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Work-in-Progress—Augmented Reality in Higher Education: Case of Electrical Drawings

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Abstract. Understanding electrical drawings can be challenging; the flat diagrams need more 3D depth, interactive exploration, and real-time dynamic circuits. This often leads to frustration, rote memorization, and difficulty applying knowledge in practice. This work-in-progress paper presents an innovative solution - an Augmented Reality (AR) application designed to revolutionize electrical drawing comprehension in higher education. Imagine diving into a virtual world where electrical components come alive: rotate them, manipulate connections, and see how changes instantly impact the entire circuit. By leveraging the power of AR, our application aims to deliver deeper understanding, boost engagement, and unlock new possibilities for active learning. No longer confined to 2D representations, students can actively explore, experiment, and build spatial reasoning skills.

Keywords: Augmented Reality, Electrical Drawings, Higher Education, STEM, Immersive Learning, 3D Visualization.

1 Introduction

Mastering electrical drawings is a critical skill for engineers. However, traditional 2D diagrams often struggle to convey the inherent 3D complexity of circuits. This can hinder a student's ability to visualize spatial relationships, comprehend component interactions, and apply theoretical knowledge to real-world scenarios [1]. Augmented Reality (AR) offers a promising solution. By overlaying digital information in the real world, AR can create interactive learning experiences that enhance visualization and engagement, fostering a deeper understanding of electrical concepts [2].

AR offers several unique capabilities that can significantly enhance the learning experience for electrical circuits, as detailed in Table 1.

Table 1. The unique capabilities of AR on the Electrical Circuit learning process.

Key capability	Explanation
Visualization and spatial understanding	AR allows students to visualize abstract concepts and 3D objects in real time, fostering a deeper understanding of spatial relationships and complex structures [3].
Interactive Circuit Manipulation	AR applications enable students to interact with virtual representations of electrical components. This allows dynamic manipulation, such as rotating components, connecting elements to build circuits, and observing real-time circuit behavior based on their actions [4].
Circuit Simulation and Troubleshooting	AR can be used to overlay virtual simulations onto physical circuit components. This allows students to visualize current flow, voltage levels, and component behavior within a functioning circuit. Also, AR can be used to introduce faults into virtual circuits, enabling students to practice troubleshooting skills in a safe and interactive environment [5].

Research demonstrates the positive impact of AR across various educational fields. Studies have shown that AR visualizations can improve students' understanding of complex scientific phenomena and engineering concepts in subjects like physics, chemistry, and electrical engineering [5–7]. AR can also create interactive language learning environments for practicing vocabulary and grammar in real-world contexts [8]. Additionally, AR applications can bring historical events and cultural artifacts to life, enriching student engagement with the past [9].

Despite its potential, AR in education faces challenges. The initial cost of AR hardware and software development can be a barrier for some institutions. Technical limitations, such as device resolution and battery life, may also hinder user experience. Furthermore, effective integration of AR requires careful pedagogical design and instructional strategies to maximize learning benefits [1]. Looking forward, research will continue to address these challenges and explore opportunities for advanced interaction and feedback mechanisms, seamless integration with existing learning platforms, and personalized and adaptive learning experiences [10]. This will unlock the full potential of AR in education, transforming the educational landscape by fostering deeper understanding, active learning, and personalized learning opportunities for all [11].

This paper contributes to the field of AR-based learning by exploring its potential to improve electrical drawing comprehension in higher education. Following this introduction, the paper delves into our novel AR application designed to enhance electrical drawing comprehension. The subsequent sections analyze the impact and contributions of this application. Finally, the conclusion outlines potential future research directions.

2 Proposed Solution: An Immersive AR Application for Enhanced Electrical Drawing Comprehension

This paper proposes a novel AR application designed to improve the learning of electrical engineering by enhancing comprehension of electrical diagrams. Built on the Unity platform and leveraging tools like Vuforia [12] for AR implementation and Blender for 3D modeling, our application offers a unique combination of creativity and technology.

2.1 The Immersive Learning Experience

Users can explore meticulously detailed and accurately animated 3D models of electrical components, from motors to circuit breakers, in their real-world context (Figure 1). This fosters a deeper understanding of component interactions, spatial relationships, and circuit dynamics compared to traditional 2D diagrams.

The application provides a user-friendly interface that guides students through the learning process. Here's an example of the experience using a printed electrical schema from the app's database (Figure 1, Subfigure 2). Upon login (Figure 1, Subfigure 1), students are presented with the main interface. Here, they can choose to launch the AR experience by selecting the "AR SCHÉMA ELECTRIQUE" button. This button then allows them to choose between two options:

- Scan QR Code: Students can scan a unique QR code associated with a specific electrical schema. This approach is ideal for accessing pre-defined circuits provided by instructors or included in learning materials.
- Use Electrical Schema from App: Students can select a pre-defined electrical schema from the app's database. This ensures compatibility with the available 3D models in the app.

AR Activation with Printed Schema: In this example (Figure 1, Subfigure 2), the student selects a desired electrical schema from the app's database and chooses to print it. Once printed, the student launches the AR experience within the application. They then point their mobile device camera at the printed schema.

Interactive 3D Model Exploration: The AR interface overlays the printed schema with interactive elements. By clicking on specific components within the printed schema (Figure 1, Subfigure 3), the application recognizes the selected element and displays its corresponding 3D model in the real world. Students can then manipulate these 3D models in real time, allowing them to rotate, zoom, and explore the components from different angles. Additionally, the application might allow for the display of multiple 3D models associated with a single element, providing students with a broader understanding of its functionalities and variations.

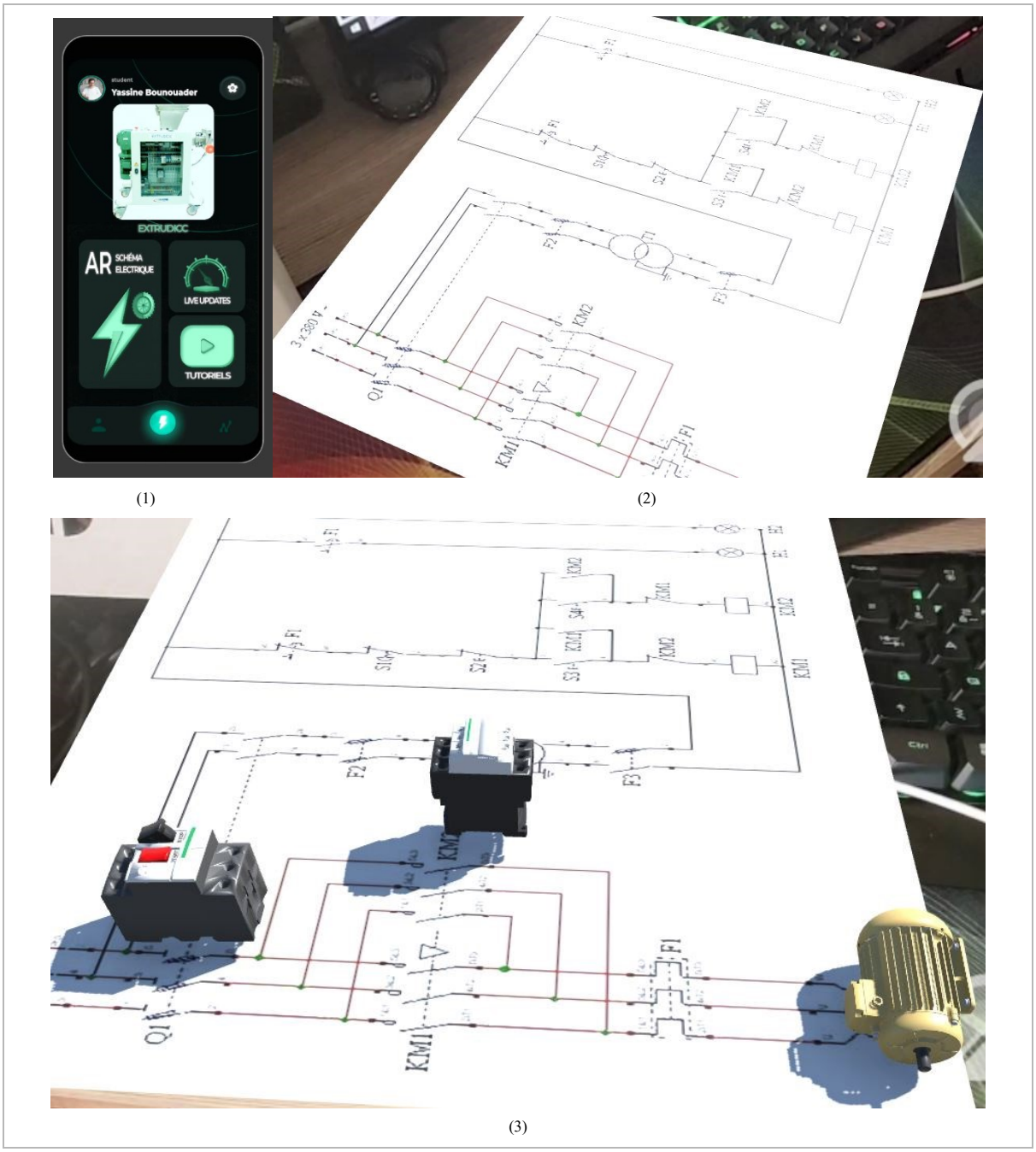

Fig. 1. Screenshot of the AR application demonstrating circuit component manipulation.

The application prioritizes engagement by transforming technical education into an immersive and interactive experience. The possibilities for exploration extend beyond classrooms and labs into an infinite virtual space.

2.2 Comprehensive Learning Environment

The application's "material verification" feature transcends simply viewing electrical components. It creates a transformative learning experience by seamlessly connecting theoretical knowledge with real-world applications. Students leverage the app's camera to scan actual electrical equipment. Upon successful recognition, the application overlays augmented instructions directly onto the scanned component. This innovative approach fosters a deeper understanding of component functions and their roles within electrical systems. Unlike static textbook diagrams, interacting with real equipment and viewing corresponding augmented information allows students to grasp how electrical components operate in practical settings, promoting a more comprehensive understanding [13].

Furthermore, material verification equips students with valuable practical skills. They learn to identify real-world electrical components, understand their safety protocols, and potentially troubleshoot common issues using the app's visual aids. This practical skill development, from scanning and receiving augmented instructions to understanding safety protocols, prepares them for future careers in engineering or electrical fields. The interactive nature of material verification empowers students to confidently approach real electrical equipment. By successfully scanning and receiving relevant information, they gain confidence in their ability to identify components and interact with electrical systems in a safe and informed manner.

This innovative feature benefits both students and educators. Material verification transforms learning from passive knowledge acquisition to an active and engaging experience. Students can explore real equipment in a safe and controlled environment, fostering a deeper interest in the subject matter. This interactive and engaging approach stands in contrast to traditional, passive learning methods.

The material verification feature serves as a valuable addition to existing teaching materials. It provides educators with a practical tool to bridge the gap between theoretical concepts and real-world applications, enriching the overall learning experience. By fostering a deeper understanding, developing practical skills, and promoting an engaging learning environment, material verification empowers students and equips educators with innovative tools for a more effective and practical approach to electrical engineering education.

3 Methodology

This section outlines the development methodology for our AR application designed to enhance electrical engineering education. We follow an iterative approach, where each stage informs and refines subsequent steps.

3.1 Completed Work: Identifying Needs and Building a Foundation

The initial phase involved a comprehensive review of traditional electrical engineering teaching methods. We conducted a gap analysis, informed by feedback from students and teachers within our lab network, to identify areas for improvement. This analysis revealed a lack of readily available AR solutions that effectively address the limitations of 2D diagrams in conveying spatial relationships and fostering practical skill development.

Building upon this gap analysis, we conducted a thorough review of existing AR applications used in electrical engineering education. This review helped us identify current trends, potential limitations [14], and areas for improvement based on the specific needs of our target audience. While existing solutions provided valuable insights [15], none fully addressed the requirements highlighted in our gap analysis.

Informed by these findings, we proceeded to develop a functional prototype of our AR application. This initial version focused on core functionalities that directly address the identified needs:

- 3D Model Visualization: Users can explore meticulously detailed and accurately animated 3D models of electrical components in a real-world context. This fosters a deeper understanding of component interactions, spatial relationships, and circuit dynamics compared to traditional 2D diagrams.
- Interactive Component Manipulation: Students can actively engage with the learning material by manipulating these virtual components in real time. This promotes exploration and discovery beyond the limitations of static textbooks.

Finally, we conducted user testing sessions with students and teachers from our electronics lab network. This crucial stage allowed us to gather valuable feedback on the application's usability, effectiveness, and potential areas for improvement. This feedback will inform the future development plans outlined in the following section.

3.2 Future Development Plans: Expanding Functionality and Assessing Impact

Building upon the foundation established through the completed work, we are focusing on several key areas for future development:

- Assessment System Integration: We are currently collaborating with an expert in electrical circuit education to develop a comprehensive assessment system. This system will evaluate student understanding by employing various question formats that go beyond rote memorization, ensuring a well-rounded assessment of learning outcomes.
- Model Variety and Scalability: We plan to expand the application's database to encompass a wider variety of models commonly found in electrical schematics. This enhanced versatility will cater to diverse learning needs and provide a more comprehensive learning experience.
- Wider User Testing and Impact Analysis: Building upon the initial user testing, we aim to conduct a more extensive study with a broader sample group from different universities, potentially across various countries.

This will allow us to assess the application's impact on a larger scale and in diverse educational settings, providing valuable insights into its effectiveness across different learning environments.

- AI, recommendation systems, and MR Integration: As a long-term vision, we envision exploring the integration of Artificial Intelligence (AI), recommendation systems models, and Mixed Reality (MR) technologies to further enhance the learning experience. AI and specifically recommendation systems could personalize learning pathways based on individual student needs, while MR could enable interactions with virtual components within the real world, further bridging the gap between theory and practice [16].

By following this iterative development process, we are committed to continuously improving our AR application and its effectiveness in enhancing student learning outcomes in the field of electrical engineering education.

4 Discussion

The development of our AR application for electrical engineering education presents a unique opportunity to explore the potential of this technology. This section will discuss the key strengths of our application and its future potential for enhancing electrical circuit understanding.

Our application takes a targeted approach, focusing on a specific learning objective: providing a deeper understanding of electrical circuits. This focus allows us to maintain a simple and user-friendly experience for both students and teachers. We build upon existing learning methods by offering an interactive layer on top of electrical schematics. Students can use drawings as markers to trigger the AR experience, revealing meticulously detailed and animated 3D models on request. This approach empowers existing practices while providing valuable supplemental information and avoiding overwhelming users [17].

Furthermore, the application fosters a deeper understanding and engagement through interactive learning. Students can explore the 3D models, promoting a more immersive learning experience compared to static diagrams. This allows for a better grasp of spatial relationships, component interactions, and circuit dynamics. Beyond this, the application caters to diverse learning styles by offering various levels of detail in the 3D models and a tutorial section with resources like public videos or documents [18].

The application's future development holds immense potential to further enhance electrical engineering education. A key focus will be on bridging the gap between theory and practice. We envision enabling students to use the AR experience directly with real-world electrical equipment. This will allow them to visualize components and circuits within a practical context, solidifying their understanding [19].

Additionally, future efforts will explore expanding the application's capabilities. This includes increasing the database of electrical components to encompass a wider variety of circuits and potentially integrating assessment functionalities to measure student learning beyond rote memorization [20].

By focusing on targeted functionality, user-centered design, and interactive learning, our AR application demonstrates the potential of this technology to revolutionize electrical engineering education. Future development efforts, particularly in bridging the theory-practice gap and expanding functionalities, will solidify the application's role as a valuable tool for educators and students.

5 Conclusion and Future Work

The proposed AR application holds significant promise for transforming the learning experience in electrical engineering, specifically by enhancing the comprehension of electrical diagrams. This innovative approach addresses the limitations of traditional methods by offering a 3D, interactive, and contextualized learning environment. This can lead to deeper understanding, improved retention, and better preparation for practical applications in the field. The potential of AR in electrical engineering education is far-reaching, and further research and development are crucial to unlock its full potential.

Fig. 2. The use of the AR-based application to enhance the traditional learning methods.

While our AR application offers a promising solution, further research and development can unlock even greater potential:

- Advanced AR Interactions and Feedback: Exploring more sophisticated interactions and real-time feedback mechanisms within the AR environment can enhance user engagement and learning outcomes.
- Integration with Existing Systems: Seamless integration of AR applications with existing learning management systems and educational resources can promote wider adoption and enhance their effectiveness within established learning environments.
- Personalized Learning Adaptations: Research can delve deeper into advanced personalization techniques, tailoring learning pathways and content to individual learning styles and cognitive abilities for even more effective and inclusive learning experiences.

By continuing to explore these areas, AR has the potential to become a cornerstone of electrical engineering education, fostering a deeper and more engaging learning experience for students, and equipping them with the knowledge and skills necessary for success in this ever-evolving field.

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