Design and Evaluation of an Augmented Reality Signal Visualization Tool for Maker Spaces

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Abstract: We present an Augmented Reality tool for learning about electronic signals and voltage, deployed in a summer school fabrication course for novices. The tool uses Microsoft Hololens devices to permit students to see electronic signals overlaid on their physical breadboard circuits. Through our study we find students who used the tool had a positive experience and found the tool to be helpful for debugging circuits, but other students were hesitant to use the tool for reasons including lack of portability, disruption of workflow, and inability to fit non-standard breadboards. We conclude with guidelines for future improvement.

Introduction

Augmented reality (AR) tools have been previously developed and used for educational purposes, and have been shown to benefit students' performance in several areas of learning (Radu 2014; Bujak et al. 2013; Wu 2013; Cai 2017). We contribute to this research by designing and ecologically studying an AR tool (called the "Holoboard") for open-ended exploration of circuits. Unlike previous research that explored AR in closed-ended activities involving electricity (e.g. Radu & Schneider 2019), our AR tool can be used as a debugging tool applicable to a wide variety of circuits. Students traditionally use open-ended tools such as multimeters and oscilloscopes to deepen their understanding of electricity principles, apply and refine previous understanding, and optimize their strategies for constructing and troubleshooting electronics (Barker 1991; Van De Bogart et. al 2015). In this research, we study the value of augmented reality as a tool for circuit exploration, and investigate how it can be integrated with problem-solving processes during novices' learning of circuits.

We created the Holoboard device which is composed of an application for the Microsoft Hololens AR device, and a trackable frame to hold standard circuit breadboards (Figure 1). Currently the device is connected to a PC, and allows students to connect their own breadboard and attach measurement probes, whose signals are displayed trough AR as holograms on the breadboard. The graph holograms are anchored in place at four locations around the frame; each location corresponded to a wire probe attached to the frame, the other end of which could be placed into the breadboard to read the voltage at that particular location. This device allows physics concepts invisible to the eye to become visible as students explore and debug circuits. Functionality is similar to a traditional oscilloscope, but designed to be simpler and integrated with physical breadboards which novices are working on.

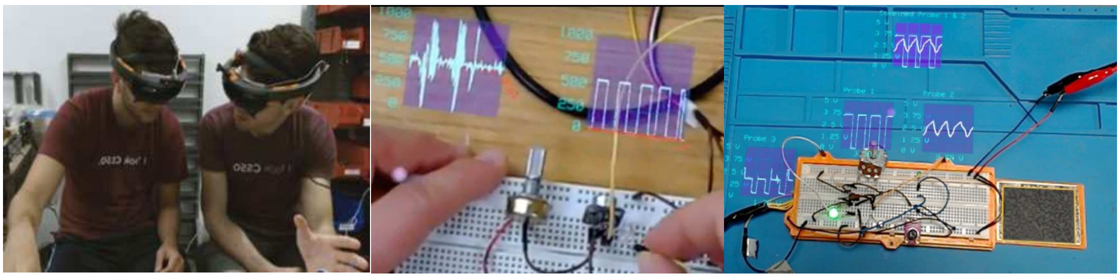

Figure 1. Two students wearing the Microsoft Hololens (left). View from the AR Holoboard device showing time-based graphs of signal voltage from students' electronic breadboard (mid, right).

User study

The Holoboard was deployed in a maker space laboratory at Harvard University and tested during the summer 2019 semester of a course for novices to learn electronics. 14 students took the course, where they learned a variety of circuitry concepts and fabrication skills. The students were given creative freedom with the final project, but had to utilize circuitry in the design. Students had access to multimeters, an oscilloscope, and the Holoboard. We were interested in answering the following questions that investigate the impact of the AR tool on novice students' ability to learn electronics: RQ1: Did students find the Holoboard engaging and useful for their learning? RQ2: How might the Holoboard be applicable to improving student learning processes?

Each student experienced the Holoboard once at the beginning of the course for their tutorial. When it was left at its station for the students to use whenever they wanted, only two students ended up using it; however, both students found it to be a positive experience. The students used the Holoboard to learn about the analog signal voltage being sent from their circuits. The first student, James (all names changed for anonymity), identified a bug in his circuit regarding voltage flow, while the second student, Robert, confirmed that voltage was flowing properly and that his problem stemmed from his code. Both of them, in their responses to the voluntary online survey, indicated that they found the tool to be helpful and intuitive to use. James elaborated on his experience, writing, "it's really intuitive and really user-friendly, which I really like. That's one thing that I didn't like about the oscilloscope, because it felt like it was more difficult and a bit too much to take in for a simple debugging error" and described the Hololens experience in three words as "simple, effective, and interesting."

General uncertainty regarding the use of debugging tools in students' learning process also seemed to be a factor. Through the course students had access to multimeters, oscilloscope and Holoboard, but both the oscilloscope and the Holoboard were not used until later in the semester, after a lecture on debugging tools and processes had refreshed students' memories about the tools and their functionalities. This indicates that the use of the Holoboard, as well as the students' use of tools in general, could benefit from changing the lecture timing or increasing the frequency of instructions about tool use for solving circuit problems. This sentiment was echoed by some of the students in the interviews. A suggestion for the physics course as a whole is to put more focus on debugging tools and methods. In addition to making the tool easier to use for the students, training the teaching staff on how to use the tool may be beneficial to students whose first instinct was to reach out for help.

Although the students who ended up using the AR Holoboard tool indicated that it was helpful for debugging and user-friendly, we observed that a large portion of students did not use the tool during their circuit problem-solving process. The Holoboard's setup process, as well as the relative novelty of Microsoft Hololens, may have contributed to a barrier of entry due to the perception that the Holoboard was a complex tool. One improvement to encourage students to use the Holoboard is to reduce the barrier of entry by simplifying the setup, so that the device does not appear as intimidating or complex. Students frequently used multimeter devices because they were "easy to use and portable". This indicates that accessibility of AR tools can facilitate their interaction into electronic problem-solving processes, but benefitting from shorter setup time, and being wireless for portability. Additionally, the Holoboard could be changed so that the tool is not restricted just to breadboards.

Conclusions

We designed an augmented reality tool for electronic signal visualizations that could be deployed in a maker space and used to aid the learning of electronics. While the current iteration of the tool garnered positive reviews from students, it suffered from barriers to entry for proper integration into students' problem-solving processes. Creating a more accessible version of AR debugging tools for a future deployment and improving integration into classroom content may benefit more students and increase their productivity in solving problems.

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