Virtual Lab Using Markerless Augmented Reality

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***Abstract*—Augmented Reality (AR) virtual labs have come forward as a solution to one of the long-prevalent problem of dangerous lab conditions, cost etc. However, marker-based AR virtual labs offer limited freedom to users. In this work-in-progress paper, a markerless AR virtual lab is presented. The armature resistance of a DC motor is determined using the markerless AR virtual lab. An application is developed using Unity2018 and ARCore software development kit. Realizing the impact of a stable and flexible AR virtual lab on the present education system, a more relevant markerless AR Virtual lab is introduced in this paper.**

Keywords—markerless augmented reality, virtual lab, ARCore

I. Introduction

Practical experience/experimentation has always been a supreme component of education. However, in many major fields of study, the experimental setup is costly and their establishments are time-consuming [1]. Many technologies have been used over the past few decades to enable technology-based virtual labs. Technologies like Intelligent Computer Aided Instruction (ICAI) were put forward and succeeded to an extend in providing a virtual experimentation setup. According to the survey in [2], the real development of virtual labs and intelligent learning were yet to come. In the case of laboratories involving high power electric machines, even the danger posed by high power is a matter of grave concern. The concept of virtual lab was introduced to address this concern [3]-[5]. The case study given in [6] studies the effect of Virtual labs in test scores in students and concluded that virtual labs indeed improve learning[7]. Following the induction of this idea, various virtual electric circuit simulation software like PSPICE (Simulation Program with Integrated Circuit Emphasis) [8], the microelectronics Weblab 6.0 [9][10], Vlab [11] etc. came to the forefront. Numerous other facilities like the Automatic Control Telelab (ACT), which introduced a user friendly interface for the simulation and testing of control systems [12], Internet based instrumentation control tools [13] also came forward. Although these simulation enablers solve the financial concerns and time constraints, they are confined to two dimensional (2D) space. They even lag behind in providing an interactive learning environment to the users. Hence the need arose to replace the conventional systems with a more interactive and user friendly virtual lab technique.

Augmented Reality (AR) is one compelling technology which removes the barrier between Physical and virtual environments. It supplements reality rather than entirely creating a virtual environment [14]. The work carried out in [15] points out the wide range of applications of AR including that in developing virtual lab set ups. By making use of three dimensional (3D) image modelling, the 3D models of various lab equipment items and devices can be incorporated with smartphones or Head Mounted Display (HMD) to enable AR based Virtual lab [16]. AR is divided into two different types viz. marker-based AR and markerless AR .The developments in the field of AR virtual labs revolved around marker recognition and processing [17]. A pictorial marker will be fed into the software system, which when identified by the device, subsequent actions take place. Such an example is explained in [18].

The ultimate aim of technology is to make daily actions and activities simpler. While marker-based AR indeed introduces a new approach to virtual labs, it has some grave limitations. The major problem lies with the freedom for the user. The experiments in the virtual environment can be carried out based only on the preset markers. Suppose we are doing an experiment based on electronics, various devices will be present only when the corresponding markers are shown to the device camera. New additional components are impossible to be added. Moreover, there are high chances that the markers could get damaged over time which will reduce its detection capability. As far as a virtual lab set up is considered freedom, efficiency, ease of use, stability and providing lifelike experience are the basic requirements. While marker-based AR has an answer to all problems of conventional virtual labs, they still lack the freedom which the user expects and also makes it a hard job to input numerous number of markers for big experiments. Although they are accurate, they proved to be unstable[19]. The present work tries to address these limitations of AR virtual lab by incorporating markerless AR to virtual labs. Markerless AR works on Global Positioning System

(GPS) module [20], Simultaneous Localization and Mapping (SLAM) [21] etc. The present work makes use of ARCore software development kit (SDK) for implementing markerless AR in virtual labs. ARCore uses motion tracking, light estimation and environmental understanding to integrate virtual and real world content.

II. Theory and Concept

The markerless AR based virtual lab is implemented using ARCore software. To make labs lifelike and free of imperfections, the ARCore software has in-built technological features which has been made use of in this experiment. Motion tracking is the major property associated with ARCore.

It uses concurrent odometry and mapping (COM) [22] to visualize the smartphone's position relative to the world. The visual information is combined with inertial measurement from the. device's Inertial Measurement Unit (IMU) [23] to estimate the position and orientation of the camera relative to the world

ARCore detects feature points for improving the understanding of the environment. The models appearing in the developed software should be tracked over time in order for improved performance. This is carried out by implementing anchors [17][24].

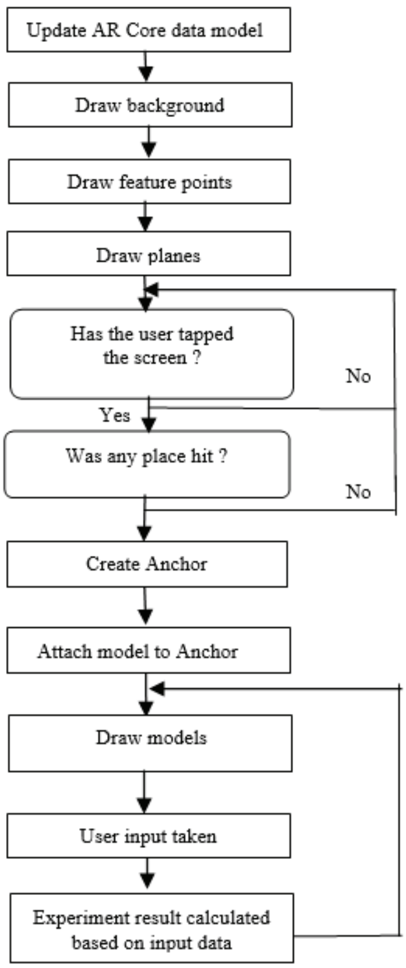

Fig. 1. Flow chart showing working of the model.

ARCore identifies the plane and places the three dimensional models of electrical components required for carrying out the experiments. The experiment can be carried out for different value of electrical quantities depending on the experiment being carried out. Fig.1 show the flow chart of the working of the markerless AR virtual lab.

III. Experiment Set-up

The marker less AR for virtual lab is demonstrated in this work with the experiment to measure the internal resistance of a DC motor.

A. *Experiment Setup to Measure the Internal Rresistance of a DC Motor*

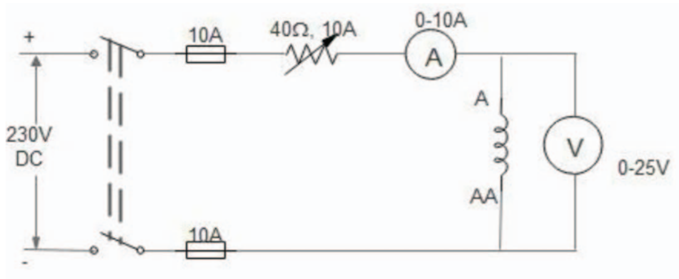

Fig. 2. Circuit diagram of the experiment.

Every armature has its own resistance called armature resistance. Fig.2 shows the circuit diagram for calculating the armature resistance of a DC motor. To measure the value of armature resistance (R_a), the experiment setup consists of a DC motor, a 0-10A ammeter, 0-25V voltmeter, 40 ohm, 10A rheostat and 230V supply. Keeping the rheostat at maximum position, the 230V DC supply is switched on. The instantaneous voltage, V obtained from voltmeter and the instantaneous current, I obtained from the ammeter are considered. By taking the ratio of the measured voltage to current we obtain the armature resistance.

The calculation is done based on Ohm's law:

$$R_a = V/I$$

B. *Applying Markerless AR Virtual Lab to the Above Experiment*

Three dimensional models of DC motor, rheostat, ammeter and voltmeter were designed using blender software [25]. An application was developed in Unity software by making use of the ARCore SDK. The application was installed in the smartphone. Fig. 3 shows the smartphone view of the experimental setup. The application was opened and using the camera, the smartphone was moved around in search of a plane surface. Once a plane surface is detected, the apparatus required for the experiment will appear on the screen. Lean touch asset for unity was used to enable gestures to control the electric quantities. The rheostat was given a set of predefined values to choose from. Based on the rheostat values, voltage and current values were obtained. Using Ohm's law, the armature resistance was calculated. When the rheostat is cutout, the voltage and current values obtained are shown in Fig.4.

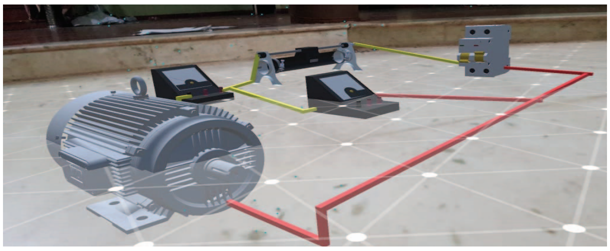

Fig. 3. Initial view of markerless AR virtual lab.

Fig. 4. View during the experiment.

IV. Survey and Comparison

The armature resistance of the DC motor was successfully calculated by carrying out the experiment. The experimental setup was successfully implemented using unity engine and AR Core SDK. Table I gives the values obtained from the experiment carried out in the marker less AR virtual lab.

TABLE I. EXPERIMENTAL CALCULATION

Voltage (V)	*Current)A)*	*Armature Resistance (Ohm)*
225	1.0	225

This attempt demonstrates the application of marker less augmented reality to virtual labs. Here, the demonstration is carried out only for this experiment. The method can be extended to more complicated experiments just by input of proper algorithm for measurement and proper three dimensional models of equipment. The present system relies on a mathematical model.

V. Survey and Comparison

The present work is aimed at improving the system of education. The major advantage of the present work is that the students need not be physically present in the laboratories to practice the experiments. The students can download the mobile application and using a basic Head mounted display, can be a part of the virtual experience.

In order to compare the existing lab setup, computer based two dimensional virtual lab and the basic level design of the present work, a survey was carried out among four students. The Vlab online virtual lab tool was used for evaluating two dimensional virtual lab experiments. The survey was designed to analyse where the present system stand compared to the existing systems. The parameters chosen for evaluation were i) safety, ii) ease of grasping concepts, iii) design, iv) feel and v) accessibility. Each parameter was rated for all the three systems by the students and the survey results are given in Table II-IV.

TABLE II. RATING FOR CONVENTIONAL LAB

Student	*Student 1*	*Student 2*	*Student 3*	*Student 4*
Safety	3	3	3	3
Ease of understanding	4	4	4	3
Design	4	4	5	4
Feel	4	5	5	5
Accessibility	4	3	3	3

TABLE III. RATING FOR ONLINE VLAB 2D VIRTUAL LAB

Student	*Student 1*	*Student 2*	*Student 3*	*Student 4*
Safety	5	4	5	5
Ease of understanding	4	3	3	4
Design	2	3	2	2
Feel	2	2	2	2
Accessibility	4	4	5	4

TABLE IV. RATING FOR PRESENT WORK

Student	*Student 1*	*Student 2*	*Student 3*	*Student 4*
Safety	5	4	5	5
Ease of understanding	4	3	4	3
Design	3	3	4	3
Feel	2	3	3	2
Accessibility	5	4	5	4

The ratings given by students for conventional lab setups are given in Table II. The rating for online Vlab two dimensional virtual lab are given in Table III and that for the present model is given in Table IV. The analysis shows that Conventional labs are best in almost all the criteria quite understandably. The question here is how close the other two systems get when compared to the conventional system. The survey is trying to identify whether the present three dimensional markerless AR virtual lab is better than the computer based online virtual lab. The students preferred 3D virtual lab over the Vlab experiments in cases of ease of understanding, design, feel and accessibility. Although the difference is narrow in the cases of ease of understanding and accessibility, the present work is well ahead in all the other aspects. The present work is even ahead of conventional labs when safety is considered. With an overall score of 76 (obtained by dding all the individual scores), conventional lab leads the survey followed by the present work with a close score of 74. The online two dimensional virtual lab lags behind with a score of 67. The present work was also tried out under different lighting conditions to evaluate the performance under differing lights. It was carried out under bright sunshine, dim light and under flickering lights in the room environment. The system was stable under all the lighting conditions.

VI. Conclusion And Future Work

The work lets the use of markerless AR to be used for implementing virtual lab, thereby letting the users experience flexible virtual lab experience. The flawless implementation of Virtual lab will help numerous number of students to learn and experience lab facilities despite financial, spatial and safety constraints. This will ensure a bright future ahead for more practical oriented educational system.

Although the work has paved way for an advanced system by solving the major problems of the conventional virtual labs, it has a few limitations which has huge scope to be addressed in the future works. Although the present work shows a good grade of stability, the accuracy of marker less AR is on the lower side, which can be overcome through subsequent researches. Since the present work is done for the sole purpose of demonstrating the markerless AR for virtual lab concept, the components used in the experiment can only be used for a particular pre-defined set of values. In researches to follow, the experiment can be made to work for any values of the electrical components used. The work need not be limited to the field of electrical and electronics laboratories. It can be applied to various fields for a wide variety of applications in the future. The aesthetics of the present work is not on the excellent side. Hence, better three dimensional modelling could be used and better lifelike models can be incorporated with the virtual lab for providing more beautiful lab environment. Same is applicable with noises associated with the machine, which will make the virtual lab more immersive.

Being one of the most sought-after technology in the present era, AR based virtual lab has more scope for improvement. Every bit of additional feature will lead towards a more accurate , stable , safe and immersive virtual world of learning.

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