Virtual reality and its possible integration into the process of distance learning focused on technically oriented subjects

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Abstract. Individual digital technologies which are aimed at simulation of real world elements are currently one of the most promising areas of interest. The growing popularity of the augmented, virtual reality technologies, as well as the industries in which their application has an increasing impact, is causing a sharp growth in the number of specialized software. An increasingly popular sector in which virtual and augmented reality has promising prospects in the field of education. It was this area that created space for the application of various software solutions during a pandemic situation. The application focused on the distance form of educational process, training and mediation of interactive experiences, which subsequently mitigate the teaching process, has found application not only in technically oriented areas. This article presents the possibilities for usage of the virtual environment created in the Rinoceros software, which is used as a supporting tool for the teaching process of technically oriented subjects. The article describes how to apply and modify specialized software for a specific area of use. Particular type of VR/ AR devices are used to mediate an interactive form of teaching, towards a specific group of students. Due to the intention of increased efficiency of this process, the article presents the possibilities of using the multiuser - host / guest functions, for full interactivity of more users. This solution allows the users to work with 2D, 3D models and CAD model assemblies in a virtual environment. It also presents the possibilities and promising areas of use which describe the other software features and their possible application in other areas, such as reverse engineering and intuitive modeling.

Keywords. Mixed reality, augmented reality, education, distance learning.

1. Introduction

The current state of the educational process and the inseparable influence that the current pandemic situation has on the educational process opens up new possibilities and methods of support or relocation of educational processes to the virtual environment. Given the history of the use of devices supporting mixed reality, the integration of these technologies into the educational process was only one of many theoretical possibilities of their use. With the advent of the trend of digitization and automation of industry 4.0 production, the increasing availability of smart devices and inevitably innovation in the gaming industry have brought a variety of different types of specialized software and hardware that is available to ordinary users, students or households. [1] Due to this demand for technology and its expansion, the economic costs required for the procurement and operation of the equipment have been
This created space for their integration into areas with lower profitability of the target group in terms of costs for procurement and ensuring the operation of mixed reality facilities. [3]

The combination of these software with the use of a device for VR called HTC Vive allows us to create a full interactive experience in a virtual environment. The main characteristic of the integration of these software and hardware into the educational process is mainly their availability, especially for the academic environment and the students themselves. In addition, the software is compatible with any gaming device that supports VR. Given the current policy and trend in the gaming industry, we can predict the increasing use of VR [5] gaming devices by a target group of users whose age is equivalent to the age of university students. This article presents specific possibilities of using specialized Mindesk VR software with the support of the Rhinoceros program. This software allows the creation of a virtual model of a room located at the Faculty of Manufacturing Technology. The model is then projected to the appropriate scale within the calibrated VR space. With the help of the device for VR and its drivers, it is then possible to integrate the selected content of the taught subjects into this environment, with the possibility of interaction of more users. [5]

2. Materials and methods

Virtual reality as such is characterized by three characteristic subgroups. They include virtual reality itself, augmented and mixed reality. Each of these technologies is characterized by a specific way of interacting with the user. Nowadays, in the field of education, we encounter mainly AR – augmented reality. Interactive experiences created by the software are easily displayed via available android and iOS devices. This allows the extension of such support for interactive learning to a significant number of users. The equipment currently in use is also a shortcoming of this technology. Despite the optimization of software and CAD models, the devices do not have sufficient computing and graphics performance.

2.1. Individual elements of virtual reality technologies

VR (Virtual reality) – With this type, it is possible to interact with things and environment that do not exist in the real world. After launching the device, the user is able to move, communicate and much more, all in a computer-generated world. The goal is to create an authentic digitized image of the real world or a credible simulation of a fictional world. It makes it possible to experience the historical world, from a walk through the streets of ancient Rome, to a vision of the future, such as a glimpse into a building that hasn’t been built yet. The possibility to look into the quantum realm, as well as walk through the solar system in the size of a regular room. All of this offers new perspectives for a wide range of disciplines, including the gaming industry and education. [6]

AR (Augmented reality) – Unlike the VR, it does not require special devices to operate. It uses software applications to add to the reality, for example on a smartphone or a tablet. Well known augmented reality applications include Google Lens/Translate, which are used to record, recognize and instantly translate text from foreign languages, or various games placing the player’s avatar in real places. As mentioned above, although special devices are not necessary, they will find their use for a more comfortable experience of some applications. That’s the reason why AR is the most available type of these technologies. [7]

MR (Mixed reality) – Quality optics, computational power and sensitive sensors are combined in this type of technology into the final projection of the object, but in real space. The object can be moved, rotated and controlled by hand movement. There are also cases in which most of the environment is generated and there are only a few physically overlapping objects. MR finds practical use in education, especially in trainings focused on manual work, such as in the areas of surgery, component assembly and design. Because the user remains present in the real world, MR can be considered a more advanced stage of augmented reality.

As already mentioned, the VR integration method presented in this article uses a VR headset for a specific solution to the problem. Devices of this type have more powerful hardware, connected directly
to the graphics processing unit of the computer. Its performance is therefore higher in comparison with e.g. android devices used in the application of AR for the educational process. [8]

2.2. Categorization of VR systems according to the dynamics of the environment and the observer:
- SīSO class (Static environment – static observer) – is the simplest case and systems of this class can be defined as images - a fixed environment that the user can only observe without the possibility of movement or interaction.
- DESO class (Dynamic environment – static observer) – As in the first case, it is just a matter of watching the object or scene without the possibility of intervention. These systems are divided into two types according to the method of origin. Offline, which takes place outside of real time, and online, which is recalculated in real time. They also differ in the size of the computing power required for their implementation, which depends mainly on the size of the virtual environment and its detail.
- SEDO class (Static environment – dynamic observer) – In this class, there is a big difference in quality compared to the previous two. Here, the user gets the opportunity to intervene in the environment, which is, however, unchanged until his intervention, and subsequently after the user's intervention. SEDO can also be defined as a continuation of DESO because of the real-time recalculation.
- DEDO (Dynamic environment – dynamic observer) – This division is the highest class, where the environment or objects can change without the intervention, but there is also the possibility of interaction. DEDO can be further divided according to the number of observers into DESDO (single), with one observer and DEMDO (multi), which allows multiple observers to interact with each other. [9]

2.3. Methodology
To simulate the educational process, the Creality Ender 3 3D printer assembly will be used in this model situation. The demonstration is focused on the possibilities of interaction with the assembly. An important part of this process is the possibility of interaction of all participants with the imported object.

The task creation process will consist of the following steps:
- creating a room model as a place to perform the simulation,
- creating the Creality Ender 3 model,
- the layout of the hardware selected for the purpose of this task,
- Multi-User connection setup and VR start-up.

The simulation in a virtual environment will be performed as follows:
- demonstration of the movement in a virtual environment,
- possibilities of interaction with the model,
- model selection, panning, rotation, scaling, dimension measurement, use of the 3D pen function, assembly layout,
- a summary of the application options for education.

2.4. Hardware
Since the goal of the article is to create a virtual environment with the possibility of connecting multiple users, the devices required for performing the task are two HTC Vive headsets with the necessary accessories. One set of devices contains the headset mentioned earlier, 2x Vive controller, 2x Base stations (Spatial sensors) and the necessary cables and adapters. Desktop computers with sufficient power to ensure smooth operation are also required. [10]
The basic part of the headset is two AMOLED displays with a diagonal of 3.6 inches with a refresh rate of 90Hz and a resolution of 1200x800 for each eye. The resulting field of view will create a display area of 2160x1200 pixels. The field of view of this headset is 110° and of course allows 360° rotation.

2.5. Software

Mindesk software was chosen as part of the effective integration of VR technology into the educational process. Among its many benefits is the work of bridging collaboration with CAD functions in VR in real time. Mindesk offers this connection for Rhinoceros and SolidWorks software. For some users, the advantage of this connection is more convenient editing of models performed in VR, as well as the possibility of cooperation of more people for better understanding and more effective work.

The used software contains a large number of functions for parametric design, which allow the creation of complex objects in several ways. It is possible to interact directly in the virtual environment, but also to create geometry or modify it in the Rhinoceros environment, which is then also displayed in VR. With the new version of Mindesk, the ability to import PointCloud has been added, which allows the creation of object geometry based on a 3D scan of a real environment, such as a room. The software also allows points to be marked and captured, making it possible to achieve high design accuracy. To speed up and facilitate design, it is possible to combine the use of individual software during a real-time connection. The use of a point cloud in the virtual interface and the possibility of directly creating the geometry of objects can be used, for example, in the reconstruction of the pipeline of the scanned room. A point cloud created in the classic way, or by photogrammetry, is uploaded in a 1:1 scale to the software interface. The designer then uses a headset to "upload" into the center of this room and begins the reconstruction of the pipeline using a modified palette of tools in a VR environment.
2.6. Multiuser link

The main advantage of the multi-user interface is that the same equipment is not required for all members. Of course, each member must have a VR device, but CAD software is only necessary for the administrator. The rest of the participants only need so-called Viewer application to connect to the room. If all parameters have been set correctly, when the VR is started by the administrator, the other participants will also see the loading window, “Linking to Rhinoceros”, on the screen. After loading a VR session on each user's computer, a multi-user session can begin. Participants can use most of the features of Mindesk and Rhino, including navigation, selection, control, or surface creation and editing. [10]

![Figure 3 Multi-user connection diagram](image)

Current limitations and possible implementations in new versions:

- The Grasshopper interface, used to edit and create complex CAD functions in VR, can only be used by an administrator. However, in future versions, the plan is to provide all participants with a simplified version of the input parameters.
- Except for the Grasshopper interface, all users share the same competences and interfaces. Later, an authorization system, that allows for the division of roles between participants, should be implemented (e.g. administrator, editor, observer).
- The live session does not offer the possibility of voice communication between the participants yet, but in case they are not in the same room, it can be provided by various applications in the background.
- Admin must manually enter the IP addresses of other members when setting up the connection, but in future versions of the software it is planned to create an automated system for searching for users. [10]

3. Results and discussion

Based on the knowledge and characteristics of the selected software and hardware, a model virtual room was created. It was used to test different types of interactivities and hardware load. The following chapters present the procedure of integrating the content of two subjects into a virtual environment.

3.1. Creation of CAD/ virtual space

Within the CAD interface of the Rhinoceros program, a virtual model of the laboratory located in the faculty premises was created. The laboratory is designed primarily for research in the field of reverse engineering and additive manufacturing technologies. Its premises are often a place where
students get acquainted with these technologies. Therefore, the subjects integrated into VR are characteristic for this laboratory. [13]

![Laboratory model created in Rhinoceros 7.0](image)

Figure 4 Laboratory model created in Rhinoceros 7.0

As already mentioned, HTC Vive allows, in addition to static interaction in a virtual environment, free movement within the created workspace by setting the Room Scale function. This requires a minimum space of 1.5x2m. When creating this demonstration, a room with space of approximately 3x4m was provided. [14] In addition to walking, movement in the VR can also be performed by a function in the software menu. A function called teleport allows the user to move to a desired location. Another possibility for moving and changing the position in the environment is, for example, rotation, which works by pressing the appropriate buttons according to the type of controller. For large models where free movement in the environment is not possible, movement can be performed by using controls.

![Laboratory model as seen by the user in a VR environment](image)

Figure 5 Laboratory model as seen by the user in a VR environment

Figure 5 shows the CAD model of the laboratory through the used hardware, in other words, the user's view into the virtual environment. As we can see, the models are displayed correctly, but their surface is not textured. Real display of the texture of the models can be achieved by using the Unreal Engine, which fully cooperates with the software and the used device. For better clarity, the glazed parts of the window frames have been removed from the model visible in Figure 5.
3.2. Inclusion of disassembly/assembly model

A specific example serving as a possible part of the educational process is visible in Figure 7. The figure also shows the use of the “Move” function, which allows you to move the object freely in space, or separately along the x, y, z axes. In this example, this feature is used to remove the printhead into the free space away from the structure and other parts of the assembly for better overview and handling in the next steps. Since the printhead is relatively small in size, the Scale function can be magnified several times for a more detailed view. The marked object can be enlarged by selecting a scale of, for example, 10:1, but also by stretching and shrinking separately in each axis. In this case, a scale of 5:1 was chosen so that the object was large enough for a detailed view, but at the same time the right size to fit in the field of view of the VR device.

![Figure 6](image)

**Figure 6** Assembly model of the Ender 3 placed within the VR environment of the laboratory

An important function for a better understanding of the placement of parts in an assembly is the ability to create sections, specifically the Section Plane function, which displays the assembly in a section according to the plane. After selecting this function, it is possible to freely rotate this plane to achieve its desired location in the object. The section can leave the created section plane in place, or serve only as a snapshot for preview.

Of course, the main function of rotation is to change the orientation of objects during design, but in this task, with hidden details, viewing certain parts of the assembly can be quite complicated, therefore, the "Rotate" function is suitable for rotating by the desired angle. The function also allows rotation around separate axes, as well as free rotation in space. An important element in a collaborative design is the possibility of interaction between users and their mutual communication. For example, with the size and shape of the controls in a virtual environment, it can be difficult to point out small details, which can be ensured by using a 3D pen that allows drawing and writing in space with the help of the controls. This way you can highlight an important detail, write a note, or create a sketch to continue the design.

![Figure 7](image)

**Figure 7** Manipulation of the printhead component within the VR
To understand, for example, the principle of operation of the device, it is often necessary to be able to display each component, even those hidden inside. Explode view is a tool used to disassemble an assembly and show all its parts. The position and orientation of each part can be edited separately and then saved with the Snapshot function for quick display at any time while working with the model. Figure 8 shows the layout of a printhead subassembly in which all its parts can be seen in detail. After the demonstration, it is possible to return to the previous steps to preserve the layout of the model, or save within the software interface.

![Figure 8](image)

**Figure 8** VR tool palette used to disassemble the virtual printhead model

### 3.3. Integration into reverse engineering

VR is beneficial when displaying large objects, spaces, or objects in scale, as we also need a small space or room defined by scanning stations, where we can import a component of any size using virtual reality. We can modify the component imported in this way in the virtual reality environment and change its scale according to our needs. However, if the component is too large, we can move around it using the already mentioned teleport function, which can move us farther. [6]

![Figure 9](image)

**Figure 9** Demonstration of the state of imported model into the software environment and model reconstruction progress

Prior to the model reconstruction process itself, the scan was enlarged to 100% of its original size. This enlargement provided a detailed insight into critical areas. Subsequently, a variety of tools with CAD functions were used to reconstruct the entire model. User interaction within the virtual environment was practically seamless. The most striking shortcomings during the reconstruction were the lack of skill of subjects with VR hardware and the kinetosis observed with long use of the device.

**Conclusion**

As mentioned earlier, virtual reality technologies are a big trend nowadays. The current situation, which has resulted in an extensive transition to a distance form of education, created a demand
for teaching in various types of virtual environments. However, the augmented reality that is currently often associated with the support of the educational process is partly limited by the technical design of the equipment. Specific cases suggest that when using this technology in combination with large data packs, the target devices lack computing power. In terms of virtual reality, the devices used in cooperation with this technology had been marked “expensive”. However, current trends in the development of computer technology, with a large contribution from the gaming industry, have achieved a reduction in these costs down to the level of a middle-class mobile device. Due to the constant demand in this area, we can predict a significant increase in demand, production and subsequent expansion of these devices for ordinary users. The availability of devices, the advent of new specialized software with a close focus on specific industries and their connection with the increasingly widespread hardware produced mostly by the gaming industry are the facts that allow the gradual integration of other virtual reality technologies into the educational process.

After its introductory part, the article presents a possible application of software and hardware for VR for the needs of teaching support. It focuses on two specific cases and presents the possibilities arising from this application. Due to the full cooperation of software for work in a virtual environment and software that has CAD functions, we will get acquainted with the possibilities of using these software in support of subjects with a technical focus. The interaction of multiple users and the ability to disassemble / assemble assembly CAD models, which also have the mutual interaction of individual components is one of the main advantages of the possibility of teaching in this environment. User interaction and their ability to participate in, for instance, design, can make a significant contribution in this way of learning. The advantage of such imported objects is the connection of the educational process, dealing with a specific subject of detailed representation and practical application of the theory associated with the practical use of software, which is applicable to various types of software used to create or reconstruct models. The basic theory of creating structures and surfaces using a combination of different types of CAD functions can be thoroughly explained to a larger number of subjects. In contrast to the normal teaching process, during which students work individually, VR will make it possible, with the help of excessive enlargement, to place greater emphasis on the use of specific program functions. This process will allow the display of details with the direct participation of the subjects. In this way, thanks to interactive experiences, we are able to achieve increased attention and interest of the target group of subjects. At the same time, thanks to the shared control of the software, it enables practical demonstration and practice of practical skills.

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