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Augmented Reality Electric Circuit Experiment

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***Abstract*—The advancement of hardware technology, specifically in mobiles devices, has provided great computational power for running and creating sophisticated large programs such as, virtual reality, augmented reality and neural network based programs. Augmented reality (AR) is one of the finest and most exciting technologies nowadays. AR enables creating computerized objects and blending them with the real world. Which can be applied to enhance and simplify many aspects in a variety of disciplines. In result, instead of reading text and imagining experimentations it is possible to simulate the experiments through equipment and experiments as same as in real world scenarios, which can be much understandable and comprehensible. In the past decade, several institutions have adopted technological methods of teaching and learning. These instructional technologies can be used by some institutions that cannot provide enough time or proper equipment to students. This is where augmented and virtual reality are mostly favorable. In result, instead of reading text and imagining experimentations it is possible to simulate the experiments through equipment and experiments as same as in real world scenarios, which can be much understandable and comprehensible. In this paper, a model of an electric circuit is created to simulate the motion of electrons and how electric current runs through a wire and provides power for different tools. The creation of such a model involves design, modeling, simulation and animation of the model. This is done by relying on several software and frameworks such as Maya3D, Unity3D, ARKit, etc..**

Keywords—augmented reality, ARKit, Maya3D, Unity3D, electric circuit

I. INTRODUCTION

There have been major advancements in our world in the past ten years. The emergence of information technology has greatly influenced the present. Educational institutes have been adopting technology for the purpose of students' education. In the early days, education was with books, blackboard, choke, etc.. which was sufficient for preparing students for the real world. On the contrary, nowadays, the young generation are faced with a completely different reality when finishing their studies. Thus, it's highly beneficial to use advanced technologies such as augmented reality (AR) to help students focus and be simulated during the courses. Moreover, this further enhanced their comprehension and visualization of subjects [1].

AR and VR have been previously used in education, for example, Water on Tap is a virtual reality software developed by Christine M. Byrne in 1996 during his PhD course. Where he tried to create an immersive virtual reality environment for chemistry education [2].

Accordingly, AR is a technology that blends computer generated three dimensional objects with the user's environment in real time. Augmented reality is different from virtual reality in that VR establishes a computer created environment for the user to experience. While AR is the real world user environment extended with computerized objects. Meanwhile, Mixed Reality can be seen as a combination of AR and VR, where real life objects are intractable and overlaid with computer generated objects [3].

This paper presents an educational AR model of the electric circuit for physics education to help the student better understand electric circuit (i.e. Amperes and Volts), which is impossible to watch by naked eye. In addition, this electric circuit is basically the movement of electrons from high potential energy to a lower potential energy and it requires a specialized Microscopes to view electrons [4] that are not available in many schools and universities now. Thus creating such a model can be significantly beneficial to students and also can be very cost effective to the institution itself.

The proposed application is built using several technologies. First the design of the different elements of the electric circuit are created with Maya3D. Maya3D is a modeling and animation software that is used to create a variety of objects, animate them and render them [5]. Second, Unity3D has been used to create the scene of the electric circuit, create special controls, and make use of ARKit augmented reality framework. Unity3D is a gaming engine, it can create powerful and efficient AR and VR experiences [6]. Third, ARKit is used for AR technology, ARKit is a platform for developing augmented reality application for iOS. It enables detection of vertical and horizontal planes, as well as 3d and 2d markers [7].

II. PREVIOUS WORK

There have been great research and application of virtual and augmented reality in the past. Studies have been carried out to show or prove the advantage of these new technologies in modern education and learning methods. Construct3D is an application of collaborative augmented reality for mathematics and geometry education. The application has been developed to help students learn mathematics and geometry at high school and university level. The work has been shown to encourage experimentation with geometric constructions and improve

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spatial skills [8]. Moreover, there are major applications of AR/VR for simulation. For example, the flight simulation software developed in Ohio Wright-Patterson Air Force Base [9]. Furthermore, there are several advantages of using AR/VR in education. First, specially designed first-person experiences to help students learn material, experiences that cannot be obtained in formal education. Second, new forms and methods of visualization. Third, student motivation through interaction and positive participation. Finally, the ability to study with a broad time schedule and not fixed by class time [10].

Physics is a great example for AR and VR simulation advantage. This is because students in such a field have little understanding and comprehension of the qualitative dimensions of the phenomena they study [11].

III. Design & Modeling

Modeling is creating 3d poly objects and assigning textures to those objects. ARKit enables rendering larger models to those created for Samsung Gear VR. VR mobile application development impose large limitations on the number of polys and textures used [12]. Maya3D has been used to model the circuit and texture it's different parts. The modeling involves creating an electric circuit with a light bulb, a switch, an electron, and a battery. The path for electrons has been created that represents a copper wire. as illustrated Fig. 1.

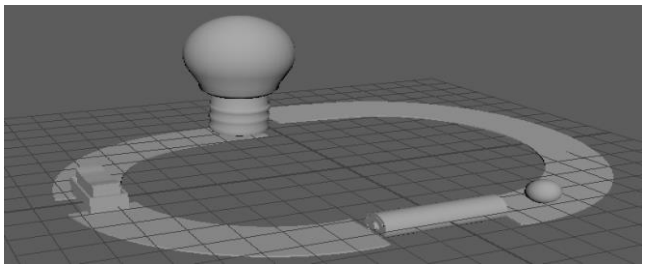

Fig. 1. Circuit Model.

Texturing on the other hand involves assigning different materials to the models. Such as creating a transparent glass material for the light bulb, or creating a blue material for the electrons. As shown in Fig. 2.

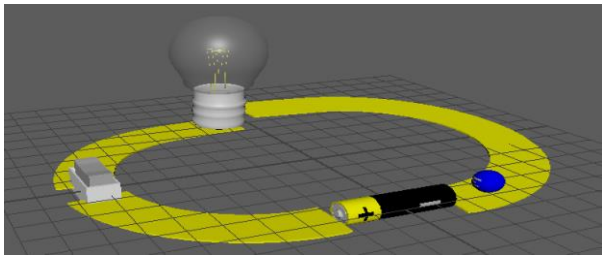

Fig. 2. Texturing of the circuit.

IV. Simulation & Animation

The AR technology has been developed in Unity3D. Unity3D is a gaming engine, for creating 2D and 3D game as well as VR/AR games and applications [6]. Moreover, since the application is intended for iOS, the ARKit plugin must be added to unity so that it can build ARKit based applications.

A. ARKit Plugin

ARKit is a framework developed by Apple for iOS devices. This framework enables iOS devices to run augmented reality games and applications. ARKit makes use of the device camera and motion sensors to enable such technologies [7]. ARKit is based on three layers: Tracking, Scene Understanding, and Rendering.

Tracking is basically finding the precise device location in a real world environments relying on the device motion sensors, gyroscope and visual inertial odometry [13].

Scene understanding is detecting feature points, horizontal and vertical planes in the users environment so that different objects can be correctly placed and anchored to the physical world around. Moreover, it can detect cross sections with the real world and apply light estimation to the placed object so that they can appear as close to reality as possible [13].

Finally, Rendering is the ability to draw these object in the scene.

ARKit plugin for unity is a platform plugin, as the name suggests, developed for Unity3d. the plugin is used in unity software so that ARKit capabilities can be utilized for AR application development in unity. Without ARKit plugin, unity cannot provide the necessary libraries for developing an iOS AR application.

For the proposed application ARKit has been imported from the Unity assets store and incorporated to the project scene. Horizontal plane detection is the devices ability to find flat surfaces in the user's environment, such as table tops, the floor, etc.. this capability has been enabled in the application so that the electric circuit can be correctly placed on a table top to look as realistic as possible. The code below is responsible for finding a cross section of a horizontal plane in the users environment so that the circuit can be correctly placed.

```
if (Input.touchCount > 0 && m_HitTransform != null)
{
   var touch = Input.GetTouch(0);
   if (touch.phase == TouchPhase.Began ||
       touch.phase == TouchPhase.Moved)
   {
      var screenPosition =
      Camera.main.ScreenToViewportPoint(touch.position);
      ARPoint point = new ARPoint {
         x = screenPosition.x,
         y = screenPosition.y
      };
      };
```

```
foreach (ARHitTestResultType resultType in resultTypes)
{
  if (HitTestWithResultType (point, resultType))
  {
    return;
  } } } }
```

As shown in the code above, a touch is captured from the device screen. Then that touch is converted into a coordinated that corresponds to a plane in the line of the position touched so that the model circuit can be placed. This relies on Hit-Testing.

B. *Hit-Testing*

Since devices render a 2D image of the 3D augmented reality scene, a touch on the screen can respond to any point along the line of the touched position. Hit-testing is responsible for detecting any objects that lie in the path of the position touched and returning an array of hit test results. This can be used to detect objects or anchors in a desired position in the real world.

In the proposed application. Hit-testing has been used to place the 3D circuit model on a flat surface as same as in the real circuit.

C. *Scene Implementation*

The implementation of the scene is basically importing the 3D electric circuit model in the unity editor from Maya3D. After importing the model, the hit-test script is attached to the model parent object to place all the circuit objects at once.

The electron objects are duplicated and placed correctly around the circuit and several animations have been created to simulate this circuit model. Moreover, an emissive material is created to simulate the bulb light turned on and a canvas is prepared with controls to enable switching the circuit on and off. As shown in Fig. 3.

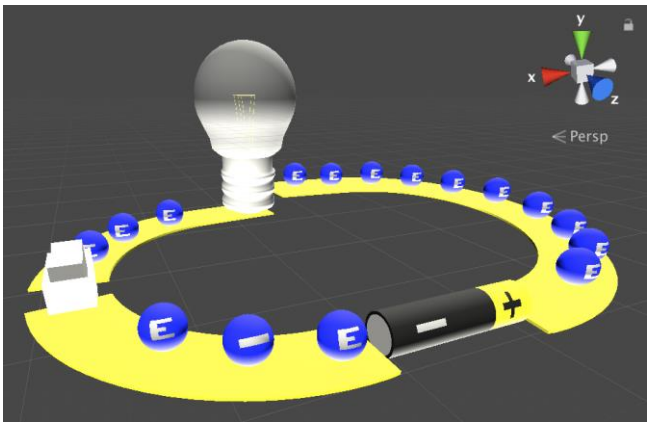

Fig. 3. Electric circuit model in Unity editor.

D. *Animation*

Animations in unity3D enable moving objects by position, rotating objects, or scaling object size at runtime. There are also complex animations used for characters. In the proposed application, animations have been used to animated the circuit switch turning on and off, also to animate the movement of electrons in the circuit. First, Animations must be created in the animations window, based on the transform properties of objects and a time frame. Then, Animations are activated by custom C# scripts.

To create an animation, first a recording must be started. Afterwards, the object transform properties must be changed and set at specified time frames. Basically, the animations are manipulating the different objects transform (i.e. position, orientation), and recording that so that it can be played by the script. As shown in Fig. 4.

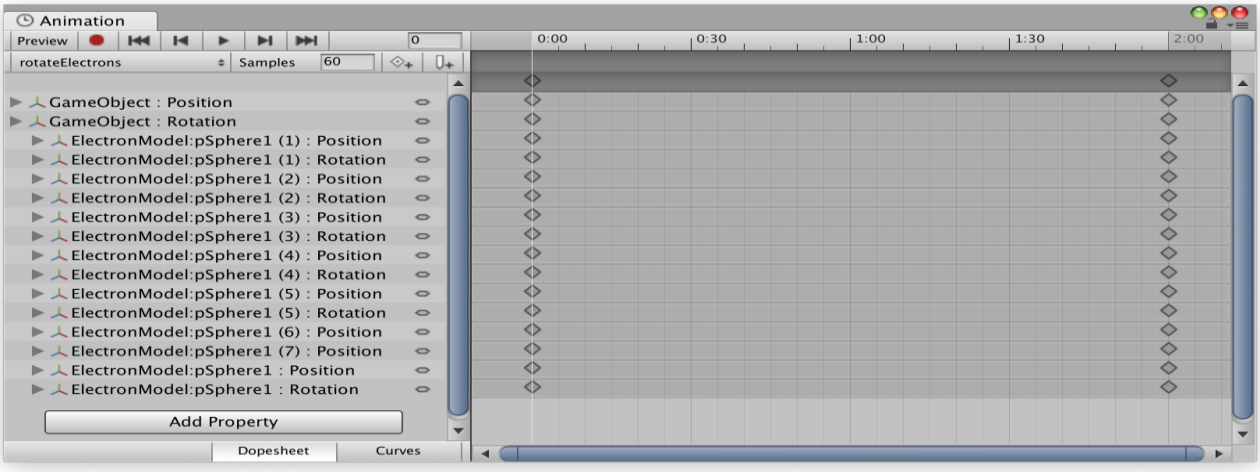

Fig. 4. Recording electron animation.

The recorded animation is saved as a clip for the next step. Afterwards, a script is written to activate the animation based on the required state. The script runs the animation and controls the switch when the playOnAnim() function is run. vice versa, the animation is stopped and the switch is raised when the playOffAnim() function is run. See code below for the controlAnim script.

```
public void playOffAnim()
{
switchB.GetComponent<Animation>().Play("OnAnim");
electrons.GetComponent<Animation>().Stop();
isplaying = false;
rend.material = transM;
}

public void playOnAnim()
{
switchB.GetComponent<Animation>().Play("OffAnim");
electrons.GetComponent<Animation>().Play("rotateElectrons");
isplaying = true;
rend.material = GoldM;
}
```

E. Canvas

A canvas is an on screen area. All user interface (UI) objects must be combined in to a canvas. A scene view object displays a canvas in a rectangle where eventSystem is used [14]. A canvas is used to create two controls (UI Buttons) in the application. The controls are then that are added on the scene view. One is used to connect the circuit and another to disconnect the circuit. The buttons are placed on the bottom of the screen at runtime and can be touched to activate or deactivate the circuit. The on button and off button are connected to the playOnAnim() and playoffAnim() functions respectively. Upon pressing the buttons calls to the intended function are made to work. As shown in Fig. 5.

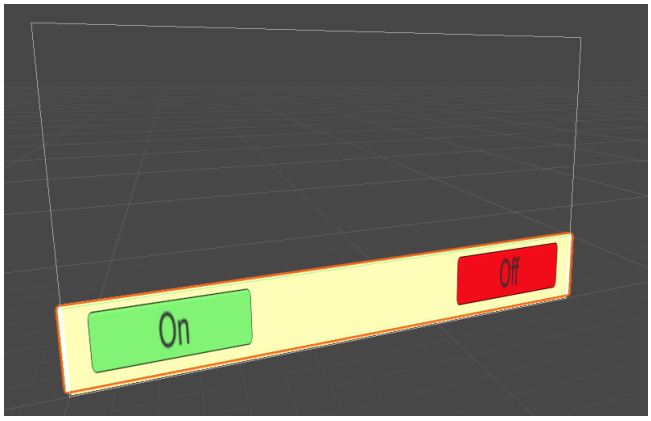

Fig. 5. Canvas of the application.

V. RESULTS

Augmented reality can considerably benefit subjects with scientific experiments. Many experiments in the fields of physics, chemistry, engineering, etc. can be simulated in augmented reality. AR can be extremely advantageous where the equipment required to study or carry out experiments are expensive or cannot be obtained. Making a more cost effective approach to learning.

Moreover, AR taught subjects are more simulating and easier to understand than just reading the subjects and having to imagine the experiments. There have been many surveys and studies regarding VR/AR for education in the past. Most indicating the importance and unique capabilities of such technologies in aspects of constructive learning [15]. Also, success of simulations in AR/VR contributes to the empowerment of students. Such exceptional instructional capabilities and the support for modern instructional approaches helps the development of cognitive skills, and the development of attitudes [16]. Using AR enables simulating real world scenario situations where students can easily see the experiments rather than just use their imagination.

This paper attempt to create an AR learning environment on mobile devices. most of the available research is implemented on specialized headsets or equipment. Construct3D is implemented on head mounted displays, special tracking devices and handheld devices [8]. While large scale applications, such as the flight simulation software in Ohio, is implemented on head mounted displays and specialized controller [9]. This limits the availability and portability of such educational software. Thus bringing AR technology and education models together in mobile devices is ideal. The application can be installed on most modern smartphones. Making it widely available to students and institutions for use.

The proposed application of the electric circuit can help student to visualize electrons and their movement rather than imagining. The model in application shows the electron movement from the negative charge to the positive charge through the light bulb. As shown in Fig. 6(a and b).

VI. CONCLUSION

In conclusion, the advancement and price of hardware has enabled running such technology on devices at our disposal already. Technologies like virtual and augmented reality can have a large variety of benefits in the present time. specially in teaching scientific subjects, where it is hard to acquire the materials, tools and equipment required for scientific experimentation.

In this paper a model of the electric circuit was created to show the movement of electrons and how electricity works. This simulation helps students in better understanding electricity in a cost-effective manner without having to get their hands-on a specialized microscope to actually see the atoms and the electrons.

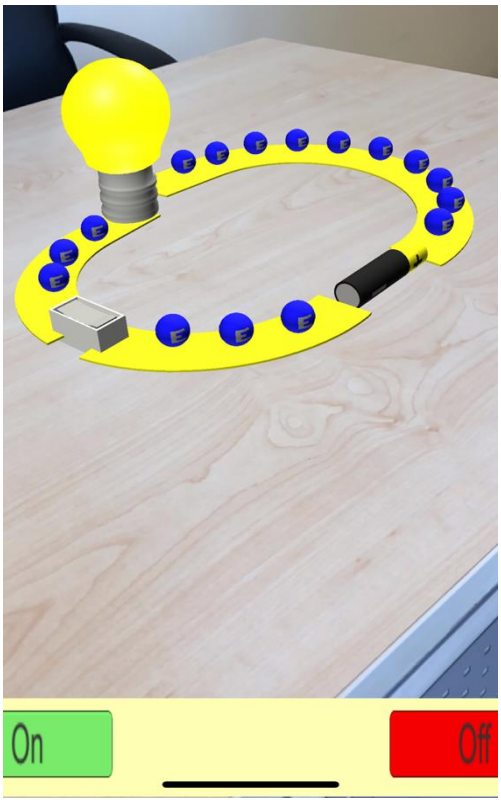

Fig. 6.a. Open Circuit at Run Time

Fig. 6. b. Closed Circuit at Run Time

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