Smart Teaching Materials with Real-Time Augmented Reality Support for Introductory Physics Education

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ABSTRACT

In this demonstration, we present a system design that helps to reduce the split attention effect in multimedia learning by providing an interactive environment with augmented reality support for elementary physics education. The system consists of three main components: smart boxes, smart cables, and visualization app. Each smart box contains an input to plug different electrical components (bulb, battery, and switches) and two sockets to interconnect the boxes with each other using smart cables. These boxes are equipped with various sensor modalities that provide information related to connected cable identifications and the physical status of the boxes. This information is shared through a Bluetooth Low Energy interface with the connected visualization device. Visualization devices range between handheld tablets with augmented reality capabilities and headwear smart glasses. These devices are used to run the supportive app. The app is responsible to track the smart boxes using markers and provide a 3D augmented visualization of information coming from them. This system targets introductory physics education, in addition holds the potential to provide assistance for more advanced electrical circuits in secondary or higher physics education.

CCS CONCEPTS

• **Applied computing → Interactive learning environments**; • **Human-centered computing → Mixed / augmented reality**.

KEYWORDS

Augmented Reality; Education; HCI; Physics

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1 INTRODUCTION

The spatially separate presentation of information sources in a multimedia learning environment may generate heavy cognitive load and split attention effect hence causing learning difficulties [2, 6, 7]. The subsequently presented system architecture may facilitate the introduction to electrical circuits for elementary school students by providing real-time 3D augmented visualizations and help to facilitate mental linkage between virtual symbolic representations and physical components through spatial and temporal proximity. It is aimed to reduce split attention effect in multimedia learning environment by implementing the contiguity and multiple representation principle. In this work, we use augmented reality (AR) to overlay the virtual symbols and circuit schematics on top of real components without blocking its visibility.

2 SYSTEM DESIGN

Our proposed system consists of three main units: smart boxes, smart cables, and visualization app. The application supports smart devices with AR capabilities (Fig.1).

2.1 Smart Component Box

A modified version of hardware system described by Kapp et al. [3] is used to design the smart boxes. Each smart box is composed of a microcontroller and various sensor modalities including low energy Bluetooth communication unit, cable identification system, and capacitive touch sensor. These units provide information regarding the identifier (ID) of the connected cable plugs, the touch status of the box, and the state of the attached component in real-time. On two sides of each box, there are two sockets to insert cable

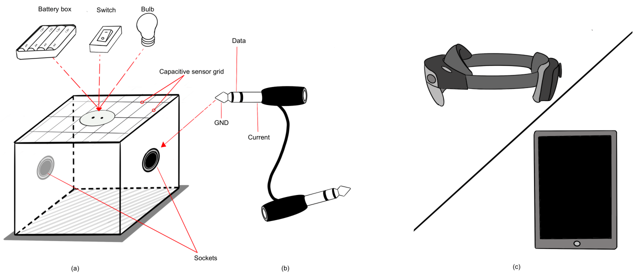


Figure 1: System components: (a) Smart box (b) Smart cable (c) Visualization devices

plugs. These sockets are used to build electrical circuits and detect the plugged cable IDs. The identification of the cables is based on the one-wire protocol. Each cable plug forms a one-wire slave with a unique 64-bit ID, with each socket representing a one-wire master, which reads out the IDs of all the plugs connected to it. Moreover, each box provides an opening (serially connected to the side sockets) to connect the electrical components on top of the box cap. Data communication between the visualization device and the smart box data is realized via Bluetooth Low Energy. For this purpose, a nRF52840 System On Chip (Nordic Semiconductor) is integrated into the smart box. A unique QR code marker is attached to each box for tracking its position and also providing information regarding attached component type and box ID.

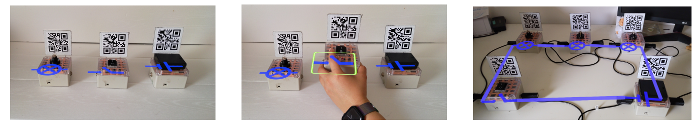
2.2 Smart Cables

Smart cables are used to connect smart boxes with each other to build a complete circuit. Each smart cable not only has a unique ID that could be read by smart boxes, but also forwards the electrical current [3]. To this end, stackable cable plugs are designed using audio jacks to provide both data and electrical current. Its stackable design provides a similar look and functionality to banana sockets used in school physics lecture and offers the opportunity to connect more than one cable in each socket and build parallel circuits.

2.3 Visualization App

The app is designed using Unity 3D game engine to run on devices with AR support. In this work we used Microsoft HoloLens and Microsoft surface tablet. The visualization app is responsible to track positions of all active boxes (using the mounted camera on the device and the markers attached to the boxes), and provide visualization of 3D symbolic representation of the attached components in front of each box. 7 x 7cm QR codes are used as markers that each embeds an unique information about the component type and the box ID. The application software also detects and provides visualization of the built circuit schemes with component symbols and lines. Each box socket is considered as a connection node. The 3D circuit schematics visualization is made by combining connection netlists of each node and their connection type (serial or parallel), the physical states of the components (e.g., on-off status of switches), and the physical location of that node in the real environment. The combination of these information allow an intractable and manipulable 3D circuit schematic visualization.

In addition, to ease the learning procedure and reduce confusion, touch status is displayed to highlight the association between the touched physical box and the corresponding virtual symbol (Fig. 2). The connection netlist of each box could be visualized separately on demand. This feature is aimed to be used in more complex systems to debug and resolve the connectivity issues.



(a) (b) (c)

Figure 2: (a) Virtual symbol representation (b) Touch status highlight (c) Circuit schematic

3 CONCLUSION AND FUTURE WORK

As a developing project over the years [1, 3–5], the proposed system has been gone through updates and modifications to find the best fitting design and approach to be used for elementary school students. As the pilot study is currently in progress, the preliminary results showed promising outcomes regarding usability of smart education materials with AR support in elementary school physics education. In our future works, we aim to investigate usage of smart materials with AR support for higher level educations.

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