Design of Multimodal Instructional Tutoring Agents using Augmented Reality and Smart Learning Objects

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ABSTRACT
This demo presents a novel technique of enriching students' learning experience in electronic engineering laboratories and the basis for its design. The system employs mobile augmented reality (AR) and physical smart objects that can be used in conjunction to assist students in laboratories. Such systems are capable of providing just-in-time information and sensing errors made while prototyping of specific electronic circuits. These systems can help reduce cognitive load of students in laboratories and bridge gaps between theory and practical applications that students face in laboratories. Two prototypes have been developed – (i) an intelligent breadboard prototype that can sense errors like loose wiring, wrong connections, etc. for a specific experiment, and, (ii) an AR application that provides visualization and instruction for circuit assembly and operating test equipment. The intelligent breadboard acts as a smart learning object. Design methods were used to conceptualize and build such systems. The idea is to merge practices of Human Computer Interaction with those of machine learning to design highly situated physically located tutoring systems for students. Such systems can help innovatively in teaching and learning in engineering laboratories.

Categories and Subject Descriptors
• Human-centered Computing →Human computer interaction (HCI) → HCI design and evaluation methods → Usability testing. • Human-centered computing → Ubiquitous and mobile computing.

Keywords
Augmented Reality, Smart Learning Objects, Education, Ubiquitous Computing, Embedded Intelligence.

1. INTRODUCTION
Physical action based laboratories in electronic engineering involving interaction by the student with equipment play a crucial role in enabling students to gain "hands-on" learning experience leading to learning of problem-solving skills. However, students often feel hindered in these laboratories due to procedural difficulties and disconnects that exist between theory and practice as laboratory experiments do not seem to be related to theory [1].

This impedes their learning and causes students to lose interest during the practical experiment. By considering Mark Weiser's vision [2] of ubiquitous computing where every day mundane objects are embedded with computational capabilities, this paper highlights the possibilities of introducing such designed artifacts – also referred to as smart learning objects (SLO), in engineering laboratories. Observations also indicate that smartphones are widely used by students to retrieve useful information using internet. These smartphones also act as an enabler for mobile AR. Therefore, this study seeks to explore the use of AR and SLO for electronics engineering undergraduate students to streamline their learning experiences in traditional instructional laboratories. AR's ability to augment the physical world with virtual information can help create highly contextualized instructions along with visualization. This characteristic makes it suitable for use in engineering laboratories to instruct students and help them correlate theory with practice.

Further, in certain scenarios, where the experimental setup is complicated, students often need more hints and instructions regarding procedures or errors committed by them on a physical experimental setup than simple visualizations. In such cases, embedding intelligence into physical laboratory objects using sensors and microcontrollers can help provide assistance to students by sensing various experimental parameters to be measured, given as input or observed by students. Such objects can be used in conjunction with AR to provide required instructions for students to follow and provide innovative and novel ways to enrich the learning experience of students in practical lab sessions.

2. METHODOLOGY
This research utilizes User-Centered Design approach as practiced in Human-Computer Interaction. Both quantitative and qualitative methods of data collection have been employed. Usability testing methods were extensively used to conceptualize and develop the prototypes. Based on the findings from literatures and user studies, two prototypes have been developed. These prototypes employ a mobile augmented reality based application and a breadboard embedded with computational capability. The following section describes the functionalities of these prototypes.

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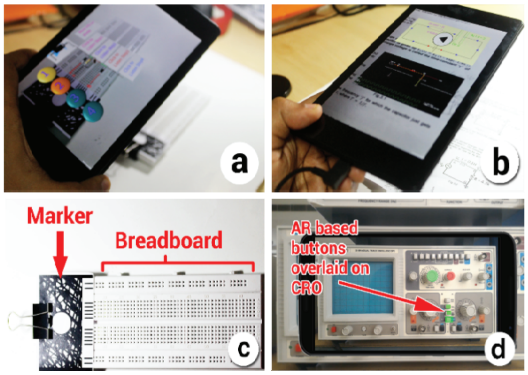

Figure 1. Features of AR instructional application. a) 3D circuit assembling instruction, b) Video instructions, c) AR Marker clipped to breadboard, d) Interface for

3. PROTOTYPES

3.1 Augmented Reality Based Instructions

An AR mobile application has been developed for android platform (see Figure 1). A marker is used by clipping onto breadboard during circuit assembly (refer Figure 1c). This marker helps the mobile AR application to overlay virtual 3D circuit assembly information onto the breadboard. The application also utilizes the figures given on students' lab manuals to present animated video simulations of the circuits that are to be prototyped and utilizes marker-less tracking of equipment in lab (e.g. cathode ray oscilloscope) to provide visual operating instructions.

The functionalities of this application include – Marker and Marker less AR tracking, providing step based visual and audio instruction regarding circuit assembly, showing videos regarding theoretical aspects of experiment and providing voice-based assistance for operating test equipment in labs.

3.2 Intelligent Breadboard

An intelligent breadboard has been developed to sense errors made by users while prototyping specific electronic circuits. This breadboard is able to communicate with user's smartphones or digital tablet which act as mediator to provide information and voice-based instruction regarding errors made while circuit assembly via Bluetooth. The voltage sensors are placed at each row of the breadboard that can detect nodal voltages on the breadboard. These nodal voltages corresponded to a very specific experiment for which task-flows and errors were stored in the database. By doing so, the intelligent breadboard acted as a SLO. The prototype has been developed using microcontroller Arduino UNO [3] and 1-Sheeld [4]. Whenever an error is sensed on the breadboard via voltage sensors, the microcontroller communicates with the smartphone via which instructions were provided to user. The types of error that can be deducted are overvoltage, loose connection at particular rows of breadboard, input voltage and nodal voltage of a specific circuit. Based on the type of error, corresponding instructions are generated for users to follow and learn. These instructions are provided to user through text-based and voice-based functionalities. Figure 2 depicts the setup of intelligent breadboard and a screenshot of its interface on digital tablet.

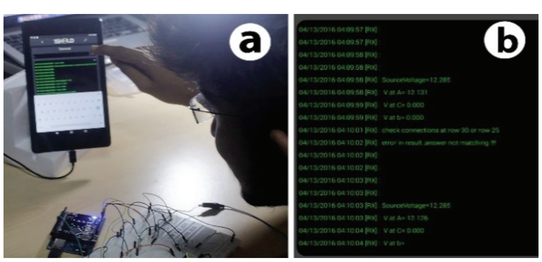

Figure 2. a) Intelligent Breadboard prototype setup. b) Screenshot of text-based instruction displaying an error made by user.

4. DISCUSSION

Our proposed learning systems provide contextualized just-in time information and instruction to students such that errors made during learning become prompts for self-evaluation and self-tutoring Such learning systems can prove highly beneficial for students in labs as it is able to provide structured information to students at the right time so that students can relate to the situation and context of the experiments they are performing in laboratories. Our proposed systems are further also able to detect trivial errors made during circuit prototyping - such as loose wirings and wrong connections, etc. for a specific type of experiment being performed by students. This reduces the burden of unnecessary trial and errors that are time consuming and cause hindrance in learning.

We hypothesize that our proposed learning systems will reduce the cognitive load experienced by students in laboratories and enrich their learning experience. Two user studies have been conducted in live lab sessions amongst thirty-six (n=36) students with our AR application. The progress so far has been validated in parts with encouraging positive results. More user studies are planned to be conducted to test our hypotheses.

The prototypes proposed and presented in this demo present various modes of interactions which are possible with SLO and AR. These are mostly screen and voice based interactions. Screen based interactions employ text and AR based approach, while the latter uses voice-based methods to impart instructions to students.

5. ACKNOWLEDGEMENT

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