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Implementation of an Augmented Reality Application for Basic Electrical Circuits

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Abstract: It is noteworthy that augmented reality is a technology used for educational purposes along with a wide range of applications ranging from defense industry to construction, medicine to automotive. In this paper, a recognition-based AR application named ARKTUNApp that can be used on basic electrical circuits in the field of electrical and electronics engineering was developed under these conditions, especially when the COVID-19 pandemic necessitates distance education. A QR code was identified as the marker, a booklet was prepared and it consisted of such basic circuit examples as short circuit, open circuit, circuit with series-connected resistors, circuit with parallel-connected resistors, RLC circuit, diode and LED circuit, environmental currents method and node voltage method with QR codes. When the users scan them, they can observe 3D simulations and animations of those circuit examples thanks to the AR application developed. Using Vuforia SDK as the software development kit and Unity3D as the application development platform, it was aimed to concretize abstract concepts and enhance interactive educational experiences. In addition, C# programming language was used to develop this application for smart devices with Android operating system. 30 students participated in the user study and their feedback about the AR application developed was obtained with a questionnaire.

Keywords: Application, Augmented reality, Circuit, Education, Engineering

Introduction

An application named ARKTUNApp was developed using augmented reality technology within the scope of this study, and theoretical concepts and situations related to basic electrical circuits taught in electrical and electronics engineering modules were simulated in a 3D environment (Cinar, 2020). Many educational institutions have turned to distance education as a result of the COVID-19 pandemic that has affected the entire world since the beginning of 2020. Considering this point, the significance of the AR application developed becomes higher.

Augmented reality is the process of combination or “augmentation” of video or photographic images in computer programming by superimposing images with useful data generated on the computer (Hosch, 2020). According to another definition, it is a variation of virtual reality and AR allows the user to see the real world with virtual objects superimposed or combined on the real world and augmented reality systems have such three basic properties as combining real and virtual environment, providing real-time interaction and being 3D (Azuma, 1997). Morton Heilig, known as one of the pioneers of visual reality, produced the cinematograph named “Sensorama” in 1957 and patented this device in 1962 (Cinar, 2020). It was followed by the fact that Ivan Sutherland and Bob Sproull developed the first HMD augmented reality application named “The Sword of Damocles” in 1966 (Yuen et al., 2011). Through this HMD, 2D object images were brought together and 3D image illusion was presented to the user (Sutherland, 1968). In 1970s and 1980s, some researchers received

education on AR at NASA, US Air Force and North Carolina University (Feiner, 2022). The terms of augmented reality were first used by Thomas P. Caudell in 1990 (Caudell & Mizell, 1992). After 2000, such giant companies as Nokia, HTC, Google and Microsoft have allocated resource for this technology, made investment in this direction and developed AR glasses.

Augmented reality consists of some components and they are basically hardware and software components. Hardware components are as follows: sensors, input devices, processors, displays and integrated systems (Tunali, 2015). Software components are as follows: software directly inside an AR application, software used to create the AR application, software used to create content for the AR application, other AR-related software (Craig, 2013).

Tracking and marker are important concepts in augmented reality. The first one is the process of recognizing the reference object and calculating its 3D location and direction. A tracking system consists of two main components: targets and sensors (Ercan, 2010). The latter one is one of the elements used to enable the real world to be mapped in 3D. It is also expressed as images that applications can define (Aslan, 2015). The most known and used marker systems are circular and square markers (Ercan, 2010).

Method

Details about the platforms to be used for the AR application developed within the scope of this study were given in the first section. The AR application was expressed thoroughly in the second section.

Platforms Used for the AR Application

Unity 3D was used because it allows its users to create games and animations in 2D or 3D. Furthermore, applications developed thanks to this platform can be run on devices with Android and iOS operating system. Android SDK was used because it allows the application to run on smart devices with Android operating system. Vuforia SDK was used because a QR code was defined as marker for this AR application and this software development kit allows its users to create a single local application.3DS Max was used because 3D models of the basis electrical circuits can be created for the AR application.

Figure 1. Addition of the QR code marker to Unity (Cinar, 2020)

Implementation of the AR Application

First of all, an educational booklet including basic electrical circuits (short circuit, open circuit, circuit with series-connected resistors, circuit with parallel-connected resistors, RLC circuit, diode and LED circuit, environmental currents method and node voltage method) was prepared. After QR codes next to these circuits are scanned by smart devices, users can see 3D models and simulations of these circuits. After this process, such

circuit components as battery, resistor, switch, diode, LED, capacitor were designed on 3DS Max. 3D models of the aforementioned basic electrical circuits were designed by using the aforementioned circuit components on 3DS Max. 3D models of the circuits were converted to FBX files and transferred to Unity3D. A menu was designed for the AR application and its user can click which circuit is wanted to be seen. C# was used to create interrelations between menu and scenes. An APK file should be created to run this application on a smart device with Android (minimum 7.0 version) operating system. Therefore, it was created on Unity3D and tested on smart devices (Cinar, 2020).

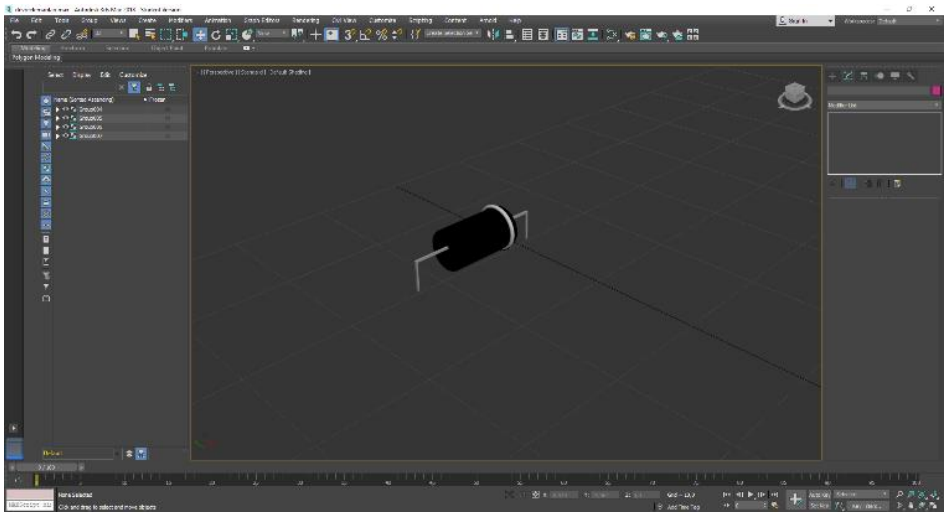

Figure 2. A 3D resistor design developed in accordance with resistor color codes for the application (Cinar, 2020)

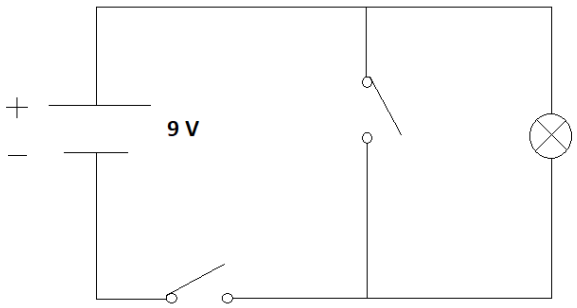

Figure 3. A 3D diode design in which the anode is shown in black and the cathode in white for the application in accordance with the original one (Cinar, 2020)

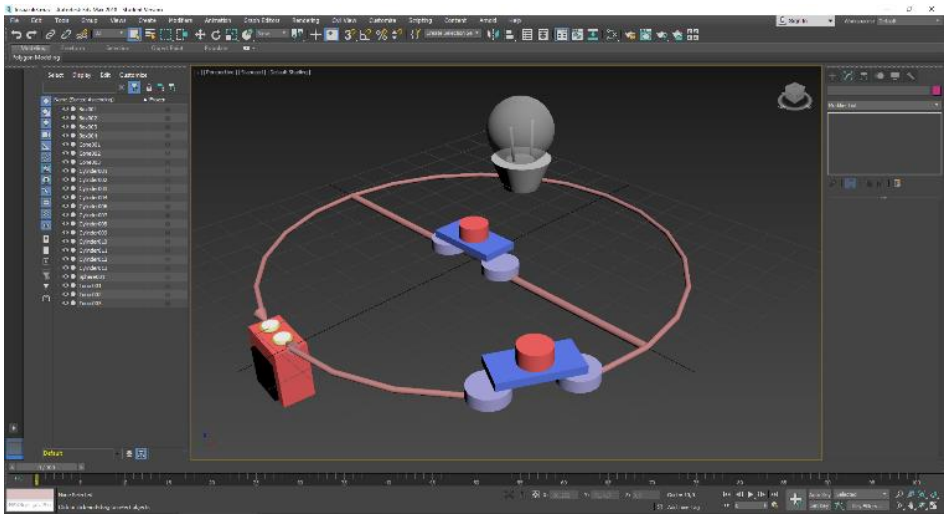

Figure 4. Example of open and short circuit found in the first place of the educational booklet (Cinar, 2020)

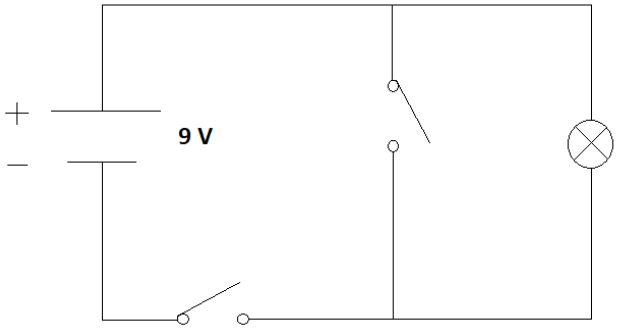

Figure 5. 3D open and short circuit design realized according to the example (Cinar, 2020)

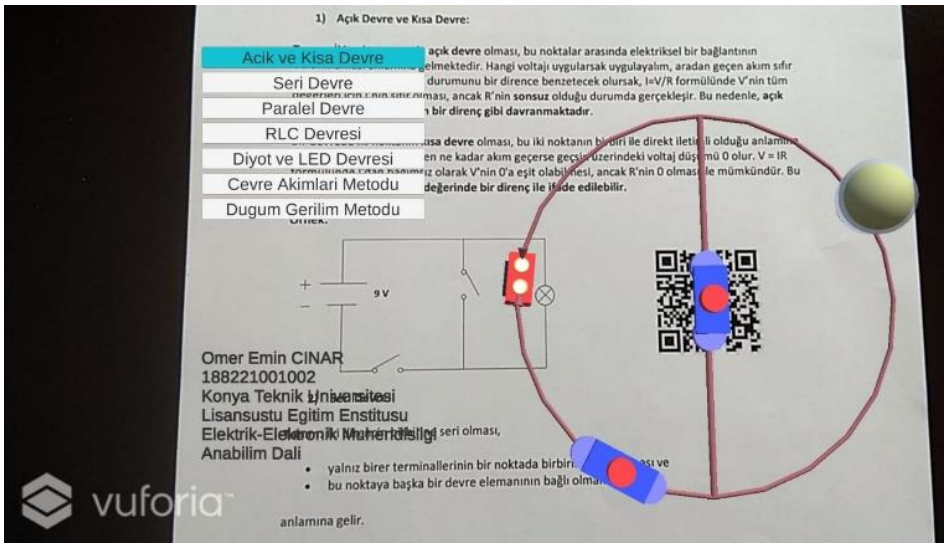

Figure 6. Menu interface and appearance of open/short circuit in the educational booklet of the AR application developed (Cinar, 2020)

Results and Discussion

Results

In order to obtain feedback on the AR application developed, totally 30 persons being undergraduate students in the Department of Electrical and Electronics Engineering or graduate students in the Department of Electrical and Electronics Engineering of Konya Technical University were informed about the purpose, content and operation of the application and they were asked to use the application. The booklet and the download link of the application file were also shared with the participants. A questionnaire was prepared so that the participants could report their ideas and experiences regarding the application. Likert scale was used in the questionnaire and 10 statements were presented. In order to indicate whether they agree with these opinions or not, 5 opinion sentences were included in the questionnaire (Cinar, 2020).

Discussion

The results of the questionnaire suggested that the AR application developed made a positive contribution to the level of understanding and comprehension of the participants about the relevant courses. 93% of the participants found the AR application useful. 97% of them thought that abstract concepts became more comprehensible. 97% of them found the menu interface of the application useful. 90% of them thought that the application contains enough circuit examples related to Electrotechnics and Circuit Analysis at the basic level. 87% of them thought that the application made learning easier. All of the participants thought that the resistance values on the circuits in the booklet match the resistor color codes in the 3D models in the application. All of them thought that the circuit components on the circuits in the booklet and the 3D models in the application are compatible with each other. They agreed that the 3D models of the circuit components and animations in the application are

realistic. 83% of them thought that the AR application increased their achievement in the related courses (Cinar, 2020). Survey results are given in more detail in Table 1.

Table 1. Survey results (Adapted from Cinar, 2020)

No	Statement	Strongly Agree	Somewhat Agree	Neutral	Somewhat Disagree	Strongly Disagree
1	I think this application is useful.	20	8	2	-	-
2	Abstract concepts became more understandable thanks to this application.	19	10	1	-	-
3	Menu interface of the application is convenient.	19	10	-	1	-
4	The application basically contains enough circuit examples related to Electrotechnics and Circuit Analysis.	16	11	-	3	-
5	This application has made learning easier.	18	8	4	-	-
6	The resistance values on the circuits in the booklet and the resistor color codes in the 3D models match each other.	26	4	-	-	-
7	The circuit elements on the circuits in the booklet and the 3D models match each other.	25	5	-	-	-
8	3D models of circuit elements are realistic.	21	9	-	-	-
9	Animations in the application are realistic.	21	9	-	-	-
10	This application has increased my achievement in related courses.	14	11	3	2	-

Conclusion

ARKTUNApp augmented reality application was developed with the aim of concretizing basic electrical circuits with 3D models and animations. 3DS Max, Android SDK, Vuforia SDK and Unity3D were used in the development of the application. It was made available for the use 30 undergraduate and graduate students, and their feedback about the application was obtained through a survey study. They found the application useful, functional, realistic and interesting (Cinar, 2020).

Recommendations

Considering the time spent on smart devices, especially mobile phones, and the recent trend towards distance education with the impact of the COVID-19 pandemic, the use of augmented reality will also increase in engineering education. Further progress can be made in this area once sufficient hardware infrastructure and know-how are provided. The approach in this paper can also be adapted to a variety of subjects and courses. The use of augmented reality technology can be very useful in lessons that may remain abstract such as Analog Electronics, Digital Electronics, Logic Circuits, as well as Electromagnetic Wave Theory. Augmented reality application can be made more useful by combining them with different technologies such as deep learning, machine learning, computer vision, image processing.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

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