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Interactive Circuits Using Augmented Reality

Rikin Desai, Roma Dave, Ronak Mehta, Abhijit Joshi, Sherrin Benjamin
Information Technology
Dwarkadas J. Sanghvi College of Engineering
Mumbai, India
rikin_desai@hotmail.com, roma_dave91@rediffmail.com, mronak25@gmail.com, abhijit.joshi@djsce.ac.in, sherrin.jacob@djsce.ac.in

Abstract — Physics is a subject where concepts are difficult to grasp unless done practically. Our project "Interactive circuits using Augmented Reality" is a research work under Project Oscar at IIT-B, which practically helps the students to perform the experiments involving different electrical components such as bulb, battery, voltmeter, resistor, switch, and ammeter in Augmented Reality (AR). This would help the students to perform physics experiments without using actual components and helps them to understand the cause and its effects. This would not only make the subject interesting but also interactive, resulting in learning.

Keywords – Augmented Reality, Blender, Marker, NyARtoolkit, Unity, Pspice, Simulation Software, Virtual Buttons, 3D Model

1. INTRODUCTION

The aim of the subject physics is to understand the natural world, in most fundamental and its broadest sense. By understanding it, we can therefore explain, predict and ultimately control events. Hence it is an essential subject for all students. Normally, physics experiments are thought to be done in laboratory with actual electrical components, but not with anything else. Students perform all experiments taking extra precautionary measures. After working with actual physical components, one may also use simulation softwares.

Current simulation software such as Pspice is used to design circuits. These softwares enabled students to work freely without taking any precautionary measures. One could develop complex circuits with much less time than what was required with actual electrical components. For that, student has to draw the circuit diagram using the MicroSim Schematics software. Next, he has to set up the simulation parameters and then run the simulation itself. Finally, he has to evaluate the simulation results using MicroSim Probe.

For doing these steps in Pspice, one has to remember values of components used and also they need to know the language in which the simulation runs. In Pspice, students get 2D representation of the circuit but, can't view 3D models. A 3D view of the components enhances tacit understanding and makes assembling and learning of circuit's fun [1]. Also, one has to know coding language to work on Pspice. There are many videos available which demonstrate many circuits but they aren't interactive. In case of errors, students need to analyze the code and then he has to make appropriate changes in it.

In fact we have to understand that this is simulation. Many people do not consider what they do is engineering unless they can see or hear or feel the results of the work done. If you are designing light saber a typical engineer needs to be able to hold the light saber in his/her hand in order to consider the project worth his or her time.

Apart from Pspice Simulation, animations are also available for students to understand various concepts of physics. But, the problem is that this mode of learning is not interactive and as mentioned previously physics concepts are difficult to grasp unless done practically.

Keeping in mind all these issues, we decided to develop an environment to perform various physics experiment using Augmented Reality. Our Project 'Interactive Circuits Using Augmented Reality' is an innovative approach to help students in performing physics experiments using electrical components in virtual world.

This is a unique way to attract students into the world of physics. Performing physics experiments virtually involves an entirely new concept of combining real world into virtual world. Currently, our focus is to teach ohm's law using AR.

2. OUR APPROACH

To develop a model for ohm's law, we used various tools, namely, Blender, Unity 3D and NyARtoolkit. Now, let us understand the role of these tools in the development of the model.

Blender is open source 3D modeling software used for animated films creation, adding or enhancing the visual effects, adding of interactive 3D applications, etc [2]. In our case, we used Blender for making 3D models of electrical components like Voltmeter, Ammeter, Resistance Box, Key, and Battery, which are required for demonstrating Ohm's law.

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Our project is completely based on working with 3D objects and its environment. These models give the appearance of real objects, which helps students to remember 3D perspective of the object that one can't see in simulation software. To do this, a concept of Marker is used. Marker is a black and white pattern which is used to display 3D models. These markers are generated using ARToolkit Marker generator. The marker is placed in front of camera, the application captures the rectangular black border and the file is saved as '.pat' file. This 'pat' file is a binary file which is mapped to corresponding 3D models in Unity, so that a 3D model is displayed over it. Figure 1 shows a marker for ammeter.

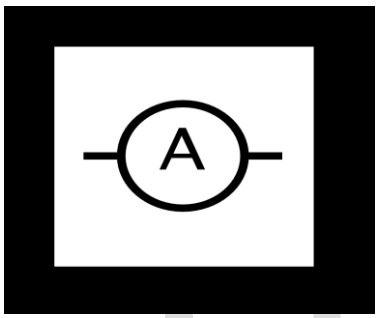

Figure 1: Marker for Ammeter

Unity is a game development eco system, a powerful rendering engine [3]. It is used to create interactive 3D content. As soon as 3D objects are ready in Blender, they are imported in Unity. Now, these 3D objects are arranged according to the circuit diagram of Ohm's law as shown in figure 2. These 3D models of various components will help to visualize the objects in much better way.

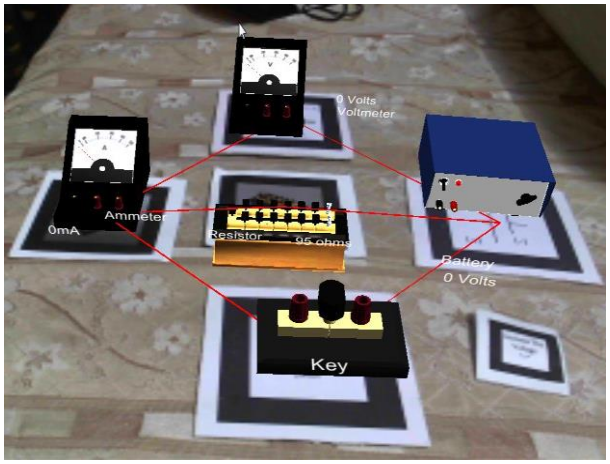

Figure 2: 3D representation of circuit diagram of Ohm's law in AR

NyARtoolkit is an Augmented Reality class Library [4]. This library provides API for Visual Augmented Reality. Using these API's, system can trace various markers.

3. WORKING OF THE SYSTEM

Now, let us see how student interact with the model to know about it and in turn learns Ohm's law.

- The student places the marker in front of webcam such that entire marker is visible to the webcam, if so done correctly then webcam detects the marker pattern with ease.
- Multiple Markers with different pattern are used to do same with exact same procedure mentioned above. But, care should be taken that no marker should overlap each other.

  Here, we need to understand what do multiple markers mean? Multiple markers mean enabling webcam to detect and trace multiple markers instead of single marker [5]. Each marker depicts corresponding 3D model. These markers are also used to display GUI text as shown in figure 2. This GUI text is used to display the name of the various components in the circuit, the parameters of the components, etc. It is also used to display the changing parameter as changed by user.
- The webcam senses the marker(s) and simultaneously checks for a Marker Object for right marker, if found successfully a 3D model is displayed over corresponding markers.
- Now, student interacts with markers and eventually with the circuit using virtual button. Here, virtual button refers to the concept of change in properties/parameters of 3D object shown on the marker with the help of another marker. The virtual buttons/markers like '+R', and '-R', are designed to increase and decrease the resistance and '+V', '-V' are to increase and decrease voltage. To see the effect of these markers, they are required to bring in front of the webcam's perspective view in the presence of their respective component. The parameter change can be seen in GUI text. The change is updated in every frame till the time that marker is present in front of the camera.

  Wiring constituted the important part of the project as any circuit is incomplete without wiring. The wiring in our case is made according to the Ohm's law. The wiring module is updated by placing one marker in front of the camera.

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Figure 3 depicts a case where the marker '+R', i.e., "increase resistance" is placed, which raises the value of resistance in the resistance box. According to the value of battery, the value of current would be displayed.

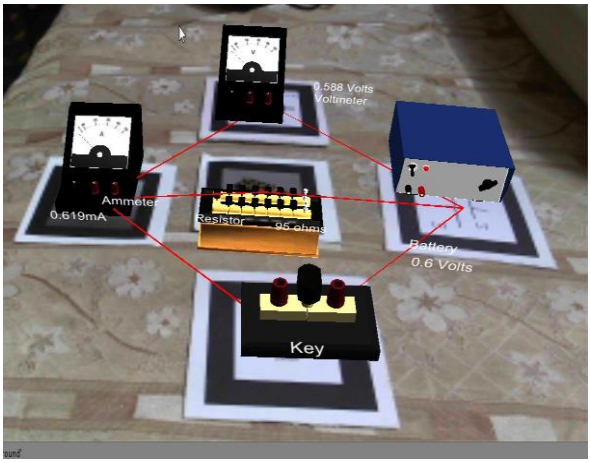

Figure 3: Voltage increased keeping Resistance Constant

A: Implementation Steps

The project is implemented as follows:

i. All the 3D models like Voltmeter, Ammeter, Resistance Box, Battery, and Key are made in Blender 3D software.
ii. After applying all the textures and materials, the models are saved as .blend file.
iii. Marker Patterns are captured using NyARtoolkit generator according to the 3D models and are saved as .pat file.
iv. NyARtoolkit which has all the libraries for Augmented Reality are loaded in Unity to work in AR using Unity.
v. The blend files, i.e., all the 3D models are loaded in NyARtoolkit project and similarly all the .pat files are stored in NyARtoolkit folder. Textures are applied in unity to all the 3D models to give it a more realistic effect.
vi. The project is then saved as .exe file which can run on any platform without Unity and NyARtoolkit. The students require only the printed markers to work with this project.

B: Implementation Challenges

Some of the challenges we face during implementation of this project are –

- The first challenge is to enable webcam to detect multiple markers, because, the existing systems are capable of detecting one marker and in turn displays only one 3D model. For implementing physics circuit in Augmented Reality, multiple electrical components are required to be displayed such as, battery, ammeter, voltmeter, and bulb.
- Another challenge in the project is interactivity, i.e., to enable students to manipulate 3D models by changing the parameters. The changes could be changing the voltage of battery or changing the resistance of a resistor and its change on the entire assembly to help students to learn physics, circuits in an interactive way. Such changes in 3D model would be implemented using the concept of virtual buttons.

C: Benefits of the System

Some of the benefits of our system are -

i. Freedom to experiment with different parameters of the components.
ii. All the 3D models can be used again and again (reusable) without getting damaged.
iii. Easy to use and interactive.
iv. Students can understand the cause and effect relationship easily as they can observe changes in the circuits.
v. It is safe to use as it would not cause any harm to the students. For example, even if the blub bursts or even if short circuit takes place it won't harm the student.
vi. Enhance tacit knowledge through experimentation.
vii. Softwares used like Blender and Unity are open source so no cost is involved.

4. CONCLUSION

The use of 3D models and its implementation in Augmented Reality would enable students not only to get their hands on with the assembling of circuit but also understand them the causal relationship based on the changes made to the parameter of the 3D electrical components. The project ensures safety of the user as no physical electrical components are involved; furthermore it enhances the tacit knowledge of the user and helps him in understanding of the circuit in easy way.

5. FUTURE SCOPE

This project implements the most basic circuit which is Ohm's Law. This could be further enhanced to implement other laws to support a wide gamut of complex electrical circuits.

The pointers of the 3D models (voltmeter, ammeter) can be rigged to enhance the understanding of the experiment for

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more realistic effect. The concept can also be used for performing experiments in any other field.

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