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TECHNOLOGIA STRUKTURALNEJ KLASYFIKACJI RAMEK WIDEO W INTELIGENTNYCH SYSTEMACH TELEINFORMATYCZNYCH

Streszczenie: W artukule opisano metodę klasyfikacji mikrosegmentów, ze względu na ich strukturalno-statystyczny poziom nasycenia. Podziału dokonuje się na trzy klasy bazując na zdefiniowanej metryce kwadratowej. Podziału dokonuje się poprzez ocenę liczbową poziomu nasycenia structuralno-statystycznego całego mikrosegmentu poprzez identifikację oraz parameteryzację obszarów spójnych, na bazie lokalnych różnych dwuwymiarowych przestrzeni w kierunku skanu diagonalego. Opracowana metoda polega na identyfikacji oraz parametryzacji własności strukturalno-statsytycznych microsegmentów. W metodzie bierze się pod uwagę lokalne charakterystyki segmentów; tj. lokalne niejednorodności struktury w przestrzeni dwuwymiarowej. Równocześnie bierze się pod uwagę zachowanie integralności semantycznj, obecność nadmiarowości psychovizualnej oraz zależności wewnętrzej korelacji dla różnych klas realistycznych ramek/klatek video.

Słowa kluczowe: ramki/klatki video, kwantyzacja, obszary spójności, intensywnośc informacji, mikrosegment

THE TECHNOLOGY OF STRUCTURAL CLASSIFICATION OF VIDEO FRAMES IN INTELLIGENT INFO-COMMUNICATION SYSTEMS

Abstract: The method of classification of microsegments by their structural-statistical level saturation in-to three classes based on the formation of a square metric for quantitative assessment of the level of structural and statistical saturation of the entire microsegment with using the identification and parameterization of coherence areas on the local basis of the

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unequal two-dimensional space in the direction of a diagonal scan was created. The developed approach concerning revealing and parametrization of structural-statistical properties of a microsegment takes into account its local unequal structure properties in two-dimensional space simultaneously from the point of view of preservation of semantic integrity, presence of psychovisual redundancy and internal correlated dependences for various classes of realistic video frames.

Keywords: video frame, quantization, coherence region, information intensity, microsegment

1. Introduction

The development of the spheres of state activity, society and the individual are accompanied by full-scale processes of informatization. A key component here is to ensure timely exchange of information between users, using wireless infocommunication technologies, including the mobile segment. At the same time, an analysis of the requirements for video services shows that the necessary time delays in the delivery of video images under conditions of a given quality of video service using wireless technologies are not achieved.
Thus, reducing the information intensity of video data to improve the performance of information systems with a given quality of video service is an urgent scientific and applied problem.
One of the ways to solve this is to conduct a preliminary classification of the microsegments of a video frame by the degree of their information load. It is necessary to take into account the need to maintain the level of complexity of the algorithmic implementation.

2. Main material

The classification of microsegments $S(X)_{i,j}^{(u)}$ by the level of their structural and statistical saturation is carried out at the first stage of the decision-making system in the process of identifying segments $S(X)_{i,j}$. Such a classification consists in establishing whether a microsegment belongs to one of three types, depending on the level of its structural and statistical saturation. Classification of a microsegment in the general case can be carried out in the spectral-spatial or time-spatial form of its syntactic description. The advantages of spectral-spatial representation for the classification of sections of a video frame are the possibility of using energy redistribution and its concentration in a limited number of transform components. A transform is here understood as an array of elements after a discrete cosine transform. At the same time, such a representation of the microsegment is characterized by the fact that the structure of the syntactic representation corresponding to the semantic perception of the information of the original video frame is destroyed, in the general case, the spectral-spatial description creates averaged ideas about the structural and statistical features of the initial microsegment. Local changes within the microsegment are not taken into account. There is a difficulty in classifying a microsegment with an average level of saturation with structural elements, but with a relatively low contrast relative to the main luminance background.

Therefore, there is a need to organize the classification of microsegments of a video frame in a time-spatial description of its brightness component. One of the effective approaches here is the use of technological mechanisms related to the identification and parameterization of coherence regions (CR).

The ***coherence region*** is understood as the local section $X(u)^{(\alpha)}$ of the microsegment $S(X)^{(u)}_{i,j}$ of the video frame, the values of the elements $x(u)_{\alpha,\gamma+\tau}$ of which are within the local attribute $\delta^{(loc)}$, which characterizes the permissible changes in their values from the position of the absence of loss of semantic integrity of the video resource (Fig. 1). In the general case, the coherence region is formed by elements that satisfy a given order of priority, but are not necessarily adjacent in location in the microsegment. Then α is the coherence region $X(u)^{(\alpha)}$ for u of the microsegment from the position of the local attribute $\delta^{(loc)}$ in the general case is described as follows:

$$\varphi(\delta^{(loc)})_{cr}: \; X(u)^{(\alpha)} = \{x(u)_{\alpha,\gamma};...;\, x(u)_{\alpha,\gamma+\tau};\, ...;x(u)_{\alpha,\gamma+\ell_\alpha-1}\}, \qquad (1)$$

$$x(u)_{\alpha,\gamma+\tau} \in [\beta_\alpha - \frac{\delta^{(loc)}}{2};\; \beta_\alpha + \frac{\delta^{(loc)}}{2}], \quad \tau = \overline{0,\, \ell_\alpha - 1}.$$

Moreover, the sequence $\{x(u)_{\alpha,\gamma};...;\, x(u)_{\alpha,\gamma+\tau};\, ...;x(u)_{\alpha,\gamma+\ell_\alpha-1}\}$ consists of elements, in the General case, not necessarily located in the microsegment at adjacent positions.

In the formula (1), the following notation is adopted:

$\varphi(\delta^{(loc)})_{cr}$ - functional of revealing the coherence region from the position of a local attribute $\delta^{(loc)}$ (coherence region). In the particular case if $\delta^{(loc)} = 0$, then the coherence region will include elements with equal values;

β_α - initial value of the coherence region or base level of the coherence region;

$[\beta_\alpha - \frac{\delta^{(loc)}}{2};\; \beta_\alpha + \frac{\delta^{(loc)}}{2}]$ - range of acceptable values for elements of the coherence region;

$x(u)_{\alpha,\gamma+\tau}$ - τ element α of the coherence region for u microsegment.

ℓ_α - number of elements in the area of coherence.

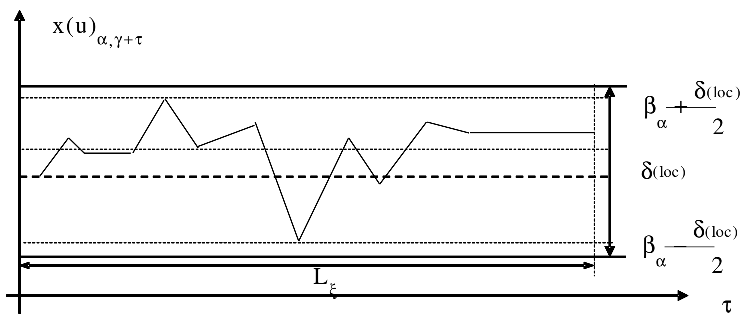

Figure 1. The general structure of the coherence region

It is clear that if for an element $x(u)_{\alpha,\gamma+\ell_\alpha}$ none of the following conditions is satisfied:

$$x(u)_{\alpha,\gamma+\ell_\alpha} > \beta_\alpha + \frac{\delta^{(loc)}}{2} \text{ or } x(u)_{\alpha,\gamma+\ell_\alpha} < \beta_\alpha - \frac{\delta^{(loc)}}{2}, \quad (2)$$

then it is the first element of the next $(\alpha+1)$ area of coherence, i.e. $x(u)_{\alpha,\gamma+\ell_\alpha} = x(u)_{\alpha+1,\gamma}$.

This option for identifying and parameterizing the structural and statistical properties of a microsegment takes into account its local non-uniform structural properties simultaneously with the position of maintaining semantic integrity, the presence of psychovisual redundancy and internal correlation dependencies for various classes of realistic video frames.

The basic parameters for revealing the structural and statistical properties of a microsegment using the formation of coherence regions are the local attribute $\delta^{(loc)}$ and the number of elements n_α in the coherence region.

By identifying the coherence region, localization of the properties of video frames in the spatial region is ensured. These properties include statistical, structural dependencies, and psycho-visual features of the visual perception of images. Therefore, the description of the video frame by the set Ω_{cr}, the identified areas of coherence, allows to evaluate structural and statistical patterns, classify the microsegment according to the degree of saturation with structural details and evaluate the number of different types of redundancy (statistical, structural and psychovisual).

Let us consider the formation of a metric for the quantitative assessment of the level of structural and statistical saturation of the entire $S(R)^{(u)}_{i,j}$ microsegment using the identification and parameterization of coherence regions by the local $\delta^{(loc)}$ feature in two-dimensional space in the direction of diagonal sweep.

It is proposed to use the dependence characterizing the informational value of the $S(R)^{(u)}_{i,j}$ microsegment regarding the preservation of semantic integrity. Then from the standpoint of the proposed approach for the identification and parameterization of structural and statistical properties will be the following correspondence:

1.micro-segments with a high level of structural-statistical saturation differ in the presence of a considerable number of sharp transitions of brightness and contrast between elements of video frames, namely, the number of elements in the coherence field does not exceed on average 4, $\overline{n(u)}_\alpha \le 4$, and its average number $\overline{\nu}^{(u)}_{ld}$ is at least 3, $\overline{\nu}^{(u)}_{ld} \ge 3$;

2.microsegments with an average level of structural-statistical saturation are characterized by the presence of a small number of brightness transitions. Therefore, the values of the corresponding parameters will be as follows: $3 \le \overline{n(u)}_\alpha \le 8$, and for the number of areas of coherence the inequality of the $2 \le \overline{\nu}^{(u)}_{ld} \le 3$ will be applied;

3.microsegments with a low level of structural and statistical saturation are distinguished by the absence of sharp changes between the elements. Therefore, they will be characterized by: $\overline{n(u)}_\alpha > 8$ and $\overline{\nu}_{ld}^{(u)} \le 2$.

The value of the level of structural and statistical saturation of the microsegment should increase with an increase in the number of coherence regions and a decrease in their lengths. The greater the number of contrast transitions, the greater the level of informational contribution of a given microsegment to maintaining the required degree of semantic integrity of the entire video resource. On the contrary, with an increase in the area of the microsegment, which has a slightly varying brightness, i.e. on the one hand, the value of $\overline{n(u)}_\alpha$ increases, and on the other hand $\overline{\nu}_{ld}^{(u)}$ decreases, the level of structural and statistical saturation will be the smallest. In other words, it is necessary to take into account the ratio between the area of the microsegment with significant brightness differences and the area of minor changes in brightness from the position of the local symptom of $\delta^{(loc)}$. Accordingly, the higher the frequency of the brightness differences, and the larger the area allotted for small parts and contour differences, the higher the structural and semantic information content.
Therefore, the value of the $\delta(x;u)$ metric should depend on the values of $n(u)_\alpha$ and $\nu_{ld}^{(u)}$. Moreover, to increase its sensitivity with respect to changes in the values of $n(u)_\alpha$ and $\nu_{ld}^{(u)}$ it is proposed to use a quadratic dependence on the values of $n(u)_\alpha$, i.e.

$$\delta(x;u) \sim n(u)_\alpha^2 . \tag{3}$$

The quadratic metric allows you to increase the distance between adjacent levels of structural and statistical saturation of microsegments. Then the metric $\delta(x;u)$ is proposed to be evaluated using the following formula:

$$\delta(x;u) = \frac{\sum_{\alpha=1}^{\nu_{ld}^{(u)}} n(u)_\alpha^2}{\nu_{ld}^{(u)} \cdot k^2} \tag{4}$$

where $(\sum_{\alpha=1}^{\nu_{ld}^{(u)}} n(u)_\alpha^2) / \nu_{ld}^{(u)}$ - the average length of the coherence region squared;

k^2 - the number of elements in the microsegment;

$n(u)_\alpha^2$ - length α squared coherence region;

$\nu_{ld}^{(u)}$ - number of coherence regions identified for u microsegment.

With this in mind, the value $(\sum_{\alpha=1}^{\nu_{ld}^{(u)}} n(u)_\alpha^2) / \nu_{ld}^{(u)} \cdot k^2$ can be interpreted as a quadratic section of the average area of the coherence region per one microsegment element.
Equation (4) defines a metric for the quantitative assessment of the level of structural and statistical saturation of the microsegment using the identification and parameterization of coherence regions from the position of the local attribute $\delta^{(loc)}$.
Consider a standard classification rule (classifier) to establish a correspondence

between the level of structural and statistical saturation of a microsegment and its class from the position of selected threshold values δ_{min} and δ_{max}. Corresponding classifier by values $(\sum_{\alpha=1}^{\nu_{ld}^{(u)}} n(u)_{\alpha}^{2}) / \nu_{ld}^{(u)}$ and $(\sum_{\alpha=1}^{\nu_{ld}^{(u)}} n(u)_{\alpha}^{2}) / \nu_{ld}^{(u)} \cdot k^{2}$ depending on the value $\nu_{ld}^{(u)}$ and the sequence $\{\ell(u)_{1}^{2};...;\ell(u)_{\alpha}^{2};...;\ell(u)_{\nu_{ld}^{(u)}}^{2}\}$ is presented in table 1. In table 1, the classes of microsegments are highlighted with the corresponding color. The darkest color corresponds to the parameters obtained for microsegments with a high level of structural and statistical saturation. On the contrary, the lack of color corresponds to the parameters for a microsegment with a low level of structural and statistical saturation. From the analysis of the table 1 it follows that as threshold values it is allowed to choose the following levels: $\delta_{max} = 5$ and $\delta_{min} = 2$.

Table 1. Classification of microsegments by $(\sum_{\alpha=1}^{\nu_{ld}^{(u)}} \ell(u)_{\alpha}^{2}) / \nu_{ld}^{(u)}$ *and* $(\sum_{\alpha=1}^{\nu_{ld}^{(u)}} \ell(u)_{\alpha}^{2}) / \nu_{ld}^{(u)} \cdot n^{2}$ *values and depending on the value* $\nu_{ld}^{(u)}$ *and the sequence* $\{\ell(u)_{1}^{2};...;\ell(u)_{\alpha}^{2};...;\ell(u)_{\nu_{ld}^{(u)}}^{2}\}$

$(\sum_{\alpha=1}^{\nu_{ld}^{(u)}} n(u)_{\alpha}^{2}) / \nu_{ld}^{(u)} \cdot k^{2}$	$(\sum_{\alpha=1}^{\nu_{ld}^{(u)}} n(u)_{\alpha}^{2}) / \nu_{ld}^{(u)}$	$\{n(u)_{1}^{2};...;n(u)_{\alpha}^{2};...;n(u)_{\nu_{ld}^{(u)}}^{2}\}$	$\nu_{ld}^{(u)}$
16	16	16; 0	1
7	14,12	15; 1	2
6,2	12,5	14; 2	2
5,5	11	13; 3	2
4	8	8; 8	2
2,4	7,3	10; 3; 3	3
1	4	4; 4; 4; 4	4
0,65	3,25	3; 3; 3; 3; 4	5
0,25	2	2; 2; 2; 2; 2; 2; 2; 2	8

As a result of using the created method for identifying significant sections of a video frame, it is possible to maintain the integrity of information about objects of interest. The probability of identifying segments as a significant informative load in a video frame reaches 95%. Accordingly, the probability of a false detection error does not exceed 5 - 7%. This means that the segments of the brightness component of the video frame are correctly evaluated to identify areas of the image that have pronounced structural transitions, texture and brightness differences. Comparative evaluation of syntactic representation methods by the level of information intensity $V'(\delta)_{t\Sigma}$ for video frames, depending on the percentage of key segments of information in them (if using the created method of classification of segments of the video frame) in terms of peak signal / noise ratio $h \geq 35\,dB$ presented in Fig. 2. video frame $D = 2048 \times 1536$.

From the analysis of the diagrams in Fig. 2, it can be concluded that for the developed method based on the differential coding of the video frame segments, taking into account the availability of key information for the peak signal-to-noise ratio at the level of 35 dB, it follows that the degree of k_{comp} reduction of information bit rate for the developed method in 20% higher than standardized platforms. This reduces the level of information intensity for the encoded bit stream using the created method compared to the level of information intensity, provides for standardized technologies from 15 to 35%, depending on the percentage of key information segments. The gain in value of the decrease in the level of information intensity increases with the increase in the percentage of base segments. In this case, the conditions are created for the redistribution of energy costs towards syntactically representing key information segments.

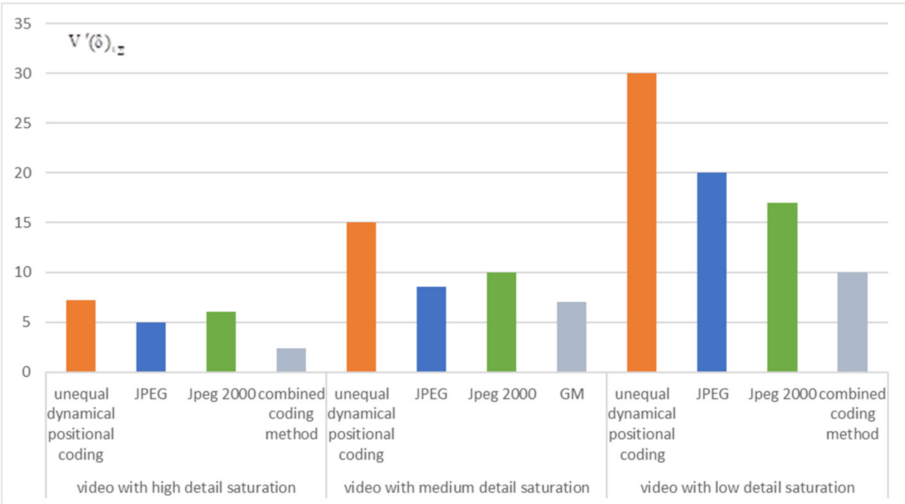

Figure 2. The dependence of the $V'(\delta)_{\iota\Sigma}$ *on the percentage of key information segments in terms of* $h \geq 35$ *dB*

3. Conclusion

According to the above material, we can conclude that it is substantiated that to classify microsegments of video frames and identify local patterns under conditions of an average level of saturation of video images with structural details, it is more efficient to use the format for identifying coherence regions as compared to using a spatially spectral description. A method has been created for classifying microsegments according to the level of their structural and statistical saturation into three classes based on the formation of a quadratic metric to quantify the level of structural and statistical saturation of the entire microsegment using the identification and parameterization of coherence regions that are locally thinned in two-dimensional space in the direction of the diagonal scan.

The method for classifying microsegments based on their structural-statistical saturation has been improved. The basic differences of the method are that for a quantitative assessment of the level of structural and statistical saturation of the microsegment, a quadratic metric is formed using parameterization of the identified areas of coherence according to a local attribute, thinned out in two-dimensional space in the direction of the diagonal scan. This allows us to take into account the local non-uniform structural properties of the microsegment in two-dimensional space simultaneously from the position of maintaining semantic integrity, the presence of psychovisual redundancy and internal correlation dependencies for various classes of realistic video frames.

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