A New Perspective to Electrical Circuit Simulation with Augmented Reality

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***Abstract*—Thanks to the augmented reality (AR) technology, this study brings a new perspective to the simulation of electronic circuits and contributes to reducing the dependency on a physical environment and equipment. Electronic circuits are detected by mobile smartphones and their simulations are displayed on the smartphone screens. This study aims to increase the learning quality by simulating and transferring in to the physical environment such invisible concepts as current, voltage etc.**

***Index Terms*—augmented reality, AR, electronic circuits, 3D graphics, mobile application, electronics education**

I. Introduction

A. *Aim of This Study*

Today we live in a world where we need to think, act, and live at the fastest pace ever experienced in the history of humanity. With the advancements mankind has been going through in such various fields as technology, business, and so forth, one thing has gained a lot more significance for our adaptation to the current pace of our world: learning faster.

With a lot of information to learn, learning methods have had to be adapted to today's changing requirements as well. Getting exposed to thousands of stimuli every day, it is quite comprehensible that modern people have difficulty in concentrating and thus, learning. This reality is among the main reasons why learning professionals around the world strive to introduce brand new learning methods to the field.

Innovative learning methods are introduced to many fields to facilitate learning. This study aims to bring these innovative learning methods into electronic education by focusing mainly on 1) technology based learning and 2) learning by experience.

With a blend of these two learning methods introduced to the electronic education, this study helps to transform originally abstract concepts into observable processes, facilitate learning through real-time and personalized experiences, enhancing the quality and permanence of the content learned by experience, and limit the dependency on a physical environment and equipment required for the experiments performed in electronic education.

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B. *Augmented Reality*

Thanks to the use of recently trending smartphones, technology is now more accessible than ever to individual users and is quite widespread, which has eventually contributed to popularity of the mobile applications. Mobile application based solutions are now favoured better compared to the computer based solutions as mobile applications are far easier to use. Thanks to these developments, a very wide audience ranging from large corporations to individual users reaches out to mobile devices as one and only address.

Augmented reality is a technology which is applied to a number of fields today and has started to be used in daily life more and more [1]. A very recent concept increasing in prevalence, AR can be defined as real environments enriched with virtual objects. AR overlays digital imagery onto the real world through hardware players such as Microsoft HoloLens, Google Glass, and Magic Leap [2] Augmented reality, thus, combines both physical and virtual objects.

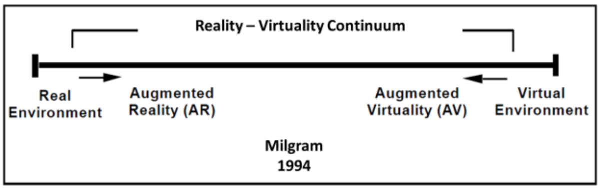

Fig. 1. Milgram's reality–virtuality continuum [3] states that there are many variations of technology-altered forms of reality. Augmented reality is one of these forms.

This study has been designed in parallel with the above mentioned two current trends (see Fig. 1) and offers a novel approach to the simulation of electronic circuits through use of augmented reality technology on mobile smartphones. This study provides a simulation of the experiments performed in electronic laboratories, where the practice and theory of electronic engineering are combined. Use of augmented reality in this context enables the transfer of such invisible concepts as current and voltage into the physical environment, and thus, offers a better learning opportunity for students.

A real learning experience combining the maximum number of senses provides a deeper and long-term learning. In this regard, augmented reality technology seems to be a developing technology in the field of education [4]. Educators have also started to accept the

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fact that the augmented reality opens new horizons in both learning and teaching. The comparative studies comparing the augmented reality based learning and conventional classroom learning have demonstrated that the augmented reality technology enables a better and further learning [5], [6]. It is because the coexistence of physical environments and virtual objects helps students to easily comprehend the complex spatial relations and abstract concepts [7].

Recent study findings reveal that as of 2015 AR has been started to be deployed in the following areas in the field of learning and education:

- Corporate trainings,
- Feedback requests from the audience during in an event,
- Trainings on archaeological fields,
- Active and motion-requiring trainings like taekwondo,
- Trainings to deaf people through enabling voiced object names,
- History trainings on historical cities and streets [8].

In the light of these developments in the fields of both learning and technology, this study makes an efficient use of today's technology and contributes to bringing novel approaches into the electronic education, enabling an easy learning, offering an opportunity to learn by experience, adding to the memorability of what is learnt, and setting the foundation of an efficient and online education system.

At this point, it is also crucial to emphasize that although AR provides the technological means to the user, content delivered through AR is in most cases more significant than the technology used in AR [9].

Looking back into the history of this recent technology, it is understood that the term "augmented reality" was first used in the 1960s at the Harvard University by Ivan Sutherland [10]. Ivan Sutherland took the first step in this field, and strived to bring the digital and physical worlds together.

Later in 1990, a Boeing technician called Tom Caudell named this technology and the first use of the augmented reality technology was in 1990s for training pilots [11]. As per the 2011 Horizon report, the augmented reality technology is expected to be put into use over the next years in such fields as education, research and so on. The fact that the augmented reality allows for adding virtual objects in to the real physical environments is believed to contribute to the quality of education [12].

The augmented reality technology could be utilized in many fields. Neurosurgery is one of the many areas of application for this technology. Use of the augmented reality technology in neurosurgery may enhance the quality of education for the medical interns [13].

In addition to medical applications, the augmented reality technology could be seen in many more areas like marketing, entertainment, travel, industry, and fashion. AR is utilized in marketing for the introduction of new products to market. Through the implementation of this technology in gamification, gamers can now live an almost real game experience as they play [14].

The augmented reality technology is used with magnetic resonance imaging (MRIs) and in computed tomography to simulate the images from these two medical scans on the patient during the surgical operation, and thus, to provide a vast information to the surgeons [15], [16]. Furthermore, augmented reality based solutions could also be utilized in treating the paralyzed patients and treating various psychological phobias [17], [18].

Research for the purposes of this study has revealed that AR applications are deployed mostly on paper (books, magazines, printouts). However, it has also been identified that real-world applications (the sky and objects) are more popular. Hence, it could be stated that the number of real-world applications of AR should be increased in order to boost the popularity of AR [8].

II. Creating Simulations of Electronic Circuits by Use of Augmented Reality Technology

A. *The Circuit to Be Simulated through Augmented Reality*

The electronic circuit to be simulated in this study is a voltage-divided circuit with LED. A schematic view of this circuit is presented in Fig. 2 below.

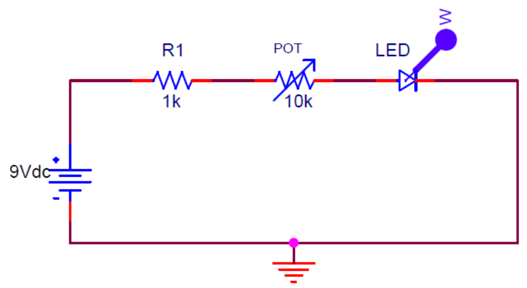

Fig. 2. Schematic view of the circuit to be simulated.

This electronic circuit shown in Fig. 2 is composed, respectively, of a voltage source, resistor, potentiometer, and light source (LED).

Potentiometer is used to change the total resistance, and circuit's current is monitored through the equivalence relation (1).

$$I=V/R \tag{1}$$

Here I is the current in ampere, V is the voltage in volt, and R is the resistance value in ohm. Amount of the current running in the circuit could be changed as the resistance value of the circuit is variable.

The equivalence relation (2) shows how the amount of current running through the circuit changes the total power consumed.

$$P=VI \tag{2}$$

Here P is the power in watt. As the amount of current running through the circuit changes the total amount of power consumed by the LED changes. Brightness of the LED increase or decrease proportionally depending on the total power consumed.

Although the current running through this circuit is not physically visible, the AR application allows for a tangible observation of any change in the total current running through the current as the LED brightness changes in proportion to amount of the current. Hence, the AR application enables a physically visible understanding of the current and facilitates learning such originally abstract concepts in the electronic education.

The amount of power consumed by LED in line with the changing values in potentiometer is presented in the following Fig. 3-Fig. 6:

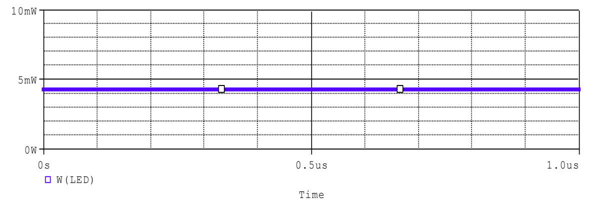

Fig. 3. Amount of power consumed by LED when potentiometer value is 0 kΩ.

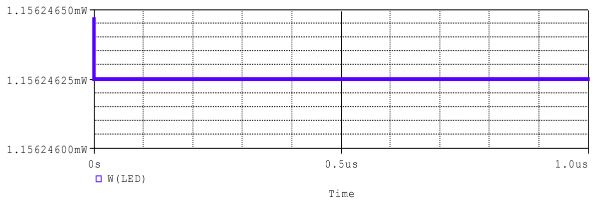

Fig. 4. Amount of power consumed by LED when potentiometer value is 5 kΩ.

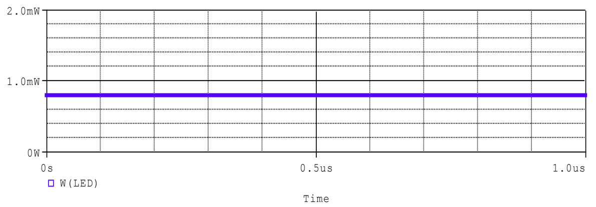

Fig. 5. Amount of power consumed by LED when potentiometer value is 8 kΩ.

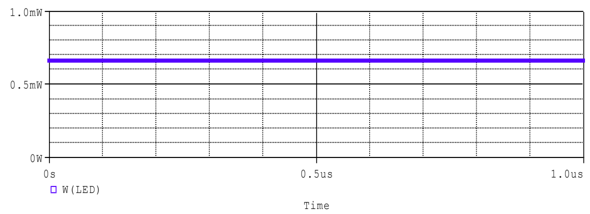

Fig. 6. Amount of power consumed by LED when potentiometer value is 10 kΩ.

B. Designing the Augmented Reality Model of the Circuit and the Android Application

Process steps for designing the augmented reality model of the circuit on the booklet/paper through a smartphone are as follows.

Android application was developed on Unity3D. Unity3D is a powerful game engine developed by the Unity Technologies Company.

Circuit schema relating to each circuit to be simulated is transferred during the application development process into the application as a marker. The marker could be such objects from the physical world as images, objects, texts and barcodes, which enable the application to recognize the circuit.

On the circuit schema used as a marker, 3D models of each circuit element to be simulated are drawn. The image marker utilized for this study is presented in Fig. 7. Once the application recognizes the image marker in Fig. 7, it starts the simulation related to this specific marker and thus, enables the student to observe the circuit in real time.

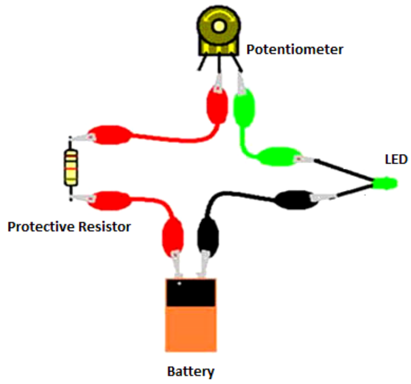

Fig. 7. Image target used in this study.

During the simulation process, scripts and simulation steps of each circuit element is required to be designed in order to simultaneously observe what sort of an effect each circuit element changed has, in line with the purposes of this study. Scripts of the application we have developed for this study are in the C# software language. This application enables us to monitor the visual and mathematical results of the outputs during the simulation.

For the circuit, the potentiometer value is 10K and the protective resistor is 1K.

In the 3D potentiometer simulation, the potentiometer knob has been designed in such a way that it could be turned 290 °on the smartphone screen.

This 290 ° angle range is scaled in between various resistance levels of a total of 10K value. Each 1 ° angle corresponds to a change of around 35 Ohms. The graphic used to show the change in angle and resistance values is presented in Fig. 8. The potentiometer value is thus changed, and the impact relating to the amount of current running through the circuit on the LED brightness is virtually monitored on the smartphone screen.

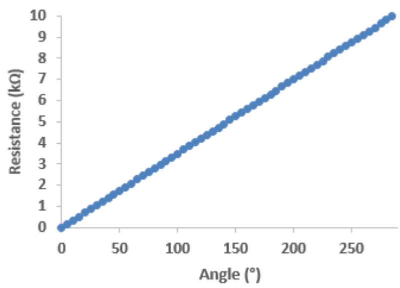

Fig. 8. Graphic showing the change in resistance value in parallel with the potentiometer angle.

Following the completion of application development, we have finalized design of the application to use this application on mobile smartphones and uploaded it to the mobile smartphones to be used for this study.

When the AR application on the mobile smartphone is started, the application activates the camera and waits for the camera to detect the previously introduced markers. Once any of the previously introduced markers are detected, the application checks the database to look up for the detected marker and decide on the related additional data to use for "augmenting" the existing physical environment.

The AR application embeds the additional data from the database in the physical environment appearing on the smartphone screen. At the ultimate step, simulation of the circuit can be seen on the smartphone display thanks to the AR application. Fig. 9 shows the process steps for the augmented reality design in this study.

C. Simulation of the Circuit through Augmented Reality

The circuit is detected by the mobile smartphone on which the previously designed Android application is uploaded. Thus, the circuit is simulated on the smartphone screen. This simulation is shown in Fig. 10. This figure demonstrates the addition of virtual information and animations on the real physical circuit drawing, and simulation of the circuit is thus examined.

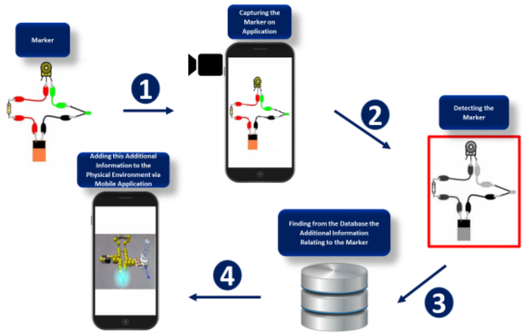

Fig. 9. Process steps for the augmented reality (AR) design of the circuit used in this study.

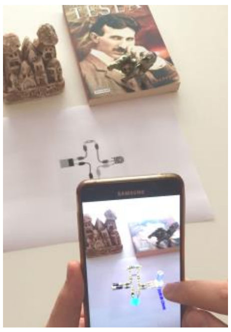

Fig. 10. Simulation of the circuit through the mobile application developed, and interactively changing the potentiometer value of the circuit.

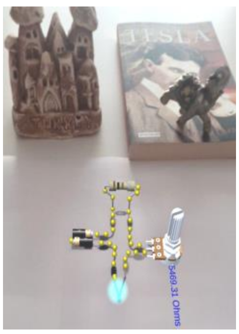

Fig. 11. Mobile smartphone's display following the simulation of the circuit through the mobile application developed. The potentiometer value is around 5.5 K.

Potentiometer value of the circuit is changed on the smartphone screen, and the related changes in circuit current as per equivalence relations (1) and (2) has been simulated. Fig. 11 shows that an increase in the potentiometer value also increases the total amount of resistance in the circuit, and this, in return, decreases the amount of current and the LED brightness. With this application, it is possible to observe the real-time effect of any changes on the circuit on the final output.

In this circuit, any change in the value of the simulated potentiometer element made on the smartphone screen causes a change also in the amount of current running. And this change in current is displayed in real time on the smartphone screen with the help of yellow dots shown in Fig. 11. When the resistance value increases, the amount of current and also size of the yellow dots representing the current decrease (Fig. 11). On the contrary, a decrease in the resistance value leads to an increase in the amount of current in the circuit, and this contributes to larger yellow dots (Fig. 12). This difference between these two cases can be seen in the Fig. 11 and Fig. 12.

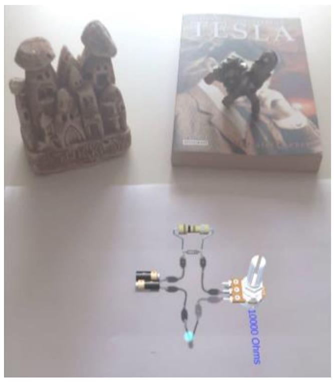

Fig. 12. Potentiometer value is 10 K.

Likewise, brightness value of the LED is also simulated on the mobile application in line with the amount of current in the circuit. Hence, any fluctuations in the LED brightness is presented on the mobile application screen.

III. Result Discussion and Conclusion

With a blend of two innovative learning methods, namely 1) technology based learning and 2) learning by experience, this study plays a significant role in introducing new approaches to the electronic education so as to transform originally abstract concepts into observable processes, facilitate learning through real-time and personalized experiences, enhancing the quality and permanence of the content learned by experience, and limit the dependency on a physical environment and equipment required for the experiments performed in electronic education.

In this study, electronic circuits drawn originally on paper have been simulated through the augmented reality technology. Use of the augmented reality technology has brought a new perspective to the simulation of electronic circuits, and contributed to decrease the dependency on a physical environment and equipment in electronic education.

Furthermore, the augmented reality based applications enable a physically visible understanding of the originally abstract concepts in the electronic education and facilitates learning through transforming the physically invisible concepts into observable processes. Values of the circuit elements can be changed on the smartphone's screen and the effects of such changes on the output are monitored in real time. Thus, such abstract concepts as current and resistance are materialized, and the difficulty in learning such concepts is substantially abolished.

Thanks to the simulation of circuits, students are able to observe how the amount of current and LED brightness changes in proportion to the total value of resistance and current in the circuit. This will enable a better, deeper and long-term learning for students.

In the upcoming studies, the electronic circuit booklet could entirely be simulated. Hence, students can simulate the circuits before coming to the class, and perform classroom experiments with a broader understanding of how circuits function.

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