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SIMULATING ELECTRICAL SYSTEMS AND LABORATORY EXPERIMENTS IN IMMERSIVE VIRTUAL REALITY

The use of Virtual Reality(VR) as a learning tool encourages the creation of software that allows users to experience learning environments on a device. This paper provides a mechanism for developing a VR system to assist interactive electrical engineering laboratories to be used in the teaching of Electrical Theory. A key point is that there is no need for the user or student to have coding experience as all the necessary items for the experiments are implemented in the software as 3D models.

Keywords: virtual reality, interactive learning, immersive virtual laboratory, educational tool.

Introduction. VR is a virtual technology that allows user activities like in the real world in a different dimension. From its beginning, VR has developed significantly and has been widely used in many disciplines. Initially used as an expensive technology that needed a significant amount of investment, complex, dangerous, or hazardous systems can now be efficiently demonstrated on a computer screen.

With an increasing need for advanced engineering higher education and innovations in 3D simulation technologies and computer hardware, a growing number of engineering teaching and training materials can be used in virtual reality environments. Virtual reality technologies can be used as an education and training method with the benefits of being safe, cost-effective, and completely controllable. Virtual reality technologies greatly improve learning performance as they provide the learner with authenticity and interaction.

VR systems are commonly known to be strong in both visual and spatial interpretation of physical environments. VR also brings the advantage of being safe for both users and machines, while at the same time giving the user the ability to be introduced to a variety of situations that are hazardous to recreation or rarely occur. The accumulation of these considerations indicates that VR can be an ideal technology for increasing the training and knowledge of electrical engineers and electricians and can also play a major role in increasing awareness of electrical safety concerns and minimizing accident rates among the general public.

Laboratory experiences help to meet the needs of diverse learners as well as build skills and emphasize the importance and real-world implementation of course material. By engaging students in engineering research through a 3D virtual laboratory, the aim is to trigger enthusiasm, interest, and the concurrent maintenance of engineering students. The virtual laboratory modules are compact, self-explanatory, and user-friendly. They allow remote students to have laboratory experiences close to those of their peers on campus. The laboratory modules discuss the needs of students with disabilities. Simulated laboratories are more accessible to learners who frequently find it challenging or dangerous.

This research considers the concept of using virtual reality technology to explain material knowledge in the context of a three-dimensional model. It presents the steps needed for the building of a project. Studying the media that may be virtually sensed by users will expand the user's vision and point of view in learning. This increases the appeal of the material, as users can view the labs in a virtual and realistic way. VR can also be a device for teachers to teach and evaluate learning virtually, and it is proven that VR can increase student learning motivation, so that learning using VR can improve their scores [1]. The work presented shows that virtual reality technology can significantly increase the efficiency of teaching and training by enabling engineers to apply technical knowledge to actual industrial problems. The simulation uses electrical laboratory measurement in a 3D simulated world that allows users to experiment and test the modeled equipment.

Background. In general, VR applications in education can be divided into two main categories: (1) Non-immersive (the window), where the user's vision of the world is by means of a flat-screen monitor serving as a "window" and (2) Immersive, which fully brings the user to the virtual environment by using lenses and two tiny displays mounted in front of the user's eyes [2].

Each of the above groups is also classified into the following subcategories. Non-immersive tools are categorized according to the type of device used to communicate with the virtual world: (1) by using traditional computer input devices, e.g. mouse, keyboard, etc, and (2) by using specially built interaction devices similar to those used in actual control, e.g. system operating consoles or vehicle control cockpits. VR immersive systems are often divided into two subcategories according to the virtual reality simulation system: (1) a head-mounted monitor (HMD) consisting of active glasses with a small screen appropriately located in front of each eye, and (2) the virtual CAVE (Cave Automatic Virtual Environment) where the virtual world is projected on the walls, ceiling and floor of a room by multiple stereoscopic projectors. In this last scenario, the user must wear passive stereo glasses to gain a 3D view of the simulated world. The major drawback of virtual caves is the high cost, which limits the use of this form of immersive VR. On the other hand, the use of HMD may also cause cyber sickness.

Virtual reality is designed to allow users to achieve telepresence in physical or imagined worlds. The word presence here implies "a sense of being in some environment", so telepresence could mean witnessing an existence in some environment through the use of communication media.

The primary concept of virtual reality is how the medium of communication and the human body should be connected. Remote communication environments may provide a simulated presence for users using telepresence or telexistence principles through the use of input devices such as HMDs. Thus, the physical environments can be immersed in a virtual atmosphere to create a life-like experience. A high-quality virtual environment is sometimes very difficult to achieve due to drawbacks on input images, computing power, etc. However, the development of CAD application programs, accelerated graphics hardware, HMDs, and other innovative technologies have helped to address the cost-effectiveness of those limitations. Virtual reality systems are typically associated with immersive, highly visual, 3D worlds.

There are a few similar approaches to the problem that already exist. Some of the examples are Labster – Lab Simulator, PraxiLabs, VR Lab Academy, etc.

Labster's virtual lab simulations allow students to work through real-life case stories, interact with lab equipment, perform experiments and learn with theory and quiz questions [3]. It has a catalog of 150+ virtual lab simulations in different fields including engineering, chemistry, etc.

PraxiLabs provides students with an immersive and interactive 3D simulation of a realistic lab, enhancing their understanding and knowledge with a virtual hands-on experience of what they've learned [4]. It also has a catalog of already created laboratory stands, each for its unique test scenario.

These two laboratory simulations are mainly desktop-based applications with preprogrammed and predefined case scenarios. There are complete sequence of tasks and actions that users need to perform in order to complete the experiments. This means that users cannot undertake experiments that are outside of the course content and have not been developed and preprogrammed in the applications.

With VR Lab Academy students are studying experiments with virtual reality technology which increases the ability to learn through virtual memory [5]. VR Lab Academy offers both VR and PC versions, but still, with predefined case scenarios.

The Virtual Environment introduced in this paper offers a full immersion of the user into the virtual environment and is completely generic, without predefined and preprogrammed laboratory experiment scenarios. It is set to be an environment in which users can undertake a variety of electrical engineering experiments. In contrast to the existing instances, this environment allows users to construct various electrical laboratory stands that are needed for the experiments without any need of an additional programming, and to use the virtual environment to mimic or substitute the actual reality electrical laboratories.

Design of the VR application. The first step is to identify and pick the particular objectives to be accomplished. Only those which could be performed by machine-generated simulation would be chosen from all the chosen objectives. The next step is to decide which of the desired targets could be used for a 3D interactive simulation. This way, the VR would not be beneficial if none of the goals is mentioned. The method of developing a VR application is determined by the following steps (Fig. 1) after the feasibility of applying VR to the chosen subject is checked.

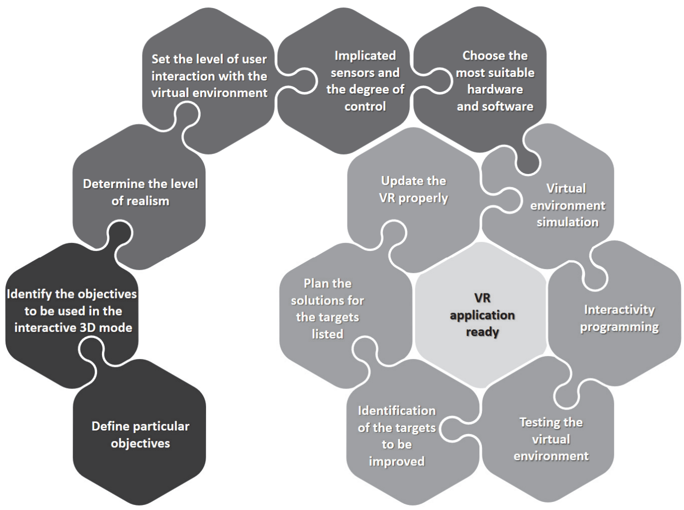

Fig. 1. Phases of the VR application design

1. Determine the most suitable level of realism for achieving each goal, ranging from very symbolic or graphical to very realistic. It is necessary to determine what activities the VR program is designed to be capable of performing and what actions users should be allowed to take. Taking into account the characteristics discussed above, the realism level is chosen to be as realistic as possible.

2. Choose the level of user interaction with the Virtual environment that defines the sensors involved and the degree of control and immersion that the user can experience. Users should be immersed in a completely interactive virtual world and interact with most of its core elements. They may even forget that are in a virtual world if the environment and the interactivity with it are almost identical to the real world.

3. Select the hardware and programming software that suits the best to the objectives presented, depending on the choices followed in the previous steps.

4. The virtual environment is developed, the interactivity is programmed, and the VR application is created.

5. The VR system is being tested by a group of specialists. It must be considered that reducing the reaction time is necessary in order to achieve as realistic VR experience as possible.

6. Ultimately, the outcome of the test enables validation to be carried out if the desired objectives are fulfilled and, otherwise, to make the necessary adjustments.

Electrical experiments to be implemented in this study require some equipment for execution, e.g. a voltmeter, an ammeter, a multimeter, a DC power supply, a resistor, etc. The design of simulation of the electrical experiments in the virtual reality environment for the training is determined by the equipment and the implementation of a direct current electrical circuit. Users use the HMD to function in virtual reality.

Hardware and software for the implementation of Virtual Environment. The selection of hardware depends primarily on the level of VR application properties specified, such as realism, immersion, and interaction, according to the objectives originally planned for the VR application. The higher the number of user senses involved, the wider the functionality of the systems and their underlying programming.

In this research, HTC Vive HMD [6] is used. It is a powerful VR headset developed by the manufacturer of HTC mobile phones and the videogame company Valve. This VR device achieves a high quality of immersion due to the use of hand-held VR stick controls that allow users to communicate with objects inside the VR environment, and sensors mounted on the walls of the room that create a virtual space where users can walk freely.

Regardless of the hardware, programming a VR application assumes some typical activities, based on the required level of realism and interactivity, such as designing 3D worlds and programming interactions. Generally, the development of the Virtual Environment is divided into two major categories. The first is 3D modeling and animation software used to create three-dimensional objects, the second is development engines. The most commonly used 3D modeling tools are Blender, Autodesk 3DStudio Max, Autodesk Revit. The second category, they are named sometimes videogame engines, graphic engines, etc. The term 'engine' here refers to a program that performs a certain kind of task, or a part of it. The graphic engines that are most used are Unreal Engine and Unity. The most popular 3D videogame production engine is Unity. Its flexibility is the primary advantage. It is a flexible graphics engine that offers a wide variety of assets. Projects can be exported to both smartphone (Android, IOS) and desktop operating systems (Windows, Linux and Mac OS), as well as video game consoles, by being cross-platform. It is also compliant with VR platforms, and it is very useful in both 2D and 3D for project design.

System requirements. The computer must meet the following system requirements:

Computer type	Desktop computer with available PCIe slot
Processor	Intel Core i5-4590/AMD FX 8350 equivalent or better
GPU	NVIDIA GeForce GTX 1060, AMD Radeon R9 480 or better
Memory	4 GB RAM or more (8 GB RAM is recommended)
Operating system	64-bit Windows 10 or Windows 7 SP1
SteamVR app	Version 1533664367 or later.

For the “Ohmic Resistances measurement” experiment users need an ammeter, a voltmeter, a DC power supply and cables. Using the Virtual environment the average technical specification of the system is:

CPU	26% (using Intel® Core™ i5-9400F)
Memory	550MB
GPU	1.5GB.

Development of the VR application. The 3D electrical equipment construction was based on the design process. Equipment and environment have been built by Autodesk Revit. The creation of the 3D model consists of electrical equipment (Fig. 2), laboratory desk and a space environment.

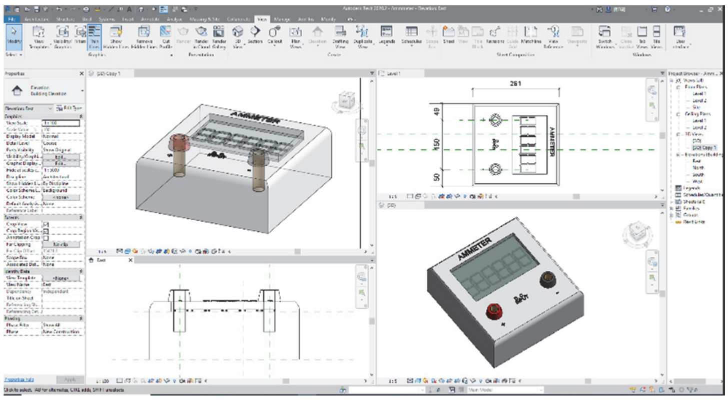

Fig. 2. The development of the 3D Ammeter model in Autodesk Revit

The development of the virtual reality environment includes the computer programming of the electrical current analysis process and the user's interaction panel to control the activity in virtual reality.

After developing the three-dimensional model, a program is created to manage the operation of the electrical scheme operation equipment by observing the equipment, configuring the values, and validating the electrical circuit installation process. The Space environment is built as if the users are experimenting with the electrical devices in the laboratory, as shown in Fig. 3.

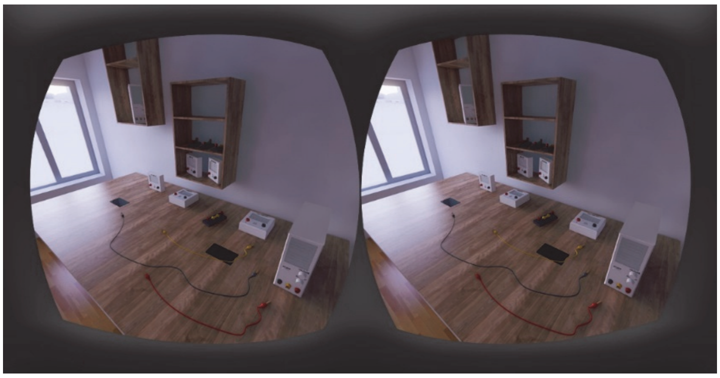

Fig. 3. A View of the Virtual reality environment on the user's eye view of HMD

The three-dimensional model involves the development of controls (buttons and tabs) on the control panel and the validation of the selection. The Unity Game Engine is used to develop and integrate all the components listed above. C# is used as a programming language. Among the many available 3D game development tools, Unity3D is selected for its free development pricing, a rich community, a lot of models and artifacts in the asset shop, supporting two of the most popular programming languages (JavaScript, C#). Unity 3D is the most cost-effective, flexible and sustainable solution to develop VR/AR application [7].

By virtually designing the required electrical circuit for the experiment, the user can use any of the created 3D models, i.e. voltmeter, resistor, ammeter, etc, and conduct different electrical experiments. This expands the scope of users, as they do not need to have coding skills, they simply need to take 3D models by the control sticks and link them to each other (Fig. 4).

Fig. 4. The Virtual Laboratory Environment

Conclusion. The use of Virtual Reality as a learning tool to educate students and users on the problem of electrical circuits, in general, is an interesting and innovative viewpoint. Access to guidance through VR, can help and provide students with a better explanation and a better understanding of the rules. The key area for implementing VR in education is immersive learning. It decreases the cost of having a student or trainee in a typically high-risk, expensive environment. In comparison, the presented technology can be operated without expensive equipment. Awareness of the virtual world will allow students to rapidly absorb themselves in electrical projects. The student can thus quickly define the parameters involved, and thus learn to design an electric circuit with greater confidence and safety.

An application aimed at the protection of electrical services using a VR immersive environment has been presented in this article. The system enables full navigation of the simulated reality and contact with most of the electrical components. Users are able to create electrical laboratory stands in the virtual environment using the component library embedded in the application and prepare the environment for the experiment as it would be done in the real world. The environment could be quickly experienced by most participants without previous experience and the activities suggested. To have a realistic experience, the attention is not just on the realistic look of the main devices, but on the environment also. Since VR technology is reusable and quickly updated, it can significantly reduce training costs and can be made accessible on the internet, eventually being a very attractive choice for remote education.

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ԷԼԵԿՏՐԱԿԱՆ ՀԱՄԱԿԱՐԳԵՐԻ ՍԻՄՈՒԼՅԱՑԻԱՆ ԵՎ ԼԱԲՈՐԱՏՈՐ ՓՈՐՁԱՐԿՈՒՄՆԵՐԻ ԿԱՏԱՐՈՒՄԸ ԸՆԿՂՄՈՂ ՎԻՐՏՈՒԱԼ ԻՐԱԿԱՆՈՒԹՅԱՆ ՄԻՋԱՎԱՅՐՈՒՄ

Վիրտուալ իրականության(ՎԻ) օգտագործումը որպես ուսումնական գործիք խթանում է ծրագրային ապահովման ստեղծումը, որը օգտվողներին հնարավորություն կտա փորձարկել ուսումնական միջավայրերը սարքերի միջոցով: Այս աշխատանքն ապահովում է ՎԻ համակարգի մշակման մեխանիզմ, որը կաջակցի էլեկտրատեխնիկայի դասավանդման ժամանակ կատարվող ինտերակտիվ լաբորատոր փորձարկումներին: Հիմնական գաղափարն այն է, որ օգտագործողին կամ ուսանողին ծրագրավորման փորձ ունենալը անհրաժեշտ չէ, քանի որ փորձերի համար անհրաժեշտ բոլոր պարագաները ծրագրային ապահովման մեջ ներդրված են որպես եռաչափ մոդելներ:

Առանցքային բառեր. վիրտուալ իրականություն, ինտերակտիվ ուսուցում, ընկղմող վիրտուալ լաբորատորիա, կրթական գործիք:

Э.А. АЛЕКСАНЯН

СИМУЛЯЦИЯ ЭЛЕКТРИЧЕСКИХ СИСТЕМ И ВЫПОЛНЕНИЕ ЛАБОРАТОРНЫХ ИССЛЕДОВАНИЙ В СРЕДЕ ПОГРУЖАЮЩЕЙ ВИРТУАЛЬНОЙ РЕАЛЬНОСТИ

Применение виртуальной реальности как инструмента обучения поощряет создание программного обеспечения, которое даст пользователям возможность испытать среды обучения с помощью устройств. Эта работа обеспечивает механизм разработки системы виртуальной реальности, которая поддерживает получение интерактивных лабораторий во время электротехнического обучения. Основная идея заключается в том, что студенту или пользователю нет необходимости иметь опыт программирования, так как все инструменты, используемые во время опытов, внедрены в программное обеспечение как трехмерные модели.

Ключевые слова: виртуальная реальность, интерактивное обучение, погружающая виртуальная лаборатория, инструмент обучения.