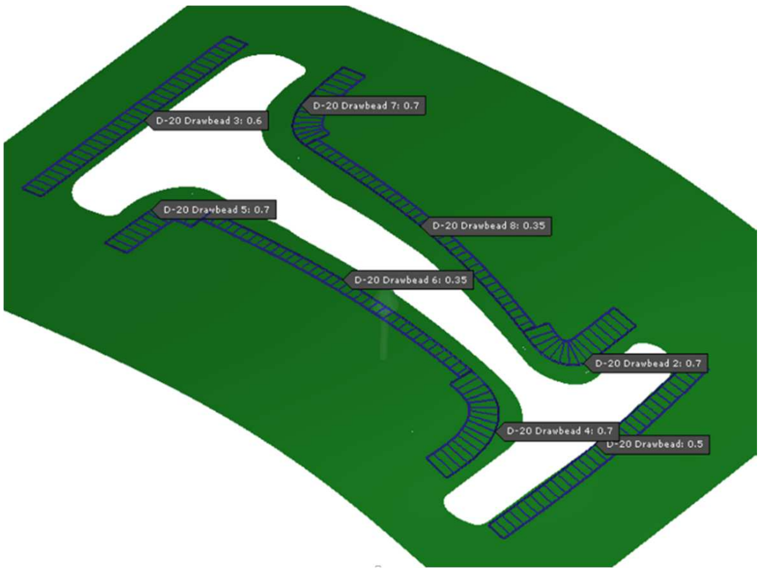
Rysunek 3. Model 3D elementu po operacji wytłaczania

Do wykonanego modelu 3D części po operacji wytłaczania koniecznym jest wykonanie symulacji tłoczenia. W tym celu przygotowuje się powierzchnie styku stempla, matrycy oraz dociskacza z wytłoczką, które następnie są importowane do oprogramowania symulacyjnego. Na podstawie zaimportowanych modeli geometrycznych można stworzyć modele MES płaskiej formatki oraz narzędzi tłocznika [3]. Na rysunku 4 przedstawiono modele MES narzędzi formujących (stempel, matryca, dociskacz), które zostały wykonane do operacji wytłaczania.



Rysunek 4. Modele MES elementów formujących

Podział na elementy skończone w programie AutoForm dokonywany jest automatycznie. Użytkownik może natomiast wybrać typ elementu spośród: BEM-5 (bending enhanced membrane), EPS-5 (elastic plastic shell) i EPS-11. Wszystkie z nich to elementy 3-węzłowe z liniowymi funkcjami kształtu. W przypadku dużych wytłoczek ważnym jest odpowiednie uplastycznienie materiału. Uzyskuje się je poprzez dodanie progów ciągowych mających za zadanie wytworzenie dodatkowych sił, ograniczających nadmierne płynięcie materiału. Rozmieszczenie progów na dociskaczu zostało przedstawione na rysunku 5.



Rysunek 5. Rozmieszczenie progów ciągowych na dociskaczu

Jako materiał wybrano stal typu AHSS gatunku: DP600 dla którego przyjęto model materiału anizotropowego w płaskim stanie naprężenia i odkształcenia Hilla. W tym celu do wyników uzyskanych ze statycznej próby rozciągania dopasowano modele krzywych materiałowych Swift'a oraz Hockett-Sherby'iego wyrażających się wzorami (1),(2):

Swift'a: $$\boldsymbol{\sigma}(\boldsymbol{\varepsilon}) = \boldsymbol{K_S}(\boldsymbol{\varepsilon} + \boldsymbol{\varepsilon_0})^{\mathbf{n_s}} \tag{1}$$

gdzie:
σ – naprężenie,
ε_0 – początek odkształcenia plastycznego,
ε – odkształcenie plastyczne,
K_S, n_S – wyznaczane parametry,

Hockett-Sherby'iego: $$\boldsymbol{\sigma}(\boldsymbol{\varepsilon}) = \boldsymbol{\sigma_{Sat}} - (\boldsymbol{\sigma_{Sat}} - \boldsymbol{\sigma_e}) \cdot \boldsymbol{e^{-a\varepsilon^p}} \tag{2}$$

gdzie:
σ – naprężenie,
ε – odkształcenie plastyczne,
$a, p, \sigma_{Sat}, \sigma_e$ – wyznaczane parametry,

Dla wyznaczonych parametrów (Tab. 1, 2) obliczono współczynnik determinacji R^2 celem oceny stopnia dopasowania modeli do uzyskanych wyników.

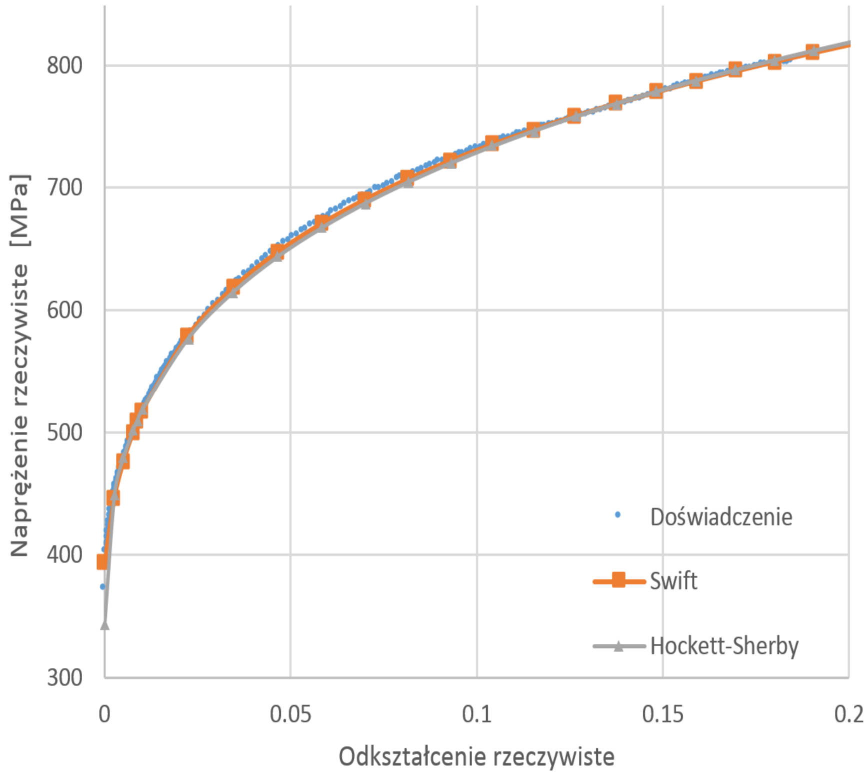
Tabela 1. Parametry modelu krzywej umocnienia Swift'a

K_s	n_s	R^2
1060,09	0,163	0,9962

Tabela 2. Parametry modelu krzywej umocnienia Hockett-Sherby'iego

σ_{Sat}	σ_e	a	p	R^2
1341,32	343,88	1,240	0,405	0,9934

Na rysunku 6 przedstawiono wyniki próby statycznego rozciągania stali DP600 wraz modelami dopasowanych krzywych materiałowych.



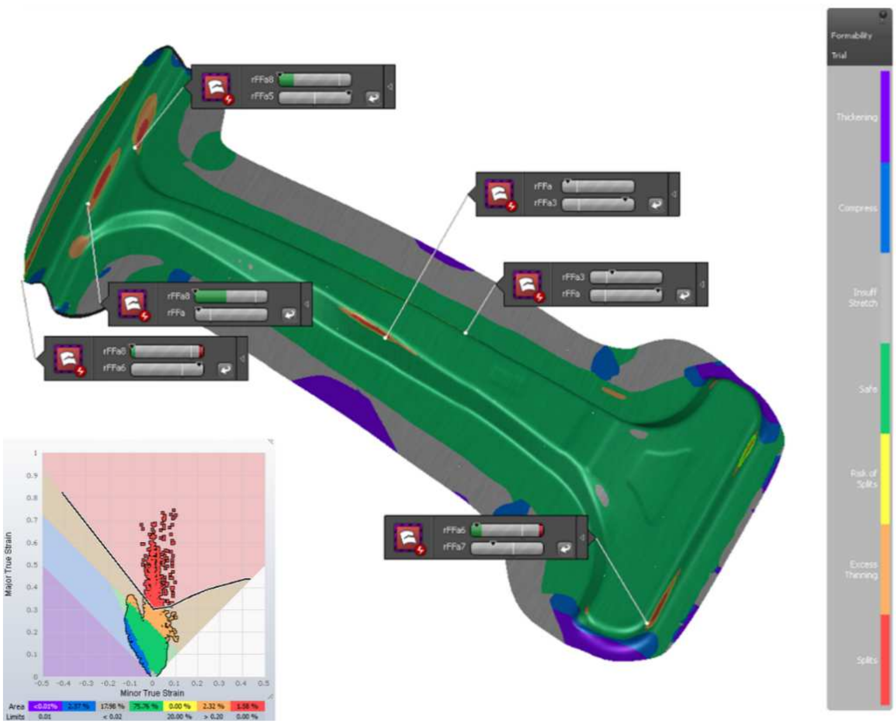
Rysunek 6. Dopasowane modele krzywych umocnienia

Oprócz parametrów modeli Swift'a oraz Hockett-Sherby'iego w edytorze materiałowym programu AutoForm, dla kryterium plastyczności Hill'a należy podać także parametry Lankford'a dla próbek wyciętych pod kątem 0°, 45° oraz 90° do kierunku walcowania oraz granicę plastyczności dla próbki wyciętej pod kątem 0°. Uzyskane parametry Lankford'a zestawiono w tabeli 3.

Tabela 3. Zestawienie uzyskanych parametrów σ_0, R_0, R_{45} oraz R_{90}

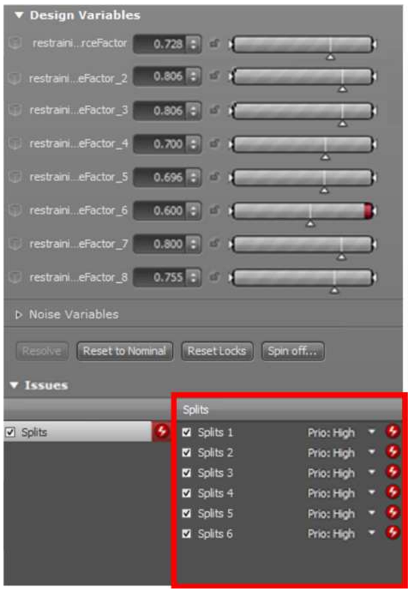
σ_0	R_0	R_{45}	R_{90}
373,1	0,843	1,21	1,072

Po wprowadzeniu uzyskanych danych do edytora i zdefiniowaniu kształtu formatki z której ma być wykonana część przeprowadzono symulacje. Na rysunku 7 przedstawiono wyniki pierwszej symulacji, która wskazuje na występowanie sześciu miejsc zagrożonych pękaniem.

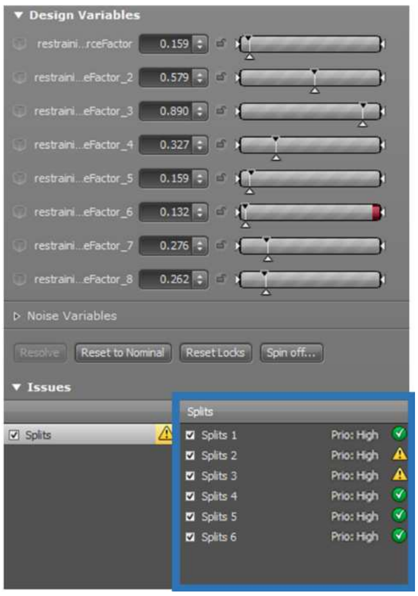


Rysunek 7. Wyniki symulacji dla wstępnych parametrów projektowych

By obniżyć pocienienie materiału oraz ryzyko pękania można wykorzystać solver Sigma programu AutoForm. W tym celu należy zdefiniować zmienne projektowe np.: siłę dociskacza, współczynniki siły progów ciągowych lub współczynniki tarcia między narzędziami formującymi, a formatką oraz ich graniczne wartości. W tym wypadku jako zmienne projektowe wykorzystano współczynniki siły progów ciągowych. Po uruchomieniu solvera Sigma program tworzy automatycznie określoną populację rodzin współczynników dla których wykonywane są kolejne symulacje. Po zakończeniu obliczeń program na podstawie wartości pocienienia oraz powierzchni obszaru bezpiecznego w zdefiniowanych miejscach wskazuje rozwiązanie najkorzystniejsze spośród wszystkich i dostarcza wartości współczynników dla tego rozwiązania. Na rysunku 8 przedstawiono wstępnie przyjęte wartości parametrów projektowych i zdefiniowane miejsca występowania zagrożeń, natomiast na rysunku 9 najkorzystniejsze wartości parametrów wskazanych przez solver Sigma oraz spodziewaną w tych miejscach poprawę.



Rysunek 8. Wstępnie przyjęte wartości parametrów projektowych oraz zdefiniowane miejsca występowania zagrożeń



Rysunek 9. Najkorzystniejsze wartości parametrów wskazane przez solver Sigma oraz spodziewana poprawa w miejscach początkowo zagrożonych

Opisany sposób postępowania znacząco wpływa na czas konieczny do poprawy jakości wytłoczki na etapie projektowania procesu (dotychchczas często to konstruktor ręcznie wpisywał wartości parametrów projektowych oraz oceniał ich wpływ na wynik symulacji). Oprócz możliwości poprawy procesu poprzez zmianę parametrów projektowych istnieje również możliwość zdefiniowania różnego typu zmiennych, które przewidziane są tolerancją określoną przez normę np.: grubość blachy, wytrzymałość na rozciąganie lub granica plastyczności. To bardzo ważne, ponieważ często różnica wytrzymałości na rozciąganie na poziomie 70MPa, akceptowalna przez normę powoduje znaczące pogorszenie jakości wytłoczki. Rysunek 10 przedstawia wynik symulacji dla parametrów obliczonych przez solver Sigma.

Rysunek 10. Wynik symulacji dla parametrów dostarczonych przez solver Sigma

Widać na nim znaczącą poprawę w miejscach wcześniej zagrożonych pękaniem. W dwóch miejscach występuje ostrzeżenie o nadmiernym pocienieniu materiału, jednak nie ma ryzyka jego pękania.

4. Podsumowanie

Restrykcyjne normy emisji spalin oraz dążenie do ograniczenia zużycia paliwa wymusza na konstruktorach ciągłe obniżanie masy samochodu bez zmniejszania jego sztywności. W tym celu stosowane są blachy o coraz mniejszej grubości i wyższych parametrach wytrzymałościowych. Przedstawiona w artykule metodyka pozwala na ograniczenie do minimum ryzyka potencjalnych pęknięć mogących wystąpić podczas wykonywania prototypów lub produkcji seryjnej opisanego wzmocnienia słupka typu B. Wykonane badania wytrzymałościowe pozwoliły na stworzenie modeli materiałowych, które zostały wykorzystane podczas przeprowadzania symulacji tłoczenia. Jak wykazano w [4] parametry modelu materiałowego wyznaczone na podstawie badań doświadczalnych mogą się istotnie różnić od parametrów modeli materiałowych dostarczanych przez producentów oprogramowania. Uzyskane wyniki wskazują również na możliwość zastąpienia w przyszłości drogich technologii tłoczenia na gorąco czy hydroformowania, przez coraz bardziej zaawansowane materiały wysokowytrzymałe formowane na zimno. Niewątpliwie w najbliższym czasie można się spodziewać nowych rozwiązań w zakresie materiałów (stali) o coraz wyższych parametrach wytrzymałościowych, stanowiących kolejne wyzwania dla inżynierów zajmujących się technologią obróbki plastycznej.

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DWUWYMIAROWY MODEL MATEMATYCZNY DO SYMULACJI LINIOWO POPRZECZNEJ MIGRACJI ZANIECZYSZCZEŃ W MATERIAŁACH POROWATYCH

Streszczenie: Nowy dwu-wymiarowy model matematyczny do symulacji liniowo porzecznej migracji zanieczyszczeń w nasyconych porowatych mediach (materiałach) opisano w niniejszym artykule. W zaproponowanym modelu uwzględniono współczynniki skali dla zjawisk w micro oraz mezzo/micro skali tj. dla procesu transferu masy. Na podstawie obliczeń symulacyjnych otrzymano rozwiązania numeryczne dla problem wartości granicznych. W szczególności w toku obliczeń zastosowano metodę różnic skończonych. Implementacja oprogramowanie została dokonana z zastosowaniem programowania równoległego dla systemu typu multi-platform.

Słowa kluczowe: transfer masy, ulepszenie, mikro-porowaty materiał, modelowanie komputerowe, migracja prostopadła, nanocząstki

A TWO-DIMENSIONAL MATHEMATICAL MODEL FOR LINEAR VERTICAL MIGRATION OF POLLUTANT IN THE CATALYTIC POROUS MEDIA

Summary: A new two-dimensional mathematical model for linear vertical migration of the pollutant in the saturated porous media is presented in this article. The model takes into account micro and meso/micro scales factor of mass transfer process. It was obtained the numerical solution of respective boudary value problem by the method of finite differences. Software implementation was done using multi-platform shared-memory parallel programming.

Keywords: Mass transfer, refinement, microporous particles, computer modelling, vertical migration, nanoparticle

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1. Introduction

The basic principles of mathematical models of mass transfer processes in porous media were presented by such set of scientists as Veryhin M.M., Serhiienko I.V., Skopetskyi V.V., Deineka V.S., Liashko I.I., Liashko S.I., Lavryk V.I., Vlasyuk A.P., Bomba A.Ia., Bulavatskyi V.M., Savula Ya.H. and other. [1, 2]. Next investigations take into account pollutant diffusion (e.g. nuclides) in soil. The study of such processes in soil was done by Prokhorov V.M., Vlasyuk A.P., Burak Ya. Y., Chaplia Ye.Ia., Chernukha O.Iu. [3–5]. At the same time scientists become interested in micro- and nanosized catalytic particles which may help in purification [6], technological [7] and other processes. We also considered the microparticles impact to the vertical migration of radionuclides in one-dimensional linear [8, 9], non-linear [10] and non-isothermal conditions [11]. Thus two-dimensional mathematical modelling which takes into account colloid-adsorbents in refinement processes of soil ranges is new. Therefore, in this paper, we will consider a new two-dimensional mathematical model of vertical migration of pollutant in catalytic porous media (micro- and nanosized colloid-adsorbents) with soil traps in the linear case.

2. Materials and research results

2.1. Formulation of the problem

Let us consider the process of horizontal soil refinement from pollutant (e.g. radionuclides). Under the influence of the pressure gradients, there occurs transfer of salts dissolved in water by the filtration flow. The filtration of salts solutions proceed thereby in accordance with the generalized Darcy law. Localization of pollutant is due to the transfer of seepage at a speed under the influence of convective diffusion in catalytic media in the presence of filter-traps (Fig. 1).

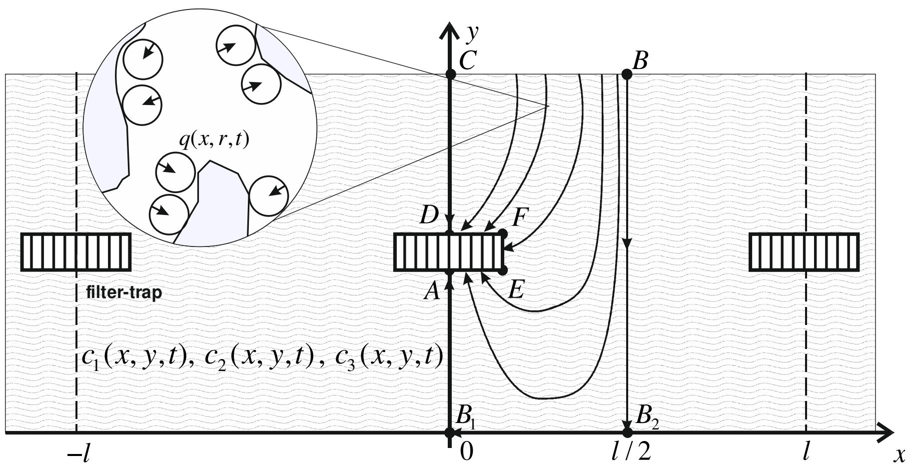

Figure 1. Migration of pollutant in saturated porous media to the set of filter-traps

2.2. Mathematical model of the problem

The two-dimensional mathematical model of the pollutant migration in linear case can be described by the following boundary problem:

$$D_1\left(\frac{\partial^2 c_1}{\partial x^2}+\frac{\partial^2 c_1}{\partial y^2}\right)-V_x\,\frac{\partial c_1}{\partial x}-V_y\,\frac{\partial c_1}{\partial y}-\gamma_1 c_1+\gamma_2 c_2=\sigma_1\frac{\partial c_1}{\partial t}, \tag{1}$$

$$D_2\left(\frac{\partial^2 c_2}{\partial x^2}+\frac{\partial^2 c_2}{\partial y^2}\right)+\gamma_1 c_1-\gamma_2 c_2+\gamma_3 c_3-\theta\left.\frac{\partial q}{\partial r}\right|_{r=R}=\frac{\partial c_2}{\partial t}, \tag{2}$$

$$D_3\left(\frac{\partial^2 c_3}{\partial x^2}+\frac{\partial^2 c_3}{\partial y^2}\right)+\gamma_2 c_2-\gamma_3 c_3=\sigma_1\frac{\partial c_3}{\partial t}, \tag{3}$$

$$\frac{\partial q}{\partial t}=D_0\left(\frac{\partial^2 q}{\partial r^2}+\frac{2}{r}\frac{\partial q}{\partial r}\right), \tag{4}$$

$$\left.\frac{\partial q(x,y,r,t)}{\partial r}\right|_{r=0}=0,\ \ q(x,y,r,t)\big|_{r=R}=\frac{k_f\cdot c_2(x,t)^{\beta}}{1+\eta\cdot c_2(x,t)^{\beta}}, \tag{5}$$

$$\upsilon_x=-k\frac{\partial h}{\partial x}+\nu\frac{\partial c_1}{\partial x},\ \ \upsilon_y=-k\frac{\partial h}{\partial y}+\nu\frac{\partial c_1}{\partial y},\frac{\partial \upsilon_x}{\partial x}+\frac{\partial \upsilon_y}{\partial y}=0, \tag{6}$$

$$h\big|_{CB}=H_1,\ \ h\big|_{AEFD}=H_2,\ \left.\frac{\partial h}{\partial n}\right|_{AB_1B_2B\cup CD}=0, \tag{7}$$

$$l_1 c_1\big|_{CB}=\tilde{C}_1^1(t),\ \ l_2 c_1=\begin{cases}\tilde{C}_1^2,\\ \left.\dfrac{\partial c_1}{\partial n}\right|_{\mathrm{AEFD}}=0,\end{cases} \tag{8}$$

$$l_3\, c_2\big|_{CB} = \tilde{C}_2^1(t),\ \ l_4 c_2 = \begin{cases} \tilde{C}_2^2, \\ \left.\dfrac{\partial c_2}{\partial n}\right|_{\text{AEFD}} = 0, \end{cases} \tag{9}$$

$$l_5\, c_3\big|_{CB} = \tilde{C}_3^1(t),\ \ l_6 c_3 = \begin{cases} \tilde{C}_3^2, \\ \left.\dfrac{\partial c_3}{\partial n}\right|_{\text{AEFD}} = 0, \end{cases} \tag{10}$$

$$c_1\big|_{t=0} = \tilde{C}_1^0, c_2\big|_{t=0} = \tilde{C}_2^0,\ c_3\big|_{t=0} = \tilde{C}_3^0,\ q\,\big|_{t=0} = \tilde{Q}^0, \tag{11}$$

$$\left.\frac{\partial c_1}{\partial n}\right|_{\Gamma} = \left.\frac{\partial c_2}{\partial n}\right|_{\Gamma} = \left.\frac{\partial c_3}{\partial n}\right|_{\Gamma} = 0, \Gamma = BB_2 B_1 AEFDC. \tag{12}$$

where $c_1(x,y,t)$, D_1– concentration and convective diffusion coefficient of pollutant in filtration flow; $c_2(x,y,t)$, D_2– concentration and molecular diffusion coefficient of pollutant in water connected with soil skeleton; $c_3(x,y,t)$, D_3– concentration and diffusion coefficient of pollutant in soil skeleton, this diffusion estimates differ by an orders of magnitude, that's why it called 'traps'; $q(x, y, r, t)$, D_0– concentration and diffusion coefficient of pollutant in particles with radius R, which located in soil skeleton; $k_f, \beta \eta$ – adsorption isotherm coefficients; θ – coefficient of micro-nanoparticle mass transfer influence on mass transfer near the ground skeleton; υ– filtration velocity; K – filtration coefficient; γ_1, γ_2, γ_3 – mass transfer coefficients; σ_1– porosity of soil; $x \in [0;\ l]$ – vertical coordinate; l_i, $i = \overline{1,6}$ – differential operators for boundary conditions when $x = 0$ and $x = l$; t – time, $0 < t < t_1$, r - radius (radial, horizontal variable) $0 < r < R$.

The equation (1) describes pollutant migration with concentration c_1; (2) describes pollutant migration in water connected with soil skeleton; (3) describes the migration of pollutant in soil skeleton (e.g. traps); (5) describes the mass transfer of pollutant with a concentration q in microparticles, which connected with concentration c_2 by equation (5); (6) describes filtration in catalytic porous media. Boundary conditions for concentrations $c_1(x,y,t)$, $c_2(x,y,t)$, $c_3(x,y,t)$, $q(x, y, r, t)$ and piezometric head $h(x, y)$ have the form (7)–(12).

Concentration q connected with a concentration $c_2(x,y,t)$ in equation (2) via adsorption isotherm (5), which becomes traditional Freundlich isotherm when $\eta = 0$, and Langmuir isotherm when $\beta = 1$ [12].

The filtration of salts solutions proceed thereby in accordance with the generalized Darcy law.

2.3. Numerical solution of the boundary-value problem

To find the numerical solution of the boundary-value problem (1)–(12) we used finite difference method. To do this we applied implicit difference scheme for the equation (2), and for (1), (3) and (4) we applied the A. A. Samarskii locally one-dimensional method with the use of a monotone finite-difference scheme [13].

The computational mesh $\omega_{h_{11}h_{12}h_2\tau}$ for finite-difference approximation with steps h_{11}, h_{12}, h_2 and τ by *Ox*-axis, *Oy*-axis, *Or*-axis and *Ot*-axis for x, y, r, t variables respectively

$$\omega_{h_{11}h_{12}h_2\tau} = \left\{ \begin{array}{l} x_{i_1} = i_1 h_{11},\ y_{i_2} = i_2 h_{12},\ r_j = j h_2,\ t_k = k\tau, \\ i_1 = \overline{0, n_{11}},\ i_2 = \overline{0, n_{12}},\ j = \overline{0, n_2},\ k = \overline{0, n_3}, \\ h_{11} n_{11} = l_1,\ h_{12} n_{12} = l_2,\ h_2 n_2 = R,\ \tau n_3 = T, \end{array} \right\} \tag{13}$$

where n_{11}, n_{12}, n_2, n_3 – steps count.

Using computational mesh provided below we find appropriate coefficients for the sweep method. At the same time, we proved numerical stability. After those steps, we become ready for computer modeling.

2.4. Software implementation

We developed a cross-platform application called NanoSurface. This program is written in the programming language C/C ++ using Qt framework. It allows us to investigate the phenomenon being studied. The application has a graphical user interface (GUI) that allow users to enter the required initial data (diffusion coefficients, boundary conditions, etc.), select appropriate mathematical model, perform necessary calculation and analyze received data using 2D/3D curves and concentration tables ($c_1(x,y,t)$, $c_2(x,y,t)$, $c_3(x,y,t)$, $q(x, y, r, t)$). The user can easily export all received data for future processing. Numerical calculations are implemented with OpenMP API for multi-platform shared-memory parallel programming in C/C++ [14]. There are three implementations of the sweep method: simple, oncoming and block. We also implemented realization of the Gauss method for testing our realizations of sweep methods.

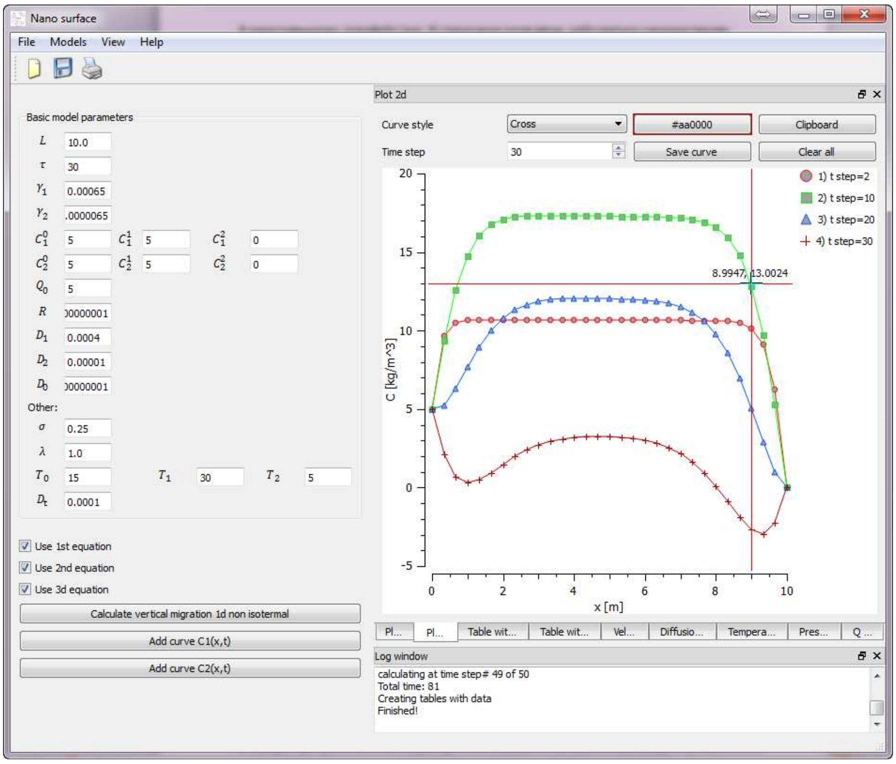

Figure 2. NanoSurface - a parallel computing software for the mathematical modeling of mass transfer process in catalytic porous media taking into account micro- and nanosized particles

3. Conclusion

We have considered a mathematical model for vertical migration of pollutant in catalytic porous media with filter-traps in the linear case. It was obtained the numerical solution of respective two-dimensional boundary value problem by the method of finite differences. We used implicit and monotone difference schemes for diffusion-convection problems. Appropriate coefficients for the sweep method were brought. At the same time, we prove numerical stability.

Using created software a series of numerical experiments and their analysis were conducted. We build curves for concentration distribution $c_1(x, y, t)$, $c_2(x, y, t)$, $c_3(x, y, t)$, $q(x, y, r, t)$ and velocity $\upsilon(x, y, t)$.

According to the numerical experiments, we can't ignore the impact of diffusion in soil skeleton. Moreover, we see the influence of microparticles on refinement process. Filtration purification process of fertile soil hold on faster it a case of presence of microparticles.

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OBLICZANIE PRZEŁOŻENIA PRZEKŁADNI PLANETARNEJ STOSUJĄC METODĘ TEORII GRAFÓW

Streszczenie: W pracy przedstawiono obliczenia przełożenia metodą grafów mieszanych. Analizowana przekładnia planetarna może pracować w sześciu trybach pracy w zależności od układu wejścia, wyjścia oraz elementów zahamowanych. Zaletami użytej metody są prostota oraz podejście algorytmiczne.

Słowa kluczowe: przekładnia planetarna, graf mieszany, algorytmizacja

GEAR RATIO CALCULATION BASED ON THE GRAPH THEORY APPROACH

Summary: In the present paper, the calculations of ratios of the planetary gear by means of graph theory method are presented. The considered gear can work under 6 working modes – depending on input, output and braked elements. The advantages of the proposed method are: simplicity as well as algorithmic approach and general modelling rules.

Keywords: planetary gear, mixed graph, algorithmization

1. Introduction

In the present paper the graph based method of analysis of planetary gears is presented. Some similar approaches were presented on previous conferences [4-5] at the University of Bielsko-Biała but for different gears which had not so many possible working modes. The graph-based methods of modelling were described in works [2, 11-13], where the present supervisor was an author or co-author. One of the first papers dedicated to this topic was the paper published in 1972 [3]. Despite the so long time of investigations and publishing, the graph-based methods started to be well

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known and frequently applied just in last 10 or 15 years. The authors from many countries were involved in the development of this field of knowledge – especially from Italy [6-7] and Turkey or Turkish origins (working in USA) [1, 8-10]. The dissertation [11] (published in English) is available in the university library and the students studying based upon ERASMUS PLUS program can study it during their stay in Bielsko-Biała.

2. Graph based method of planetary gear analysis

The considered planetary gear is presented in Fig. 1.

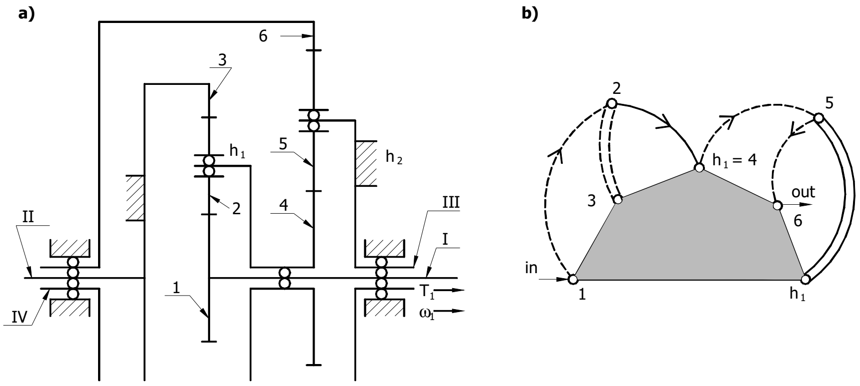

Figure 1. Scheme of the considered gear (a) and the assigned mixed graph (b)

The main elements are: 1 – sun wheel, 2,5 – planetary, h_1, h_2 – arms (carriers), additional condition: $h_1 = 4$ i.e. a particular element is simultaneously a carrier and a sun wheel, 4 – second sun wheel, 3,6 – ring wheels (named sometimes drums or crown wheels). Elements 3 or 5 can be braked by means of adequate brakes. Depending on the elements being temporarily: an input, an output or a braked element – the possible work options or modes can be distinguished. These are collected in the Table 1.

Table 1. Considered cases of work (duty) conditions of the planetary gear

Case	***Braked elements***	***Input***	***Output***
A	3, h2	1	6
B	3, 6	1	h2
C	3, 1	h2	6
D	1, 6	3	h2
E	1, h2	3	6
F	6, h2	1	3

In what follows, consecutive work modes of the gear are considered. In the considered method, the number of teeth are positive in every case in opposition to the Willis approach where the numbers of teeth of ring wheels (internal directed teeth) are considered as negative. The data related to the first case is presented in Table 2.

Table 2. Details of operations of the gear for the I-st working mode

Case A)	Braked ($\omega_i = 0$)	Input	Output
	3, h2	1	6

The method of analysis consists in:
(a) abstracting and simplification – focusing the attention on kinematics, only, i.e. we neglect housing, bearings as well as such phenomena like vibrations or lubrication,
(b) assigning a mixed graph to the simplified scheme of a planetary gear,
(c) refining a graph – adding double lines – representing braked elements,
(d) indicating the input and the output elements (connected to motor and working machine or wheels of a car), in general – it could be more inputs or outputs,
(e) showing the path though the graph – representing the passage of power and rotating movement from motor (input) to machine (output),
(f) distinguishing of so called f-cycles [11-13] – encoded by *(a,b)c*, where: *(a,b)* dashed edge, representing meshing of elements *a* and *b*. Additionally, *c* – represents an adequate carrier,
(g) writing the equations upon the codes of cycles in an algorithmic manner,
(h) solution of the system of algebraic solutions.

In Fig. 2, the further graphs assigned to the gear for further considered cases are shown where different inputs, outputs and braked parts are shown.

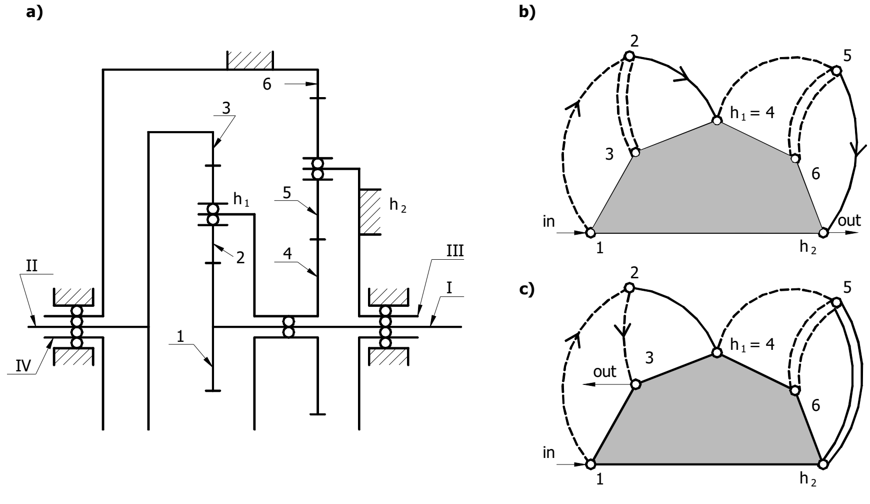

Figure 2. Scheme and graphs: (a) scheme of the gear; (b) assigned graph for the second case, (c) assigned graph for the sixth case

For the first considered case we have 4 f-cycles given underneath via codes and equations (1)-(4):

F-cycles	Equations	
(1,2)h1	$\omega_1 - \omega_{h1} = -N_{21} \cdot (\omega_2 - \omega_{h1})$	(1)
(2,3)h1	$\omega_2 - \omega_{h1} = +N_{32} \cdot (\omega_3 - \omega_{h1})$	(2)
(5,h1)h2	$\omega_5 - \omega_{h2} = -N_{h1,5} \cdot (\omega_{h1} - \omega_{h2})$	(3)
(5,6)h2	$\omega_5 - \omega_{h2} = +N_{65} \cdot (\omega_6 - \omega_{h2})$	(4)

The system can be simplified, considering braked elements: ($\omega_3 = 0$) and ($\omega_{h2} = 0$), as follows:

$$\omega_1 = \omega_{h1} - N_{21} \cdot (\omega_2 - \omega_{h1}) \tag{5}$$

$$\omega_2 = \omega_{h1} + N_{32} \cdot \omega_{h1} \tag{6}$$

$$\omega_{h1} = -\omega_5 / N_{h15} \tag{7}$$

$$\omega_5 = +N_{65} \cdot \omega_6 \tag{8}$$

Now ω_1 can be calculated substituting eq. *8)* in *7)* then *7)* in *6)* and finally *6)* in *5):*

$$\omega_1 = -\omega_6 \cdot N_{65} / N_{h15} \, (1 + N_{21} \cdot N_{32}) \tag{9}$$

Ratio i (input rotational velocity divided by output rotational velocity) can be easily obtained:

$$i = \omega_1 / \omega_6 = -N_{65} / N_{h15} \, (1 + N_{21} \cdot N_{32}) \tag{10}$$

We can write the following equation considering that: $N_{ij} = z_i / z_j$ where: z_i and z_j equal to the number of teeth on the wheels i and j, respectively:

$$i = -z_6 / z_{h1} \, (1 + z_3 / z_1) \tag{11}$$

The data for the second working mode are given in Table 3. The modified scheme and graph are presented in Fig. 2 a,b.

Table 3. Details of operations of the gear for the 2-nd working mode

Case B)	Braked ($\omega_i = 0$)	Input	Output
	3, 6	1	h2

The same cycles – as in the case A) - can be used to write the system to solve. The system can then be simplified, considering braked elements (($\omega_3 = 0$) and ($\omega_6 = 0$),), as follows:

$$\omega_1 = \omega_{h1} - N_{21} \cdot (\omega_2 - \omega_{h1}) \tag{12}$$

$$\omega_2 = (1 - N_{32}) \cdot \omega_{h1} \tag{13}$$

$$\omega_5 = (1 - N_{h15}) \cdot \omega_{h2} - N_{h15} \cdot \omega_{h1} \quad (14)$$

$$\omega_5 = (1 - N_{65}) \cdot \omega_{h2} \quad (15)$$

Ratio *i* can be obtained

$$i = \omega_1 / \omega_{h2} = (N_{21} \cdot N_{32} + 1)(N_{65} - N_{h15}) / N_{h15} \quad (16)$$

We can write the following equation considering $N_{ij} = z_i / z_j$ with z_i and z_j equal to the number of teeth

$$i = (z_3 / z_1 + 1) \cdot (z_6 / z_{h1} - 1) \quad (17)$$

Table 4. Details of operations of the gear for the 3-rd working mode

Case C	Braked ($\omega_i = 0$)	Input	Output
	3, 1	h2	6

This case can be considered as a one-row gear, because of the braked elements. So, the analysis is restricted to 2 f-cycles:

F-cycles	Equations	
(5,h1)h2	$\omega_5 - \omega_{h2} = - N_{h1,5} \cdot (\omega_{h1} - \omega_{h2})$	(18)
(5,6)h2	$\omega_5 - \omega_{h2} = + N_{65} \cdot (\omega_6 - \omega_{h2})$	(19)

The system can be simplified as follows:

$$\omega_5 = \omega_{h2} \cdot (1 + N_{h15}) \quad (20)$$

$$\omega_5 = + \omega_6 \cdot N_{65} + \omega_{h2} \cdot (1 - N_{65}) \quad (21)$$

Ratio i can be obtained

$$i = \omega_{h2} / \omega_6 = N_{65} / (N_{h15} + N_{65}) \quad (22)$$

We can write the following final equation, considering as previously: $N_{ij} = z_i / z_j$ with z_i and z_j equal to the number of teeth:

$$i = z_6 / (z_{h1} + z_6) \quad (23)$$

Table 5. Details of operations of the gear for the 4-th working mode

Case D)	Braked ($\omega_i = 0$)	Input	Output
	1, 6	3	h2

F-cycles	Equations	
(1,2)h1	$\omega_1 - \omega_{h1} = - N_{21} \cdot (\omega_2 - \omega_{h1})$	(24)
(2,3)h1	$\omega_2 - \omega_{h1} = + N_{32} \cdot (\omega_3 - \omega_{h1})$	(25)

(5,h1)h2 $\omega_5 - \omega_{h2} = -N_{h1,5} \cdot (\omega_{h1} - \omega_{h2})$ (26)

(5,6)h2 $\omega_5 - \omega_{h2} = +N_{65} \cdot (\omega_6 - \omega_{h2})$ (27)

The system can be simplified, considering braked elements, as follows:

$$\omega_{h1} = -N_{21} \cdot (\omega_2 - \omega_{h1}) \tag{28}$$

$$\omega_2 = \omega_{h1} + N_{32} \cdot (\omega_3 - \omega_{h1}) \tag{29}$$

$$\omega_5 = \omega_{h2} - N_{h1,5} \cdot (\omega_{h1} - \omega_{h2}) \tag{30}$$

$$\omega_5 = \omega_{h2} + N_{65} \cdot \omega_{h2} \tag{31}$$

Ratio *i* can be obtained:

$$i = (1 + z_1 / z_3)(1 + z_6 / z_{h1}) \tag{32}$$

Table 6. Details of operations of the gear for the 5-nd working mode

Case E)	Braked ($\omega_i = 0$)	Input	Output
	1, h2	3	6

In this case, once more, two elements are braked. Therefore the considered equations are as follows:

F-cycles Equations

(1,2)h1 $\omega_1 - \omega_{h1} = -N_{21} \cdot (\omega_2 - \omega_{h1})$ (33)

(2,3)h1 $\omega_2 - \omega_{h1} = +N_{32} \cdot (\omega_3 - \omega_{h1})$ (34)

(5,h1)h2 $\omega_5 - \omega_{h2} = -N_{h1,5} \cdot (\omega_{h1} - \omega_{h2})$ (35)

(5,6)h2 $\omega_5 - \omega_{h2} = +N_{65} \cdot (\omega_6 - \omega_{h2})$ (36)

The system can be simplified, considering the braked elements, as follows:

$$\omega_2 = \omega_{h1} \cdot (1 / N_{21} + 1) \tag{37}$$

$$\omega_2 = \omega_{h1} + N_{32} \cdot (\omega_3 - \omega_{h1}) \tag{38}$$

$$\omega_{h1} = -\omega_5 / N_{h15} \tag{39}$$

$$\omega_5 = +N_{65} \omega_6 \tag{40}$$

Finally, the current ratio *i* can be obtained

$$i = \omega_3 / \omega_6 = [(N_{21} + N_{32}) / N_{21} N_{32}] \times N_{65} / N_{h15} \tag{41}$$

We can write the following formula for the ratio:

$$i = (z_2 / z_3 + z_1 / z_2) \times z_6 / z_{h1} \tag{42}$$

Table 7. Details of operations of the gear for the 6-th working mode

Case F)	Braked ($\omega_i = 0$)	Input	Output
	6, h2	1	3

In this case, the system can be considered as a one-row gear, because of braked elements. Due to the fact that ($\omega_{h2} = 0$), ($\omega_6 = 0$) therefore, ($\omega_{h1} = 0$) and ($\omega_5 = 0$).

The elements *5,6, h_2* can be considered as temporary redundant. The modified graph is presented in Fig. 2 c.
In consequence, two f-cycles are taken into account:

$$\text{(1,2)h1} \qquad \omega_1 - \omega_{h1} = -N_{21} \cdot (\omega_2 - \omega_{h1}) \tag{43}$$

$$\text{(2,3)h1} \qquad \omega_2 - \omega_{h1} = +N_{32} \cdot (\omega_3 - \omega_{h1}) \tag{44}$$

The system can be simplified, considering braked elements, as follows*:*

$$\omega_1 = -N_{21}(\omega_2) \tag{45}$$

$$\omega_2 = N_{32} \cdot \omega_{h1} \tag{46}$$

Ratio *i* can be obtained

$$i = \omega_1 / \omega_3 = -N_{21} \cdot N_{32} \tag{47}$$

We can write finally the following equation:

$$i = -z_3 / z_1 \tag{48}$$

All modes were considered, calculating the adequate ratios. As can be seen the consecutive considerations are similar, performed accordinng to the same pattern. The graph-approach gives elegant and effective tool of modelling.

3. Conclusions and final remarks

The exemplary compound planetary gear was modelled and analyzed by means of the mixed graph method. The ratios for the 6 possible working modes were calculated. The method has such advantages as: algorithmic approach and repeatable generation of equations. Moreover, the method leads to the system of algebraic scalar equations having solution which can be easily calculated.

A good engineering practice should be comparison of results. On the design stage, when the artifact is only in a virtual reality, at least different theoretical approaches should be utilized. The graph-based method is an additionally approach to the traditional Willis approach.

However, graph modelling has wider range of application including e.g. enumeration of design solutions [14] and synthesis.

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BADANIE SYSTEMU KORELACJI Z ORTOGONALNYMI FILTRAMI LAGUERRE'A ANALIZUJĄC SYGNAŁY SEJSMICZNE SŁABEJ INTENSYWNOŚCI

Streszczenie: Praca jest poświęcona problemom obróbki sejsmicznych sygnałów słabej intensywności w korelacjach systemach z poprzednią ortogonalną obróbką. Przeprowadzono szereg praktycznych eksperymentów i otrzymano wyniki analizy pracy typowego systemu korelacji i korelacji systemu z wejściowymi ortogonalnymi filtrami Laguerre'a przy nadejściu sygnału pod postacią poli-harmonicznego gasnącego sygnału i przeszkód, które są prezentowane w postaci liniowych losowych procesów stochastycznych.

Słowa kluczowe: sygnał sejsmiczny, przeszkoda, przetwarzanie korelacji, Laguerre'a ortogonalny filtr

RESEARCH OF THE CORRELATION SYSTEM WITH LAGUERRE ORTHOGONAL FILTERS IN ACTION LOW INTENSITY SEISMIC SIGNALS

Summary: The work is devoted to problems of processing seismic signals of weak intensity in correlation systems with previous orthogonal treatment. A number of practical experiments were conducted and results achieved showing an analysis of a typical correlation system and correlation system with Laguerre orthogonal input filters receiving the amount of desired signal as a poliharmonic fading signal and noise that are presented as a linear random processes.

Keywords: seismic signals, noise, correlation processing, Laguerre orthogonal filter

Scientific and technical problems of mineral exploration, including oil and gas are strategic problems in each country. The main method of geophysical exploration of mineral resources based on the study of the surface structure earth crust is seismic. This method is the most used and one of the most accurate and reliable methods of exploration. Introduction of the modern environmentally clean non-explosive vibration seismic research methods leads to decrease intensity of useful signals, which

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carry out information about the structure of geophysical environment and thus reduce the signal / noise ratio on the inputs seismic sensors, the action of various kinds of noises that arise at distribution of resilient waves.

Actual task of seismic research is detection and measure characteristics of the seismic signals low intensity the presence of noise. On the foreground the task of improving accuracy, noise immunity and reliability of the results of research and development of effective methods of their solution using noise protected correlation and orthogonal methods.

Therefore, scientific problem improving of mathematical models seismic signals and correlation method using orthogonal processing and create the appropriate algorithms and software for the implementation digital signal processing techniques in seismic systems is actual and important.

The general structure of the investigated correlation system of signal processing shown in Figure 1, where $R_{12}(\tau)$ response for a typical system and $\overline{R}_{12}(\tau)$ for orthogonal correlation measuring system.

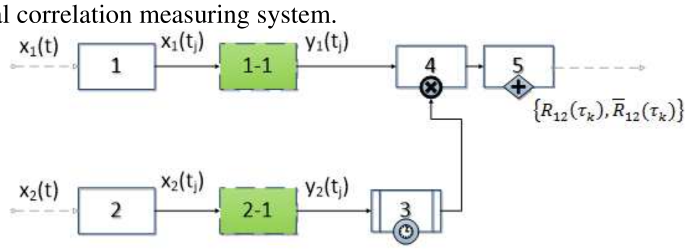


Figure 1. The general structure of correlation measuring system with Laguerre orthogonal filters: 1, 2 - ADC analog seismic signals, 1-1, 2-1 - discrete Laguerre orthogonal filters, 3 – modulus shift by time signal with discrete argument; 4 - signal multiplication module; 5 – adding (integrator) module products of signals

Using the results of research published in [1] at the output of the correlation system we get the correlation transform $\overline{R}_{12}(\tau_k)$

$$\overline{R}_{12}(\tau_k) = \sum_{l=0}^{N} h_{12}(\tau_l) R_s(\tau_k - \tau_l) + \overline{R}_z(\tau_k), \tag{1}$$

where $h_{12}(\tau_l)$ - cross-correlation transform Laguerre function, $R_s(\tau_k)$ - cross-correlation transform useful seismic signals, $\overline{R}_z(\tau_k)$- correlation transform of the noise, which is determined by the formula (2)

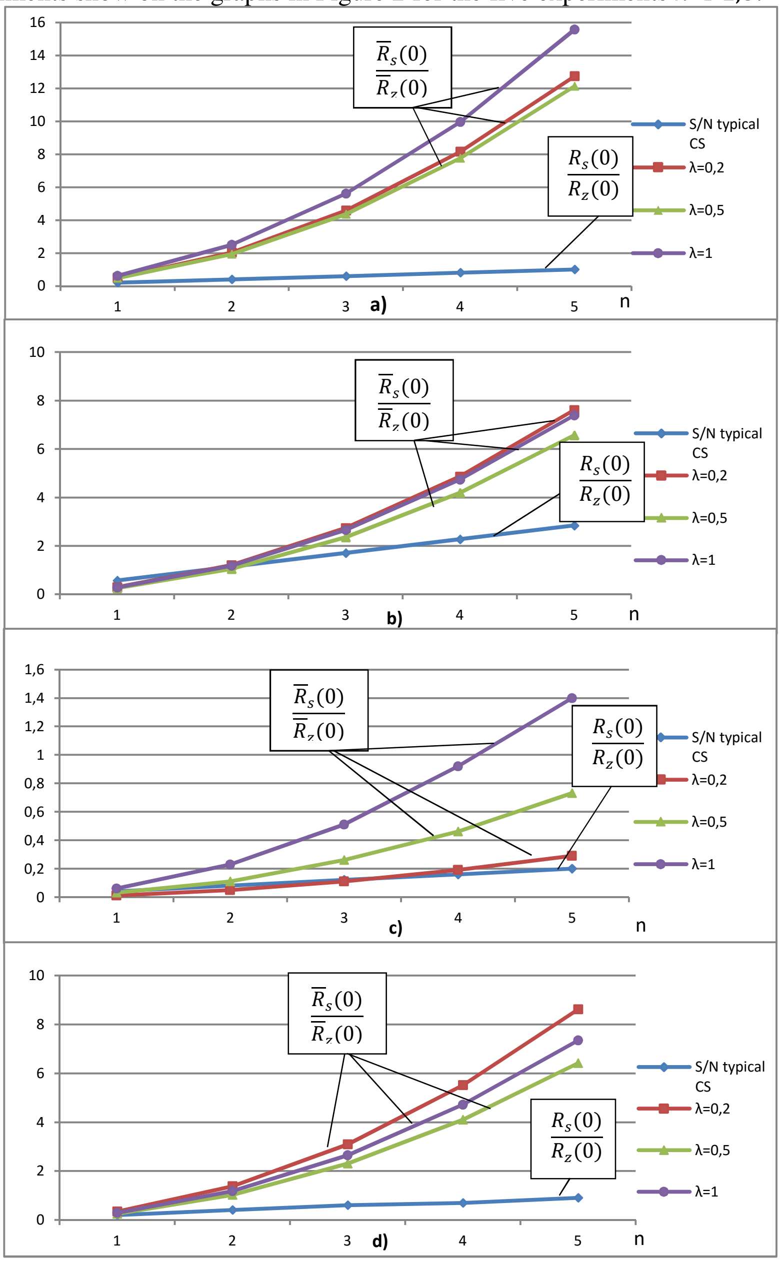
$$\overline{R}_z(\tau_k) = \sum_{l=0}^{N} h_{12}(\tau_l) R_z(\tau_k - \tau_l), \tag{2}$$

where $R_z(\tau_k)$ – correlation function of the input noise.

Justification mathematical models of seismic noise, and analysis of their processing in correlation systems with the previous orthogonal filtration given in [2, 3, 4]. In [5] presents the results of research useful seismic signals in correlation systems with the orthogonal filtration.

To determine the efficiency of correlation system with Laguerre orthogonal filters compared with the typical correlation system used the signal /noise ratio, that is $\frac{\overline{R}_s(0)}{\overline{R}_z(0)}, \frac{R_s(0)}{R_z(0)}$.

Have been conducted computer simulation experiments with different signal / noise ratio at the input of the systems. For an example the results of the computer experiments show on the graphs in Figure 2 for the five experiments $n \in \overline{1,5}$.



a) - white noise b) - painted noise c) - RC noise, d) - RLC noise

Figure 2. The results of experimental signal/noise ratio research at the output of the correlation system.

At the computer modeling used the following characteristics of useful signals and noises:

- useful signal represents the sum of the four harmonic signals with different amplitudes and frequencies,
- variance, ie $R_z(0)$ in all experiments select as a constant for different type of noises.

This made it possible to generate signals with different signal / noise ratio at the input of the researched correlation system and with the further definition the relation of their output.
As shown in Figure 2 the use of previous orthogonal filtration to correlation system makes it possible to improve the signal / noise ratio by the selection Laguerre filter settings. Particularly in figure 2b in the first experiment, the typical correlation system showed the best result. In processing the of useful seismic signal with noise hindrance type RC (Figure 2c) increase parameter λ = 0,5; λ = 1 Laguerre orthogonal filter allowed to improve the result of processing input signal
The results of the experiments are shown in the graphs illustrate under what conditions the correlation system with Laguerre orthogonal filters is more effective than the typical correlation processing by the action of the seismic signals of low intensity.
Based on the proposed model was developed a software for modeling seismic signals and processing in simulation experiments.

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EKSPERYMENTALNE POMIARY HAŁASU UKŁADU MECHANICZNEGO

Streszczenie: Celem artykułu jest wykazanie możliwości wykorzystania hałaśliwości układu mechanicznego do jego diagnostyki. Jest to możliwe ponieważ na podstawie tego parametru można określić dynamiczne właściwości systemów mechanicznych. Eksperyment przeprowadzono dla rzeczywistego układu mechanicznego, które zawiera pneumatyczne elastyczne sprzęgło. Przebiegi hałasu uzyskuje się podczas zmiany ciśnienia w pneumatycznym sprzęgle. Ponadto, właściwości dynamicznych układu mechanicznego były monitorowane w trakcie ustalonego stanu pracy obiektu.

Słowa kluczowe: hałas, drgania, układ mechanicznego

EXPERIMENTAL MEASUREMENT OF THE NOISE OF THE MECHANICAL SYSTEM

Summary: The aim of the article is to demonstrate a use of noise of the mechanical system as a parameter that can determine dynamical properties of the mechanical systems. The experiment is carried out on the realized mechanical system, which includes a pneumatic flexible coupling. Noise courses are obtained during varying the pressure in the pneumatic flexible coupling and dynamical properties of the mechanical system are monitored during the steady state.

Keywords: noise, vibration, mechanical system

1. Introduction

The noise is unwanted sound that creates an unpleasant or disturbing sensation for the human. Except that fact, the noise generated by mechanical system has a negative impact on durability, reliability and safety of the mechanical system, which are part of the machinery. Periodic movement of the working machine, which thus creates a

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periodic force cause a vibration and noise. Therefore, vibration and noise can never be totally excluded. In order to obtain knowledge of whether and how noise and vibration are interconnected, an experiment was conducted and described in this article. At our Department of Construction, Automotive and Transport Engineering, Faculty of Mechanical Engineering of Technical University of Kosice was designed and implemented a mechanical system in which the measurements were carried out. The measured parameter was a noise of the mechanical system under certain parameters of the mechanical system [1, 3, 4, 5, 6, 7, 8, 9, 10].

2. Designed mechanical system

For the realization of noise measurement, the mechanical system (schematically shown in Fig.1) was designed in Laboratory of Measuring and Tuning of Torsional Vibration at the Department of Construction, Automotive and Transport Engineering [2, 3, 4].

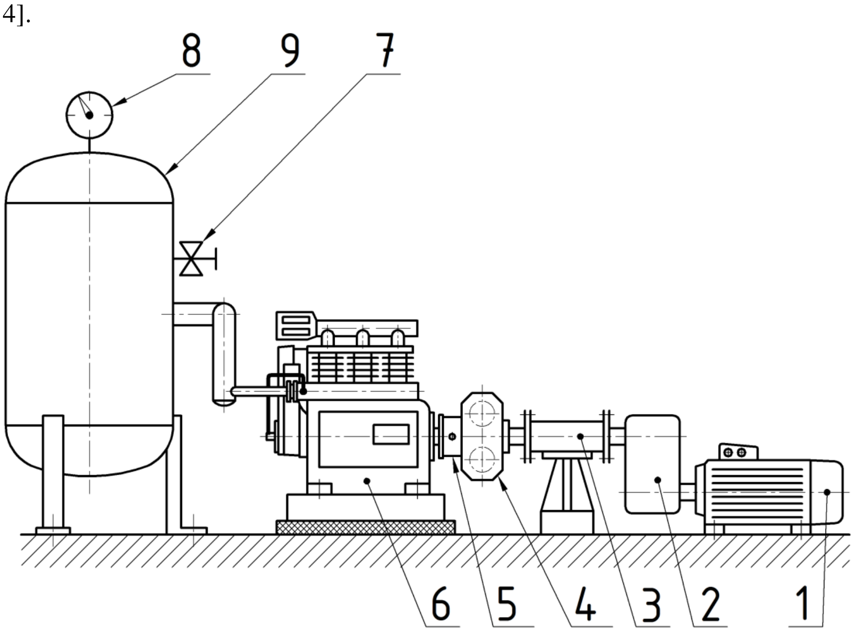

Figure 1. Scheme of designed mechanical system

Designed mechanical system is made up of three-cylinder air compressor (6), which is driven through a pneumatic flexible coupling (4) by three-phase asynchronous electric motor (1). Label (5) belongs to a place in a pneumatic flexible coupling, where the air is filled. After electric motor, two-speed gearbox (2) and torque sensor (3) are located. Consequently, the compressed air flows from the compressor to the pressure tank (9) with a volume of 300 l. Air pressure in the pressure tank is controlled by a throttle valve (7), which regulates the mechanical load on the whole system and it is written off from the pressure gauge (8) [1, 2, 3].

Following figure shows photographic image of the mechanical system monitored in Laboratory of Measuring and Tuning of Torsional Vibration. Individual positions of parts of the mechanical system correspond to the indications in Fig. 1.

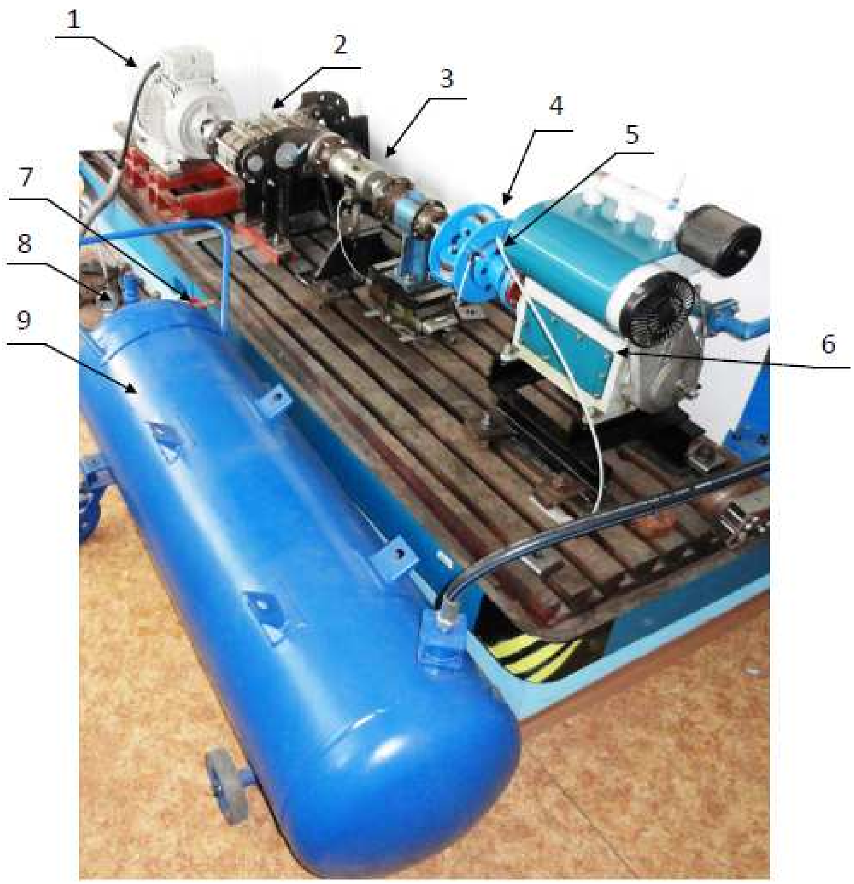

Figure 2. Experimental mechanical system

3. Description of noise measurement

A mechanical vibration that distributes and transmits energy is an evidence of the existence of vibro-acoustic waves in the environment. It negatively affects the lifetime of structural components and mechanical systems. Mechanical vibration which propagates in the mechanical systems and machine structures transmits a part of its energy to the environment in the form of acoustic oscillation (sound), which affects the noise conditions of that environment.

For specification of measurement conditions, following paragraphs describe location, methods and measuring apparatus of the implemented measurement.

3.1. Location of the measurement

Measuring apparatus was placed enough far from the mechanical system to simulate real conditions during work running of machinery which can present such mechanical system. In other words, the measuring apparatus was placed on a tripod at a height from the floor in which the hearing organ of a person working with the machinery is [2].

3.2. Method of the measurement

Noise level of the mechanical system was measured during a change of the pressure of the gaseous medium in the pneumatic flexible elements of the coupling. The range of the gas pressure was from 200 kPa to 700 kPa, and a change of the operating speed of electric motor range from 100 - 1000 rpm^{-1} and as well as in their combinations. Length of measurement cycle at different parameters of the mechanical system was 20 s. The mechanical system was under constant load of 0.5 kPa and the measurement was carried out in a steady state [2].

3.3. Quantity and Unit of the Measurement

During each measurement, the value A-weighted equivalent sound pressure level in dB was measured over a period of time.

3.4. Measuring Apparatus

In experimental noise measurement of the mechanical system, the following devices were used:

- handheld sound analyzer Brüel & Kjær Type 2250
- Microphone Type 4189, nominal sensitivity 50 mV / Pa
- Acoustic Calibrator Brüel & Kjær. [2]

4. Experimental noise measurement

During the experimental noise measurement in Laboratory of Measuring and Tuning of Torsional Vibration at our department, A-weighted equivalent sound pressure level was read directly from the sound analyzer. The results of measurement are shown in the following graph as a dependence of a noise on the revolutions of electric motor.
The measurement was performed at steady operation of the mechanical system with the following parameters:

- pressure in pneumatic flexible coupling: 200 ÷ 700 kPa; scaling of 100 kPa,
- electric motor operating speed: 200 ÷ 1000 rpm; scaling of 50 rpm.

Fig. 3 shows courses of noise changes in the mechanical system during a change of the operating speed of electric motor in the range of 200-1000 rpm, with scaling of 50

rpm. As can be seen from the course, the lowest noise value is recorded at an operating speed of 200 rpm, which was measured for L_{Aeq} at intervals of 81 dB - 83,5 dB. With an increasing operating speed there also increase in direct proportion the value of noise level with an increasing pressure in the pneumatic flexible coupling. The most significant increase of noise is observed at a pressure of 200 kPa, when during an operating speed of 350 rpm, in the range of 150 rpm, a noise level increased up to 10 dB. At the same pressure of 200 kP in a pneumatic coupling and at a speed of 500 rpm, the first resonance of the mechanical system was reached. The resonant peak is recorded at level of L_{Aeq} 96.1 dB.
Other resonances that occur during a change of air pressure in the pneumatic flexible coupling in range of 100 kPa were recorded periodically in the range of operating speed 550-750 rpm, at every 50 rpm [2].

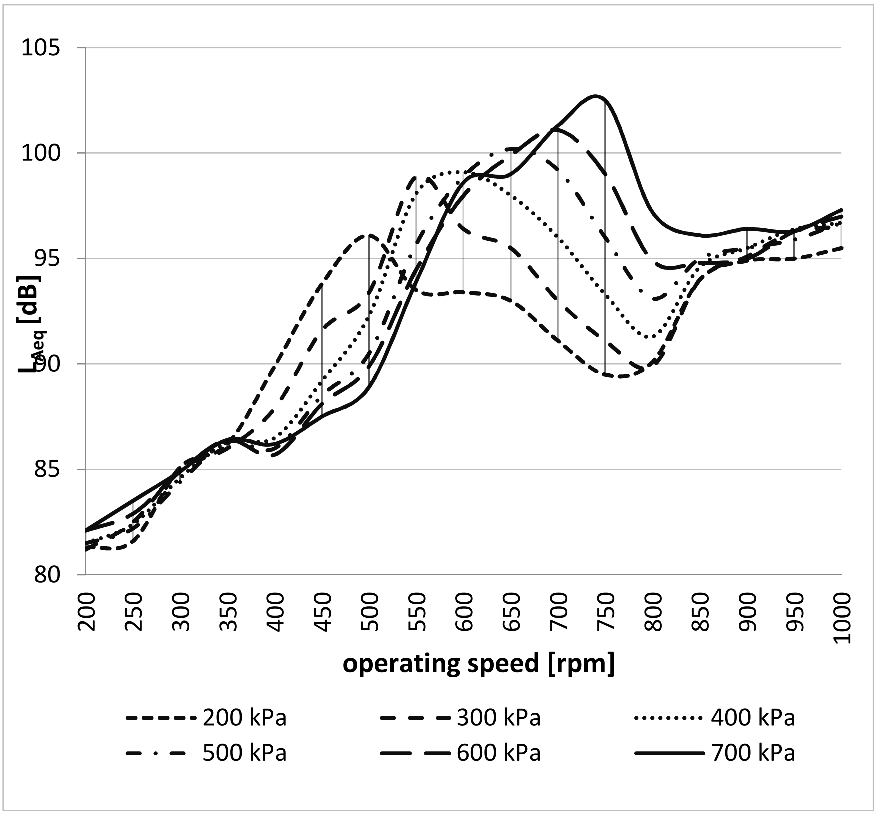

Figure 3. Courses of the measured noise of the mechanical system

5. Conclusion

After summarization of the received results, we could confirm a possibility of use a noise of the mechanical system as a parameter that can determine dynamical properties of the mechanical system. As well, it is possible to state a creation of resonances from the courses of the nosiness. Therefore, a noise could be considered as a factor used in a solving of mechanical system´s questions.

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INDEKS NAZWISK
INDEX OF NAMES