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Creation of a virtual learning environment for the needs of teaching industrial engineering

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Abstract: The virtual learning environment represents an innovative and interactive approach to practical learning. This article focuses on the application of virtual reality in the teaching of industrial engineering subjects. At the beginning, the article offers an introduction to the issue under investigation. At the core, the article introduces the methodology of creating a virtual learning environment for teaching industrial engineering subjects. The article discusses the two main units of the methodology. These are the creation of a library of 3D models of the desired objects and the creating of a learning virtual environment using the library of 3D models. Both main units are divided into smaller parts and steps. This approach ensures the modularity of the methodology for wide use and ease of modification. The main objective of the methodology is considered to be the use of virtual reality tools for teaching industrial engineering subjects. Furthermore, the article introduces the LeanOn application, which serves as an example of the implementation of the methodology. The final part is concentrated on the evaluation of the results. In the results, the positives but also the negatives of the virtual learning environment created using the proposed methodology are pointed out.

Keywords: Virtual reality, Methodology, Education, 3D modelling, Application development;

Przygotowanie wirtualnego środowiska edukacyjnego na potrzeby nauczania inżynierii przemysłowej

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Abstrakt: Wirtualne środowisko nauczania stanowi innowacyjne i interaktywne podejście do praktycznej nauki. Niniejszy artykuł koncentruje się na zastosowaniu wirtualnej rzeczywistości w nauczaniu przedmiotów z dziedziny inżynierii przemysłowej. Przedstawiono przegląd literatury, przedstawiono metodologię tworzenia wirtualnego środowiska uczenia się. Omówiono dwa główne działania, są to: tworzenie biblioteki modeli 3D pożądanych obiektów oraz tworzenie wirtualnego środowiska edukacyjnego z wykorzystaniem biblioteki modeli 3D. Oba moduły podzielono na mniejsze części i etapy. Ponadto w artykule omówiono aplikację LeanOn, która służy jako przykład wdrożenia metody. Ostatnia część koncentruje się na ocenie wyników, w których przedstawiono zalety oraz wady metody.

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Słowa kluczowe: Rzeczywistość wirtualna, metodologia, edukacja, modelowanie 3D, tworzenie aplikacji;

1. Introduction

In recent years, there has been a rapid increase in the use of virtual reality technologies in education. More and more educational institutions and businesses are implementing such forms of technology in their teaching processes. The reason for the wider use of virtual reality is its ability to offer an interactive and realistic environment that allows students to experience learning in a practical and fun way while bringing a new perspective to established information about the subject area being explored [1,5].

Implementing virtual reality in teaching has many benefits. Students can move around in a 3D environment, experimenting with different scenarios, which contributes to a deeper understanding of the curriculum. Virtual reality also allows for a personalized approach to learning, where students can adapt the pace and style of learning to suit their needs. In addition, it encourages collaboration between students and creates an environment for exploring new concepts [2,5].

It is to such a way of learning, or how such a way of learning can be created, that this article is devoted to the creation of a virtual learning environment for the needs of teaching industrial engineering subjects. The article takes as its main goal to bring a methodology that can simplify and concretize the necessary parts of the creation. The conclusion of the article is to verify the functionality of the methodology in the creation of a simple LeanOn software. This provides hands-on proof of the ability of one person to create a learning virtual environment without the need for a whole team of specialists. A virtual learning environment created in this way can provide an option for hands-on learning [3].

2. Methodology of creating a learning virtual environment into virtual reality

For more practical teaching of industrial engineering subjects, it is often used to visit a company or to meet people from practice for lectures. However, outside of this, it is almost impossible to transfer these conditions and valuable experiences to regular teaching. A major problem with practical teaching arises especially during a global pandemic or the unavailability of a willing suitable enterprise. [2].

For such a transfer, however, at least a little knowledge of several areas such as 3D modeling, game design, or programming is needed. All these areas have a very large amount of information, and a large amount of knowledge is needed to understand them fully and in detail. At the same time, each of these areas offers multiple solutions and possibilities for creating a virtual learning environment using virtual solver technology. Therefore, it is necessary to guide novices as well as experienced developers from each area in the best way by creating a comprehensive methodology. Such a methodology serves as a guide that does not restrict the user too much and provides a basic skeleton. [4,6].

The proposed methodology does not push the creator into one correct solution, but itself offers several alternative solutions for the best flexibility of user creation. To validate this methodology, a virtual learning environment of the LeanOn application was created. This application currently contains one level with a scenario designed for the subject of production management. The methodology thus developed for the creation of a virtual reality learning environment (application) is suitable for inclusion in the teaching of almost any industrial engineering subject. It brings a new perspective to a common and static problem. Virtual reality can take students into practice without having to leave school. The methodology consists of two main interrelated units:

1. Creation of a library of 3D models of the desired objects,
2. Creating a virtual learning environment using a library of 3D models.

A closer look at these two main units and their procedures can be seen in Figure 1. The individual parts will also be described in terms of creating a LeanOn application. The individual steps of these parts will be addressed in more detail in subsequent articles and the continuation of the research.

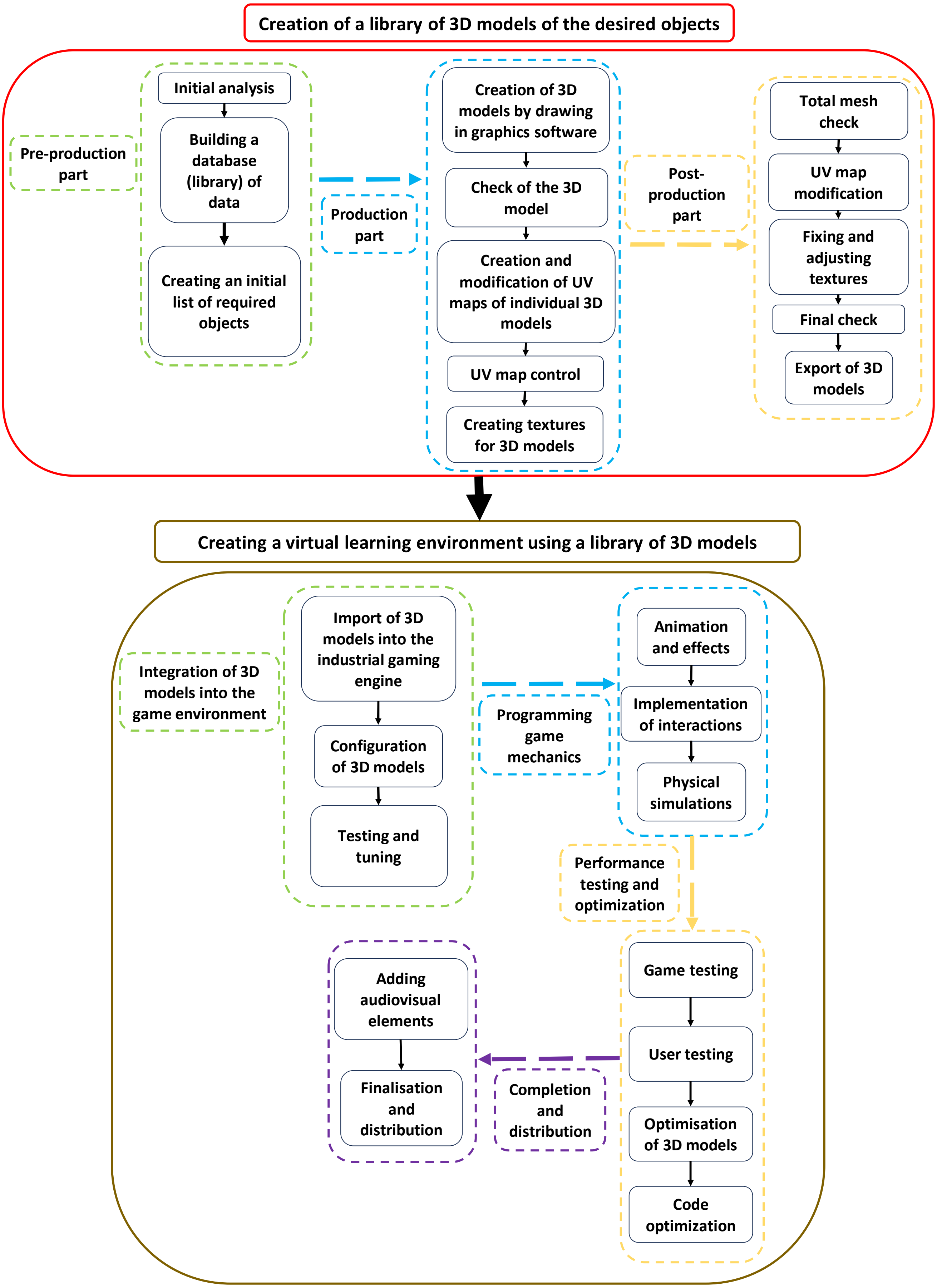

Figure 1. Methodology of creating a learning virtual environment into virtual reality

2.1. Creation of a library of 3D models of the desired objects

The first big and essential unit is the creation of a library of necessary 3D models, which the creators plan to draw from. The 3D model library should be populated with 3D models that are suitable for virtual reality. Thus, they must not exceed the vertex complexity level. At the same time, this unit also partially corrects the overall ideas for the final form of the product, i.e. the virtual learning environment. In the methodology, this first main part is mainly responsible for the analytical and preparatory phase, when all the necessary background, i.e. data for the future creation, is collected. The first part thus consists of three smaller parts:

1. pre-production part,
2. production part,
3. post-production part.

The three parts consist of individual concrete steps that build on each other. However, the methodology tries to be flexible and open to specific needs. In some of the smaller steps, there is a need for continuity. Failure to do so can lead to mistakes, which often result in a great loss of time. Such time loss then arises because of the need to repeat an entire step or even a smaller part. This methodology and its steps, based on the experience of the authors, prevent such errors.

2.1.1. Pre-production part

The first steps used by the methodology fall under a smaller part called the pre-production part. As the name suggests, the steps performed in this minor part lay the foundations for future applications and precede the actual creation or acquisition of the individual models. In this part, data is extensively collected and the basic premise of the overall form and functioning of the future learning virtual environment in the form of an application is established. At the same time, after these steps, a list of required objects, i.e. 3D models, which are necessary for creation, emerges as one of the results.

The creation of a LeanOn application to teach the subject of industrial engineering was chosen as a test of the functionality of the methodology. Specifically, it concerns the teaching of the subject of production management. The LeanOn application has as its main objective, in a virtual environment, to display a fictitious industrial hall. This application is primarily intended for students, educators, and researchers. It aims to provide hands-on experience without the need to visit real plants. It uses the Ella Platform, which is an industrial-gaming engine. To obtain the necessary models, a combined approach of creating 3D models and using existing models from online libraries was chosen. To create 3D models, the software Blender was chosen, which allows their manual creation. The pre-production part of the LeanOn application involved the creation of the hall objects and their contents, while the necessary data and resources were gradually collected to complete the application.

2.1.2. Production part

This is the time-consuming part in terms of creating the actual 3D models for a fully functional 3D model library. 3D models are not only drawn in this part but also take on their external appearance in the form of textures. The production part can only be considered complete when all 3D models from the initial list of required objects have been obtained. It is also possible that extra objects will be added during the production process and thus extend the initial list. It is because of thinking and creative activity that one as a creator, with the help of creating small parts, often realizes that new components still need to be added for the final whole.

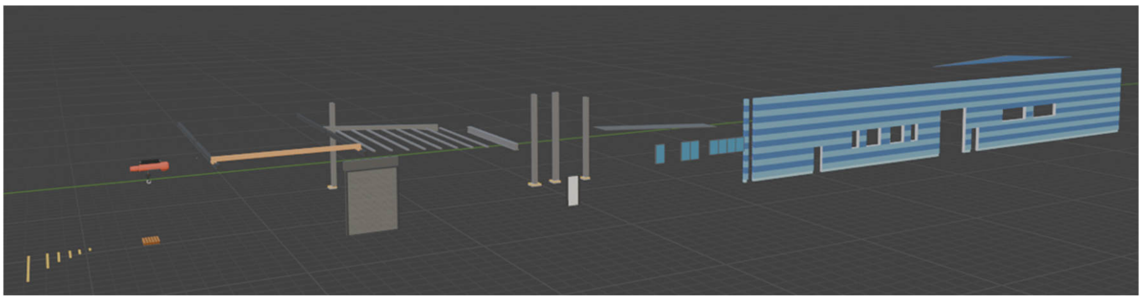

Figure 2. Part of the completed 3D model library

During the production part of creating the LeanOn virtual reality learning application, the main part of 3D models was created in the graphics software Blender. Objects forming the hall and production equipment, such as Euro pallets or cranes, were designed, taking care to ensure the correct orientation of polygons, control of duplicate vertices,

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and topology of the models. Object origins were positioned correctly, and all moving parts were distributed as required. UV maps were checked during the creation process. The UV Colors method was used for texture creation to optimize texture display and reduce performance requirements when interacting in the virtual environment. Models were continuously checked to ensure that polygons were not rotated incorrectly, causing unwanted transparency. The Blender software includes tools to assist with the automatic creation of UV maps, but manual editing was often necessary to achieve ideal results. The textures were then unified using a colour palette obtained from an internet-based generator, saving the performance of the application without compromising its quality or functionality. This part thus ensured optimal preparation of the 3D models for further creation and integration into the learning virtual environment. The produced part of the 3D model library based on the production part is shown in Figure 2.

2.1.3. Post-production part

The last minor part of creating the library of 3D models of the desired objects is the post-production part. This part represents the output control for the produced and edited 3D models. In a way, it is the icing on the cake that we are trying to achieve on the 3D models. After this part, all models should be ready for their full use. This is to work with them in the industrial-gaming engine.

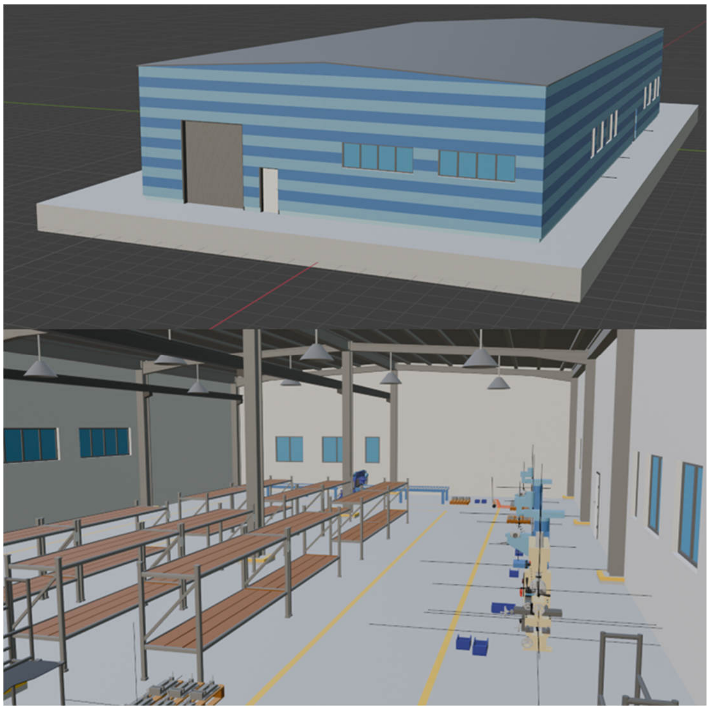

Figure 3. Built 3D model of the hall for the LeanOn application

The post-production part ensured a detailed mesh check of the 3D models for the LeanOn application. This check went smoothly, with the only issue being the incorrect orientation of the polygons on two parts of the crane. However, no problems were found with the UV maps. Visual inspection revealed fourteen mis-coloured polygons on six objects, which were quickly corrected using the UV Colors method employed. The models were then ready for export. However, before the actual export, the models were used to build a production hall scene in the Blender graphics software. A sample of the prepared hall is shown in Figure 3. The export to the Ella Platform (industrial gaming engine) was done in gLTF format with the specific parameters required by the platform. These parameters include, for example, the chosen format or the need for tangents. The exported models were ready for further processing and use in the development of the LeanOn application.

2.2. Creating a virtual learning environment using a library of 3D models

Virtual learning environments based on 3D models represent an innovative approach to teaching and training that harnesses the power of virtual reality and interactive environments. In this section, the process of the actual creation of such a virtual learning environment designed for virtual reality is examined in more detail. This process focuses on the integration of 3D models into an industrial-gaming engine. This integration is intended to ensure that a model of the desired environment suitable for virtual reality technology is created. When creating a learning virtual environment using a library of 3D models, it is also crucial to consider the user interface, logic, and game mechanics that contribute to the overall experience and effectiveness of the learning experience. Each step is essential to the successful creation of a dynamic and user-friendly application that can reinforce learning objectives and improve information retention and student engagement in the learning experience. In the case of creating a virtual learning environment using a library of 3D models, this second unit is divided into four smaller parts, which are:

1. integration of 3D models into the game environment,
2. programming game mechanics,
3. performance testing and optimization,
4. completion and distribution.

Together, these steps form a complex process that requires a coordinated effort. It is a stage where every detail is carefully considered and implemented to achieve the goal of creating a dynamic and meaningful virtual environment that provides users with a valuable and engaging experience.

2.2.1. Integration of 3D models into the game environment

The first minor section explores the process of integrating 3D models into the game environment, an important step in creating a learning virtual environment. The proper integration of the models ensures that the later parts of the second part of the methodology work smoothly. The integration of 3D models into the game environment is a cornerstone in the creation of a quality learning virtual environment. During this minor part, the scene in which the learning virtual environment will take place is built. In some cases, part of this smaller part is still in progress while the graphics software is being developed. Thus, according to the established methodology, still within the first unit, which is the creation of a library of 3D models of the desired objects. Often it is necessary, during integration, to reload the 3D model back into the graphics software and make the necessary corrections.

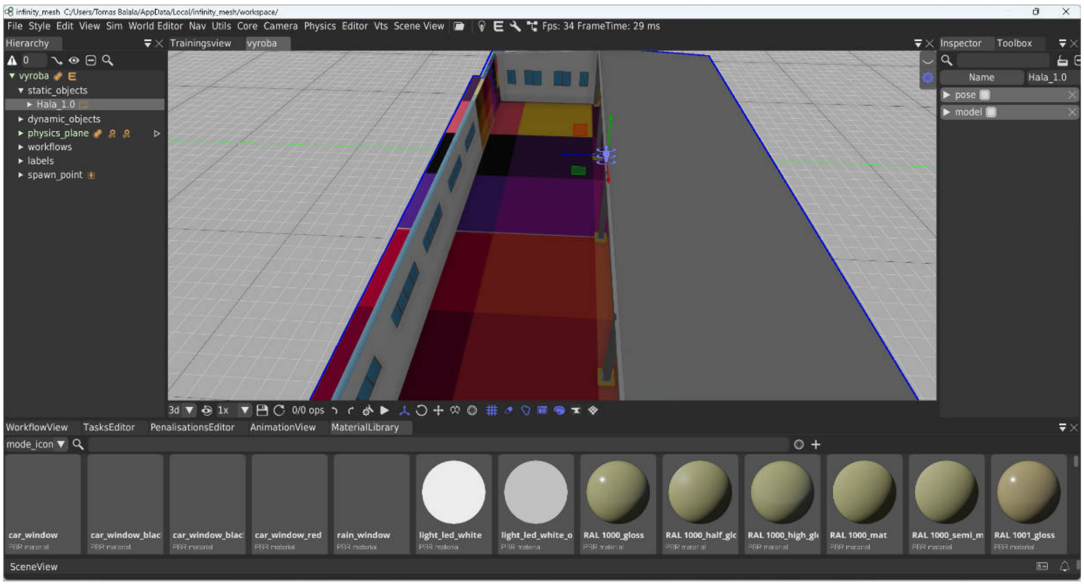

Figure 4. Texture display error in the Ella Platform (industrial-gaming engine)

During the creation of the LeanOn application, 3D models were imported into the Ella Platform (industrial-gaming engine) in glTF format, following the instructions of the first unit. During this, special export settings were observed. The import was successful, but some models had incorrect textures, which was later corrected by removing duplicate UV maps in Blender. An example of such an error is shown in Figure 4. Thus, an overall visual inspection of the models was performed to ensure that all objects were in the correct location and that the textures were free of errors. Subsequently, scene testing and fine-tuning were performed, including checking the physical properties of the objects. The lighting for the entire scene was adjusted. No performance or functionality issues were noted during testing. During testing, it was also checked that the user could not walk through walls or fall through the floor, all of which worked correctly. Overall, the optimization went smoothly, with the frame rate being kept stable at sixty frames per second.

2.2.2. Programming game mechanics

Programming game mechanics is a necessary and important step in creating a virtual learning environment using 3D models. This process involves the implementation of interactions, rules, and functions that define the behavior of the 3D models and the user in the game environment. Typical game mechanics include movement, jumping, object collection, combat, puzzle solving, and many others. Programming these mechanics overwhelmingly requires knowledge of a game engine programming language such as C#, C++ for Unity, or Blueprint for Unreal Engine. It also requires the use of game frameworks and APIs (Application Programming Interface) to manipulate 3D object models and events in the virtual environment. However, nowadays, thanks to the availability of complex libraries, and artificial intelligence, new possibilities are being brought to the market. These provide less user-intensive and more user-friendly solutions. This means that the user no longer needs to know the programming directly but enters their requirements via pre-compiled commands. However, the programming language is always running in the background. Programming game mechanics is one of the cornerstones of creating a fun and engaging gaming environment.

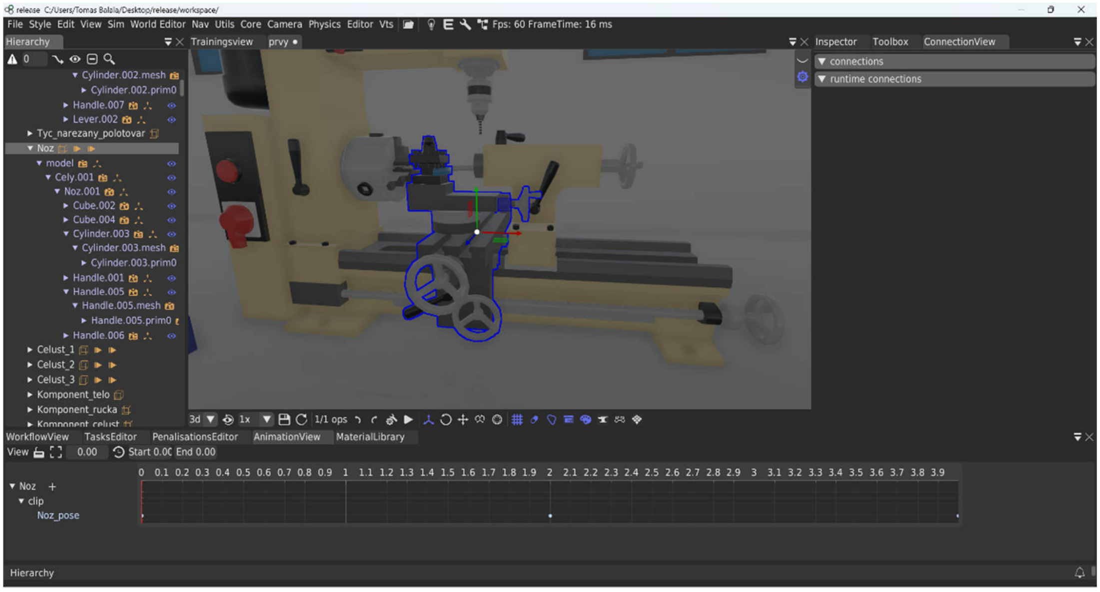

Figure 5. Animation creation in the Ella Platform (industrial-gaming engine)

For the development of the LeanOn application, simple animations were used in the programming part of the game mechanics. These were created directly in the Ella Platform (industrial-game engine) to introduce users to the basic interaction options. First, however, it was necessary to separate parts of the 3D models and set up interaction zones for them, thus enabling their subsequent animation. The animations were created through keyframing as also shown in Figure 5. During frame keying, the initial and final positions of the models were determined. Subsequently, the Ella Platform (industrial-game engine) provided a smooth transition between these positions. Each object was given an interaction function through the workflow, where it was determined how it should behave when clicked. For example, whether it should be visible or what animation it should trigger. In addition, informational descriptions were added for users to describe the necessary actions. Once the animations and interactions were complete, all the workflows were merged into one master workflow that controlled the order of triggering when the learning environment was turned on. Tasks were created for the user to complete for better orientation. Each task had its own main task with smaller steps. The basic physics of the Ella Platform (industrial-game engine) was implemented without the need for any intervention. This process was completed by final tuning of the game mechanics and fixing minor bugs and typos.

2.2.3. Performance testing and optimization

The process of performance testing and optimization involves systematic testing of the virtual learning environment to identify potential bugs, deficiencies, or areas of poor performance. At the same time, efforts are also made to optimize the learning virtual environment for maximum performance and smooth running. During testing, the performance of the learning virtual environment is monitored and analyzed, including loading speed, response times, and memory utilization. Based on the testing findings, various adjustments and optimizations are made, such as simplifying 3D models, optimizing textures, optimizing algorithms, or optimizing graphics engine settings. The aim is to achieve a smooth and stable running of the virtual learning environment on different hardware configurations and to ensure a positive experience for users.

During the game testing part of the LeanOn application, basic bugs such as an animation not starting or a workflow aborting due to a missing object were discovered. There was also an invisible object error caused by incorrect visibility logic. Such incorrect logic is shown in Figure 6. These problems were quickly solved by assigning the correct 3D models or by modifying the visibility logic. Thanks to the workflow that was stopped and marked in red during the errors, was enabled quick identification of trouble spots.

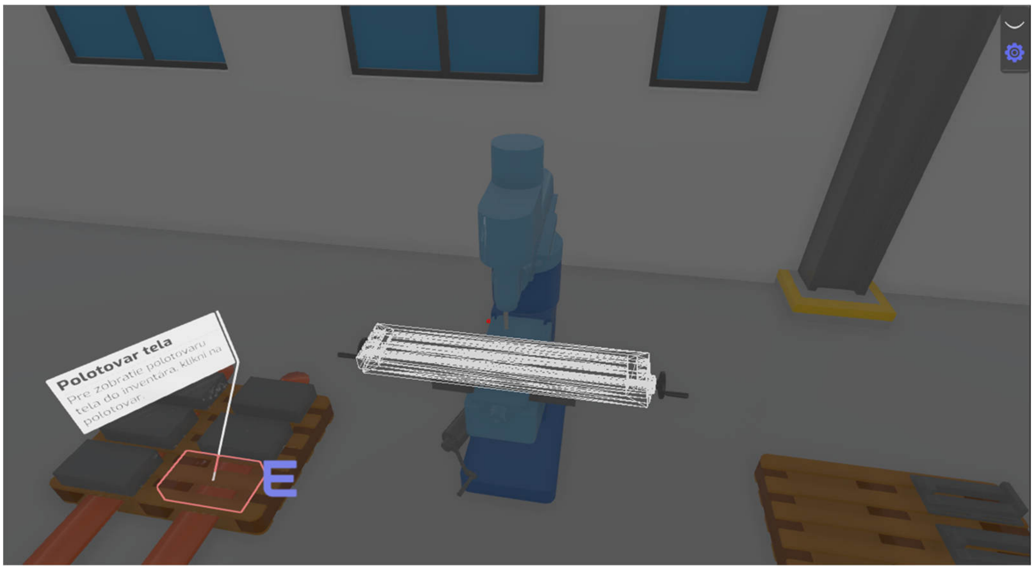

Figure 6. Faulty 3D model display logic

Testing went smoothly with the help of seven testers who were satisfied with the instructions and the app's controls. During virtual reality testing, there was a bug when activating the interaction on Oculus Quest 2, which was on the side of the Ella Platform (industrial-game engine). This bug has been resolved in collaboration with the platform developer. Due to the optimization of the 3D models for virtual reality, there was no reduction in application fluidity during testing. Overall, all created workflows were checked and revealed no major flaws, and there were no interventions in the code of the LeanOn application being created. This was due to the absence of any code that was directly created for the application during development.

2.2.4 Completion and distribution

As the very last part, not only the whole creation of the virtual learning environment using the 3D model library, but also the whole methodology is completed and distributed. This last smaller part comes after the successful completion of the development and testing of the entire learning virtual environment. Final adjustments and tuning are being made to ensure the highest quality and functionality. This includes the last fixes for bugs and shortcomings discovered, final performance optimization, the addition of sound effects and music, and localization into different languages. Finally, the actual distribution of the virtual learning environment in the form of an application via the chosen path. An important aspect is also the support and updating of the application after its launch, to ensure its continued quality and user satisfaction.

No sound effects were added during the last part of the methodology in LeanOn. In the last step of the learning environment design methodology, cosmetic adjustments were made to the descriptions and took place testing of critical parts of the application. Finally, the application was successfully exported along with its one level from the Ella Platform (industrial-gaming engine). Testing on a monitor and in virtual reality using the Oculus Quest 2 and Meta Quest 3 headsets came next, where no issues were found. The LeanOn application was, therefore, ready to be deployed in classrooms and labs. Whereby the application LeanOn is now open and ready for expansions and new levels.

2.3 LeanOn – application of virtual learning environment

Based on the developed methodology, a LeanOn test application was also created during the development and description of the individual steps of the methodology. It is a virtual environment learning application designed for the subject of production management, which uses virtual reality as a form of interactive learning. At the same time, knowledge from production management, specifically workshop production management, is used to create the scenario and flow of the learning virtual environment. However, knowledge from other areas of industrial engineering, such as the design of production and assembly systems or the field of technology, has also been used to create the scene of the video game environment. The application provides a new and dynamic approach to the issue of production

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management. Thanks to the application, students can acquire new practical information, several of which would not be easy to get in classic forms of exercises. The LeanOn app can provide students with the opportunity to get directly involved in production management without having to visit the plant. The app's virtual learning environment, powered by virtual reality technology, provides such an opportunity. During the development, a library of 3D models was created for this application, based on which it is possible to create the environment of the production hall according to your wishes and needs.

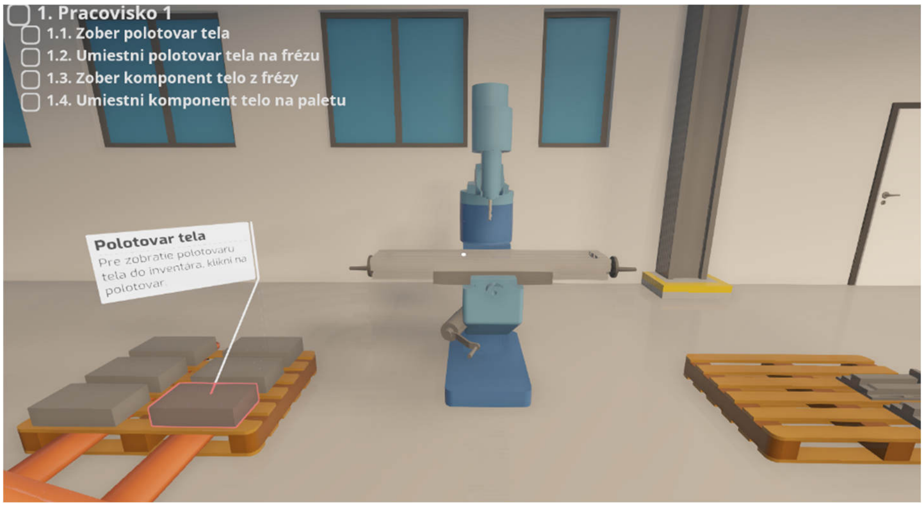

Figure 7. User's starting position in the first-level scenario

The current virtual learning environment of the LeanOn application has one level, on the creation of which the functionality of the proposed methodology designed for the creation of such a virtual learning environment was demonstrated. The scenario of that level takes the user through five workstations, looking at what equipment is commonly used to manufacture some of the components for a basic machine vise. To better visualize the application, an example of the user's starting position in the first-level scenario is provided in Figure 7. Within the level, the user processes the individual components. In the final step, he/she brings these components together to create the final product, which he/she packages and prepares for export. This is therefore a simple demonstration of the material flow in a company or a demonstration of the work of the different departments that occur in a company. LeanOn virtual learning environment not only supports interactive learning but also allows you to work with modern and up-to-date technologies.

3. Results

Within the framework of the use of virtual reality (VR) as a learning tool, a methodology has been proposed that allows for a more in-depth exploration of different areas in companies and institutions. The methodology focuses on the creation of a learning virtual environment that can enrich teaching not only in a specific subject but in a wide range of industrial engineering fields. It includes two main parts: Creation of a library of 3D models and Implementation of these 3D models in an interactive environment. After successfully mastering these parts, users can experience an enriching experience that surpasses traditional methods such as texts or 2D simulations. Likewise, incorporating virtual reality into teaching is not just about replacing existing approaches, but also complementing and enhancing the overall learning process.

In addition, the use of virtual reality technology provides practical skills. With the increasing use of these technologies in the academic environment, new opportunities for innovative teaching are opening, promoting not only technical proficiency but also an interest in modern technology. Although there are some challenges in the field of virtual reality and the use of virtual learning environments, such as issues of hygiene and comfort when using VR headsets for long periods. Thus, it can be stated that the technology is constantly evolving and improving dynamically. Such applications in education not only expose existing shortcomings but also discover new potential for teaching in several areas of industrial engineering.

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