Virtual reality as a new trend in mechanical and electrical engineering education

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Abstract: In their daily practice, academics frequently face lack of access to modern equipment and devices, which are currently in use on the market. Moreover, many students have problems with understanding issues connected to mechanical and electrical engineering due to the complexity, necessity of abstract thinking and the fact that those concepts are not fully tangible. Many studies indicate that virtual reality can be successfully used as a training tool in various domains, such as development, health-care, the military or school education. In this paper, an interactive training strategy for mechanical and electrical engineering education shall be proposed. The prototype of the software consists of a simple interface, meaning it is easy for comprehension and use. Additionally, the main part of the prototype allows the user to virtually manipulate a 3D object that should be analyzed and studied. Initial studies indicate that the use of virtual reality can contribute to improving the quality and efficiency of higher education, as well as qualifications, competencies and the skills of graduates, and increase their competitiveness in the labour market.

Keywords: virtual reality, immersive education, education, mechanical and electrical engineering

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1 Introduction

According to the European Commission Education & Training 2020 programme, as well as the report on the Modernization Agenda of Higher Education [1], one of the main challenges facing higher education is improvement of quality and relevance of teaching and learning. The expectations of the European market in relation to universities are expressed in qualified, competent and skilled graduates. Future employees should have a thorough education, as well as knowledge, practice and experience in a particular field. They are required to solve unexpected tasks that involve intricate and unforeseen operations which require the application of gained knowledge in practice. Graduates prepared for such situations will affect the economic growth and prosperity of the European market. According to the Operational Programme Human Capital study, nearly 80% of employers reported problems with finding qualified workers in 2014. This correlates with the results of surveys conducted by Career Office of Lodz University of Technology, which show that over 50% of mechatronics graduates feel unprepared for their professional work. Moreover the surveys show a high demand for practical exercises, which the university is unable to provide due to limited resources in both staff and equipment.

In recent years mechanical and electrical engineering have joined the list of the most demanded study programmes. Many students have problems with understanding issues connected to these disciplines, due to their complexity, the necessity of abstract thinking and the fact that some concepts are not fully tangible. Deficiencies in fundamentals prevent further development and exploration of more complicated problems.

Currently, classes are divided into two parts, theoretical lectures and the practical laboratory lessons. During these laboratory sessions, students get limited access to machines or conduct computer-based simulations. In their daily practice, academics frequently face lack of access to modern equipment and devices, which are currently in use in industry. There are no opportunities to disassemble available devices for the purposes of presenting...
the components and construction, as well as clarifying related physical phenomena. Laboratory exercises must be carried out under supervision, therefore, students do not have the ability to self-configure the equipment, experience states of emergency or the effects of misconfiguration, as these may lead to the equipment being permanently damaged. Moreover, there are no possibilities to practice and catch up outside the laboratory schedule.

Current solutions rely on modern technology such as online courses, blended learning, various computer-based platforms and other options that allow students to repeat the same topic and make mistakes several times in order to learn from them. Numerous examples of hardware and software that have been successfully used in education process indicate that ed-tech industry solutions can improve learning outcomes for most students. More and more educational centers have started to introduce powerful new technology-based tools that help them to meet diverse student needs. For example, Virtual Labs (Government of India Initiative), provides remote-access to labs in various disciplines of science and engineering. Students of Indian universities can access numerous tools for learning, including web-resources, video-lectures, animated demonstrations and self-evaluations. However, most of these packages consist of online or semi-interactive video courses, which do not include a hands-on approach or give any opportunity for experimentation, but rather resemble a one directional lecture. Such tools provide the student only with theoretical knowledge of a particular subject; the practical part is omitted entirely. Only by combining theory and practice (even in a virtual environment) will students gain real experience [3].

The paper is organized, as follows. The next section describes methodology: technology and software, scenarios of exercises, details of 3D modelling, the created application and the results. Section 3 shall present a discussion of the results, the conclusion and plans for the future.

2 Method

2.1 Motivation

Virtual Reality (VR) is a technology that provides an interactive computer-generated environment, usually with a dynamically changing scenario in which one can see and move. VR simulates a user’s physical presence in an artificially created world and allows them to interact with that virtual environment [4]. Most VR applications and solutions focus on gaming and commercial industries, due to these areas providing the largest groups of VR headsets recipients. However, the possibilities of virtual reality do not end with gaming. Dynamic growth and interest in the subject of virtual reality have rendered it applicable in many other areas, such as the military, psychology, medicine and teaching applications. Use of information and communication technologies has been found to improve student attitudes towards learning. Moreover, virtual reality plays an important role in the teaching process, providing interesting and engaging ways of acquiring information. It can help teachers to explain complex issues due to its graphical nature combined with an explorative approach, physical interactions and intuitive interfaces.

The case study by Beijing Bluefocus E-Commerce Co. Ltd. and Beijing iBokan Wisdom Mobile Internet Technology Training Institutions, presents the difference between VR-based teaching and traditional teaching in learning astrophysics. The team conducted two tests: immediate and retention on groups of students with VR-based teaching and traditional teaching. The immediate test was completed to show the differences in learning efficiency and the academic performance of the groups, the retention test was conducted to compare how long the students could retain knowledge. According to the conclusion of the case study VR-based teaching improves students test scores. The score of the VR group on the immediate test was 93 right answers, and the traditional teaching group 73. What is more in the retention test, the average score of the VR group was 90, which was 32.4% more than that of the traditional teaching group which had an average score of 68. The results show that VR-based teaching can not only improve the knowledge gained by students after classes, but can also help them to retain this knowledge [5].

Virtual reality can be a powerful tool in supporting and facilitating learning and teaching processes. A lot of surveys and reports show that most students remembered what they saw in VR and concluded that VR is a more memorable environment than laboratory-based demonstrations [8]. Ultimately, the laboratory-based method (a less efficient form of learning) results in deficiencies in fundamental knowledge and practice of graduates, which may lead to inability to properly react to challenges that arise in future workplaces. To work around the problems, an innovative method for teaching and learning based on virtual reality (VR) shall be proposed. VR environments allow educators to conduct learning activities, which are difficult to implement during regular laboratory lessons (such as states of emergency). By including VR laboratories as a part of the existing curriculum, it is believed that it will be possible to improve the quality and efficiency of higher education, qualifications, the competences and
skills of graduates, as well as increase their competitiveness in the labor market.

2.2 Methodology

The project was conducted according to design thinking (DT) methodology, which is an innovative approach to generate and develop ideas that match the end user’s needs. The iterative cyclic process identifies the desires of the target group, which they may not even be aware of. It is based on intuition, creativity, logic and having an optimistic way to cope with the challenges. It has been used as a method of inventing products, services and experiences with a focus on the people who will use them, derived from five structured phases (see Figure 1): empathize (or discover), define, ideate, prototype and test [6].

2.3 Technology

Figure 2: HTC Vive - a virtual reality headset developed by HTC and Valve Corporation, source: www.microsoft.com/

The device provided for the project was the HTC VIVE. HTC and Valve Corporation developed this virtual reality equipment, with the first launch of the product being on 5th April 2016. This device (see Figure 2) is composed of:

- Wire-connected Headset - comprising a screen, two lenses and a set of detectors: gyroscope, accelerometer and laser position detectors. On this headset, the distance between both eye lenses can be adjusted, allowing adaptation for various face types and shapes. There is a headphone jack, a front camera to see the external environment without removing the headset, and a microphone that can be used during multiplayer games or phone calls via a Bluetooth connection to a mobile phone.
- Wireless Controllers - with a number of programmable buttons, a touchpad and sensors such as a gyroscope, accelerometer and laser position detectors.
- Lighthouses - emitting pulsed infrared (IR) lasers to detect the position of the headset and the controllers. These devices can be placed in the corner of the area used for simulation and can cover an area of 12.25 m².
- Connector Box - to connect the headset to the computer or TV [7]. For further information, please see the HTC Vive website: https://www.htcvive.com.

To develop the virtual environment of the prototype Unity 3D - Game Engine was used. This was considered the most appropriate software to create VR applications [2]. The programming languages used for development were
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JavaScript and C#. To design and develop all necessary virtual objects in the virtual scenes 3ds Max software was used.

2.4 Application scenario

The scenario for the tool included five stages:

- Controls Tutorial - The idea of this stage was to provide the user with a tutorial, which illustrated how to use the HTC VIVE controls while in virtual reality. This includes showing what each button on the remote is used for and how to navigate through the selection menus.

- First menu - The menu has a visual of a laboratory, where the user could select the appliance of their choice. For the purpose of this project, a washing machine and its components were the focus (see Figure 3). For selection, the device was highlighted and selectable.

- Select Activity Type - In this stage, the user could select an activity, component or phenomenon to learn about.

- The core of the application - An interactive VR simulation (Figure 1) for learning and teaching mechanical and electrical concepts, such as: the construction of a device and its individual components, defining principle operations, all necessary mathematical and physical descriptions, all mathematical models and physical phenomena essential to simulate and visualize devices in action.

2.5 Testing

The application was tested by a group of 60 students (20 male and 40 female) of different ages ranging from 20 to 24 years. The students who did not have any previous experience with VR were presented with an introductory VR simulation prior to the test. Each test was performed individually, during a single session in a separate room. The student was positioned at the center of the room and asked to put on the VR headset. When the student was comfortable with the environment, the session was started. During one session the student was supposed to use all available functions and go through each of the available exercises (see Figure 6). Then, the student was directed to another room for an interview.

During the interview, students were asked to rate on a scale from 1 to 5 (1 meaning the lowest score, 5 highest):

- How was the experience?
- Is this kind of presentation useful for memorization?
- Is this kind of presentation useful for understanding?
- Did the presented device seem real?
- Would you like to use the system as a part of classes?
In addition, a similar test was conducted among 15 academics. Similarly to the students group, all academics without any previous experience with VR were presented with an introductory VR simulation prior to the test. Each question for the academics survey had a 1 to 5 rating. The questions were as follows:

- How do you rate the experience?
- Do you find this tool useful for presenting the exercises?
- Do you find this tool useful in passing down knowledge?
- Did the presented device seem real?
- Would you like to use the system as a part of your classes?

The results of the interview are presented in Figure 7.

Almost every student gave the best rating for the experience in the VR environment. All agreed that this kind of presentation has positive effects on understanding and memorization. Almost all would like to use this system as a part of their classes.

In the case of the academics, the most important feedback is that a VR educational tool was perceived as useful in both enhancing the presentation and passing down of knowledge. Additionally, most of the respondents indicated that they would like to incorporate such a tool into their classes.

Neither group found the presentation to be realistic enough. However, taking into consideration that the presented simulation was in its prototype phase there is still room for improvement in that area. What is also worth noticing is that even though the presentation might not have seemed realistic to all respondents, they still found the tool to be useful and the overall experience got high scores.

3 Conclusion

According to [9] virtual/augmented reality (VR/AR) earned its first billion dollars in 2016, with about $700 million in hardware sales, and the remainder from content. The estimated sales of VR headsets amount to about 2.5 million units and 10 million game copies. In addition, Goldman Sachs predicts that AR and VR can easily earn about 80 billion dollars till 2025. Today, apart from Facebook and Oculus, most of global giants such as Samsung, HTC, Sony, Microsoft, Google, and LG have introduced commercial AR or VR solutions. This increase in the number of VR devices involves a growing demand for applications created on these platforms. Many experts are convinced that VR/AR has the potential to be one of the most groundbreaking technologies of the next decade and forecast that it may be a new turning point for the development of multimedia technologies.

Increasingly, at the forefront of this innovation wave, one can see schools, universities, and educational organizations who have noticed how augmented and virtual reality technologies could reshape students experience, improve outcomes, deliver innovative new learning methods,
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and even train professionals. These statistics present how rapidly the global market of VR/AR is growing.

Immersive learning is the main area for applying VR/AR in education. It allows reduction of the cost of putting a student or a trainee in a normally high-risk, high-cost setting, or in a difficult-to-access environment. Moreover, one can train with the latest available equipment without the necessity of purchasing expensive machinery. This results in stronger retention of the presented material and improvement in educational outcomes.

In this study, an interactive virtual reality environment was developed to demonstrate that VR may serve as a relevant asset to the mechanical and electrical laboratory. Most participants without prior training, could easily interact with the platform and complete all the indicated exercises. Data collected from short surveys show that VR can be useful for improving the understanding and memorization process. However, some students and academics felt their immersion broke because the environment did not feel real. Overall, to provide a realistic experience, focus should be put on the surroundings, not only on the realistic look of the main device. In the future, instead of an empty room as the surroundings, an entire laboratory with various posts to choose from shall be designed.

From the technical side, further development of this project would have to take into consideration utilizing additional devices and functions to make the prototype a complete mechanical and electrical laboratory tool. To make the application more useful in a practical setting it would be necessary to make it available for multiple VR platforms. By doing so the application can be used on smaller and less expensive devices making the application portable (remote learning) and more attractive from an economical point of view.

Additionally, the presented prototype sparked the idea for creating a VR-based mechatronics laboratory which could familiarize users with construction and operation principles of electric motors, present work of typical production lines or their most important fragments, and show electro-pneumatic actuators and controls used in the industry. All the ideas based on discussion with both the academic and student groups were gathered and submitted in a grant proposal to the Erasmus+ programme for strategic partnerships for higher education. The grant proposal received funding and further work will be continued in the ViMeLa (Virtual Mechatronics Laboratory) project [10].

References