Virtual Reality (VR) Lab for Enhanced Learning in Lower-Level Electrical and Computer Engineering (ECE) Courses (Analysis & Logical Design)

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Activity Report

Abstract—The primary objective of this VR lab is to provide an immersive and engaging platform for students to master the skill of decoding resistors' resistance values through color bands, a foundational skill in electronics. Traditional methods of teaching this topic often rely on static diagrams and textbooks, which can be challenging for students to grasp and may lead to misconceptions. By leveraging VR technology, this educational tool aims to address these challenges and improve comprehension, retention, and overall student performance.

Index Terms—Electrical and Computer Engineering, Immersive Learning Environment, Remote Access, Interactive Tutorials

1 The Problem

ENGINEERS are important and necessary workers, who with their high intellect and strong technical abilities, create significant difference for the masses. One significant challenge in this context is the insufficient number of students who contemplate engineering as a viable career path, and even fewer who persist in pursuing it over the long term. The aim of this project is to provide an accessible and enjoyable tool, designed to captivate the interest of potential students.

2 Inspiration

VR immersive learning technology is already being used in various fields, especially in the Medical and Aeronautical fields [1]. From nurses and paramedics to aircraft maintenance engineers, VR provides a safe and isolated environment to practice and nail down simulated protocols that may be too expensive to run in real life. With XR we can provide the same concept, rather than replacing the classroom or a laboratory session we have a tool that helps students learn at their own pace.

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3 Design Constraints

- **Time Costs:** A fixed timeline, such as a semester or academic year, may limit the depth of development and testing that can be achieved
- **Technology Limitations:** Availability and compatibility of VR hardware and software may impose constraints on the project's design and functionality.
- **User Access and Acceptance:** Ensuring that students have access to VR equipment (headsets, computers) can be challenging, especially if the hardware is not readily available to all students. The project also heavily relies on user adoption. Resistance

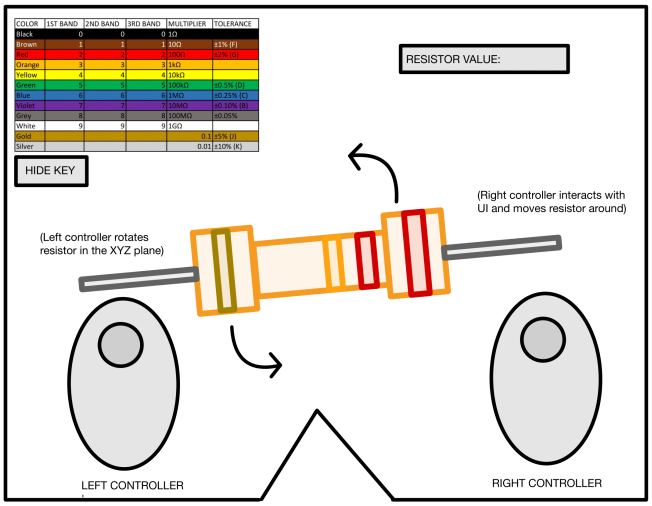

Figure 1. Example of what everyone would see vs. what the user would see.

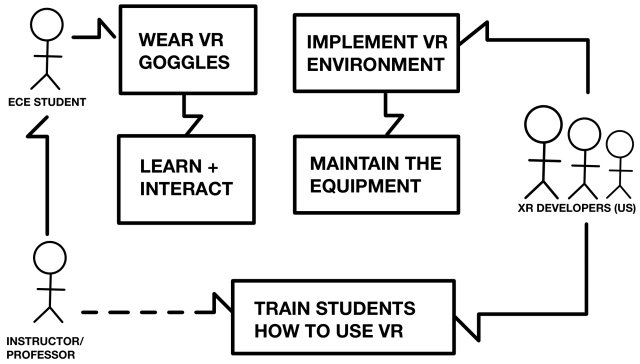

Figure 2. Use case diagram with students, instructors, and developers labeled

to using VR technology or unfamiliarity with the medium can be a challenge.

- **Educational Integration:** Aligning the VR lab with the existing ECE curriculum and gaining buy-in from instructors.

4 Proposed Solution

Our current solution for the presented issue is the development of an XR program. Implementation of said program for wearable technologies is implied.

4.1 Engineering Diagram

A visual example of our first prototype is included in Figure 1.

4.2 System Requirements

4.3 System Users

This VR lab is designed for new or introductory ECE students, the primary objective is to offer an immersive and accessible learning experience. Upon entering the virtual environment, students can explore and learn about the resistance values of resistors through interactive tutorials, zooming in on components, and practicing decoding resistance values based on color bands. Immediate feedback and progress tracking are integrated into the system to enhance the learning process. As shown in Figure 2, we as the developers are encouraged to instruct students and instructors on the proper utilization of the equipment and ensure its optimal functionality throughout the process.

4.4 Functional Requirements

1) **Headset and Tracking:** High-quality headset for immersive 3D visuals and accurate tracking of user's heads and hands.
2) **Working XR Environment:** Functional developer environment to test experimental code.
3) **Documentation and Tutorials:** Provide comprehensive documentation and interactive tutorials to help users get started and troubleshoot issues.
4) **User Interface (UI) and Interaction:** User-friendly menus and interfaces within the VR environment. Options for interacting with objects and menus in VR, such as gaze-based selection or hand gestures.

4.5 Non-Functional Requirements

1) **Performance:** The VR lab should provide a smooth and responsive user experience, with minimal latency or lag during interactions, to ensure that learning activities are not hindered by technical issues.

Factors		Alternative 1		Alternative 2		Alternative 3		
Criteria	Weight	QR Code	Weighted	Virtual Learning	Weighted	D-to-P Integration	Weighted	
Usability	8	4	3.2	8	6.4	6	4.8	
Cost	1	8	6.4	5	4	7	5.6	
Accessibility	3	10	8	3	2.4	3	2.4	
Time consumption	3	8	6.4	6	4.8	3	2.4	
User interactivity	6	3	2.4	9	7.2	8	6.4	
Educational Impact	10	5	4	9	7.2	9	7.2	
	31	38		40		36		RAW SUM
			30.4		32		28.8	WEIGHTED SUM

Figure 3. Decision Matrix

2) **Accessibility:** The VR lab should be designed to be accessible to all types of users to ensure equitable access for all students.
3) **Feedback and Metrics:** Collect user feedback and performance metrics to continuously improve the VR experience. Implement analytics to monitor user behavior and performance metrics.

4.6 Justification

The development of a Virtual Reality lab for ECE students is well-justified by its capacity to significantly enhance the learning experience, bridging the gap between theory and practice through immersive, hands-on simulations. This technology not only offers accessibility and flexibility but also fosters engagement, motivation, and improved retention rates among students, preparing them for what to expect in this field. In our decision matrix, as illustrated in Figure 3, we evaluated three alternatives based on criteria such as cost, educational impact, usability, and more. The VR lab for calculating resistance values happens to be the most favorable option, with a weighted score reflecting its balanced performance across these criteria. Hence we highly recommend proceeding with this alternative, as it aligns with our project's goals and priorities.

5 Initial Prototype

5.1 Semester Goals

Our semester objective is to achieve a functional alpha version of the project, enabling us to gather user feedback and assess their experience. This will allow us to gauge user responses and determine the potential directions for the final product.

5.2 Year Goals

Our ultimate objective is to create and implement the first VR instructional tool for Electrical and Computer Engineering (ECE) students at the University at Albany. We'll provide an immersive environment for students to learn the ins and outs of a banded resistor all at their own pace. We hope to expand this idea to other components (capacitors, inductors, transistors) and other areas of ECE as well (visualization of EMF and radio frequency signals) that would be harder concepts to grasp on traditional 2D educational media.

5.3 Work Responsibilities

- **Joren Cruz:** Scheduler, Archivist.
- **Diego Tapia Araiza:** Point of Contact.
- **Daniel Wang:** Editor, Treasurer.

References

[1] Fionnuala McAuliffe,"Learning Outcomes of Immersive Technologies in Health Care Student Education: Systematic Review of the Literature," Journal of Medical Internet Research, https://ncbi.nlm.nih.gov/pmc/articles/PMC8848248/ Accessed: October 9, 2023