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Designing and Developing a Remote IoT Lab for Enhanced Lab Classes

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Pedagogical Study

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Abstract

The COVID-19 pandemic accelerated the adoption of remote labs, offering students hands-on experiences while adhering to distancing measures. Challenges include replicating real-world experiences, ensuring equitable technology access, and maintaining engagement. Despite these challenges, the future of remote labs appears promising. Institutions must invest further, collaborate with the industry, and utilize data analytics and AI. This research focuses on designing a remotely accessible IoT laboratory, balancing hands-on learning with reduced physical presence, and shaping the future of higher education. It highlights the potential of online teaching and hybrid laboratory models, emphasizing practical experience integration with theoretical learning. The study presents the IoT lab design and implementation and conducts interviews and questionnaires that assess system readiness and usability. Participant feedback emphasizes coding skills, continuous hardware use, and system versatility. This work contributes to the evolution of remote labs in modern education.

Keywords: IoT lab; Remote learning; Virtual lab

Introduction

The COVID-19 pandemic has reshaped higher education and necessitated alternative solutions for laboratory classes (Tsang et al., 2021). The rapid expansion of remote labs is a notable development, addressing the need for social distancing and remote learning (Van den Beemt et al., 2023). This paper explores the design and development of a remotely accessible IoT (Internet of Things) laboratory, aiming to balance hands-on learning with reduced physical presence while emphasizing accessible and flexible laboratory experiences.

The foundation for this paper rests on the growing significance of electronic and virtual laboratories in contemporary education (Alkhaldi et al., 2016). These laboratories offer flexibility in learning, especially in a world that increasingly demands remote or distance education (Nurutdinova et al., 2022). Traditional laboratory work remains essential for many scientific and technical disciplines, but advancements in technology now enable students to engage with experiments and practical work from remote locations (Leontyeva, 2018). Virtual labs come in two primary categories: simulator-based labs and virtual labs with physical equipment, offering flexibility and practicality in remote learning (Tomov, 2008).

Remote labs operate through an intermediary layer, known as the "interface," which connects users to the lab equipment (Haque et al., 2015). This interface provides a user-friendly experience for monitoring and initiating experimental processes. On the equipment side, the remote infrastructure monitors and controls the lab equipment, incorporating tools like video cameras, microphones, and various sensors, ensuring the equipment's proper functioning for each user (Heradio et al., 2016).

IoT technology has become increasingly central to the success of remote laboratories. An IoT-based virtual laboratory comprises a physical lab, computer embedded systems, and an IoT platform, enabling remote experimentation and data management (Ramya et al., 2020).

This work explores the potential of an IoT-based virtual lab to revolutionize laboratory education by offering a flexible, engaging, and accessible learning experience.

IoT Virtual Lab Design

In the planning and development phase, a critical step is creating a use case diagram to guide the project. The use case diagram visually represents system interactions and distinguishes between students and lecturers. As it shown in Figure 1, it outlines four main use cases for each.

1. Lecturer's Lesson Planning and Experiments Use Case: This use case involves lecturers activating the central system, entering identification data, selecting instruction modes, defining subjects or experiments, configuring components, performing internal tests, determining the experiment type, saving data, updating the cloud-based system, and conducting data tests before system shutdown.
2. Student's Physical Lab Use Case: In the student's use case, the process begins with system activation, followed by data entry for identification and lecture details, and operational mode selection. Students then assess the need for hardware and software, use them as required, prepare for experiments, configure the experiment, conduct internal tests, and determine the experiment type, specifying lecture details.
3. Lecturer's Monitoring Use Case: For lecturers, this use case involves identifying themselves within the system, selecting the online mode, and engaging in various online activities, such as reviewing experiment results or scheduling online lectures.
4. Student's Remote Lab Use Case: Students use this use case to identify themselves, assess online activities, like reviewing experiment results, accessing real-time data, attending online lectures, or reviewing personal activities.

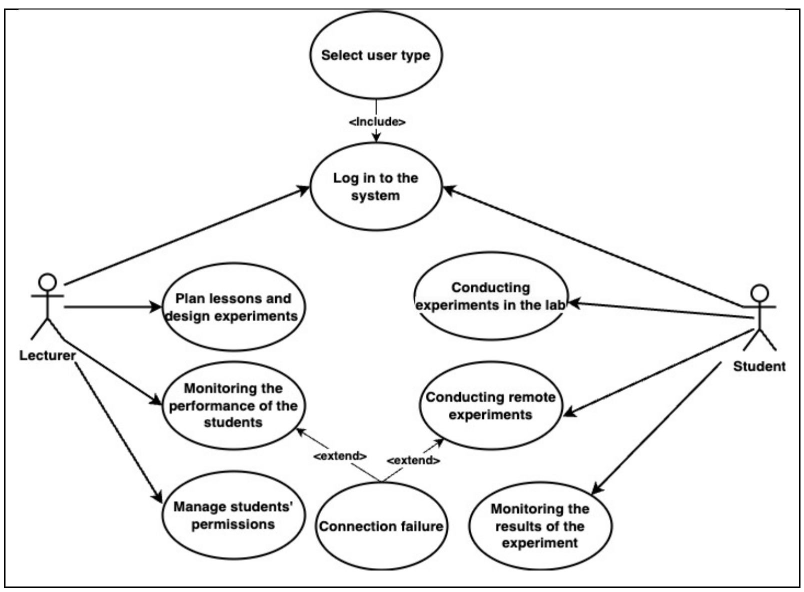

Figure 1. Use case diagram

User Interface

The system's user interface is central to its operation and accessibility. It is designed to function seamlessly across various operating systems. Users access the central cloud system by selecting their user type (teacher or student), Figure 2a, and entering their pre-registered username and password, Figure 2b.

Each user has a personalized workspace linked to their assigned course, experiment, or research project, Figure 2c. This framework facilitates administrative actions for teachers and lecturers and different activities for students. Within the control panel for lecturers, they choose between delivering lectures or conducting experiments, providing necessary details and descriptions, Figure 3. The system offers versatility, allowing students to engage in independent experiments based on their ideas.

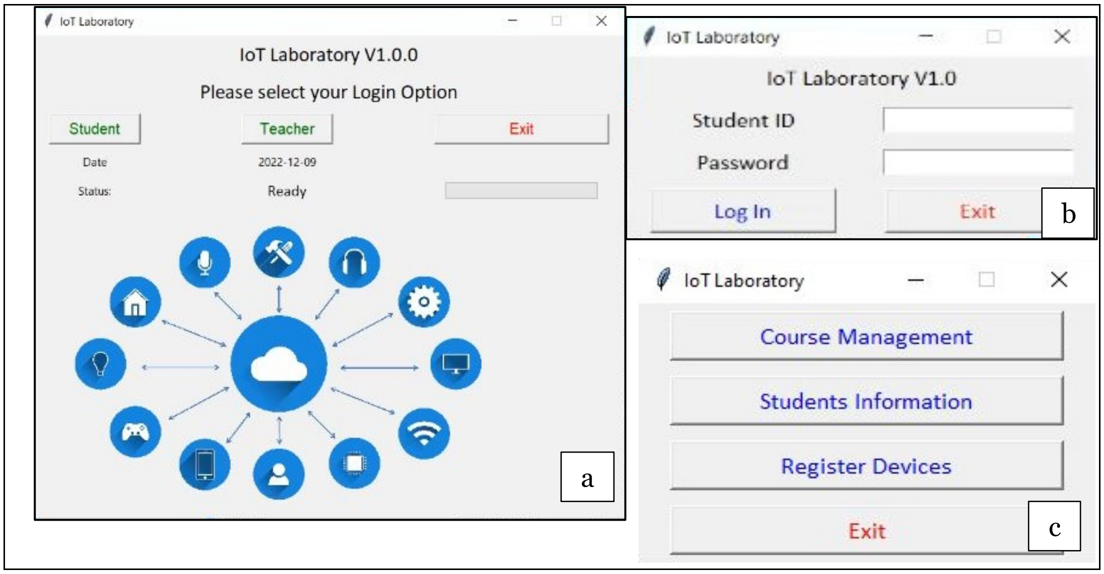

Figure 2. UI for entering the system

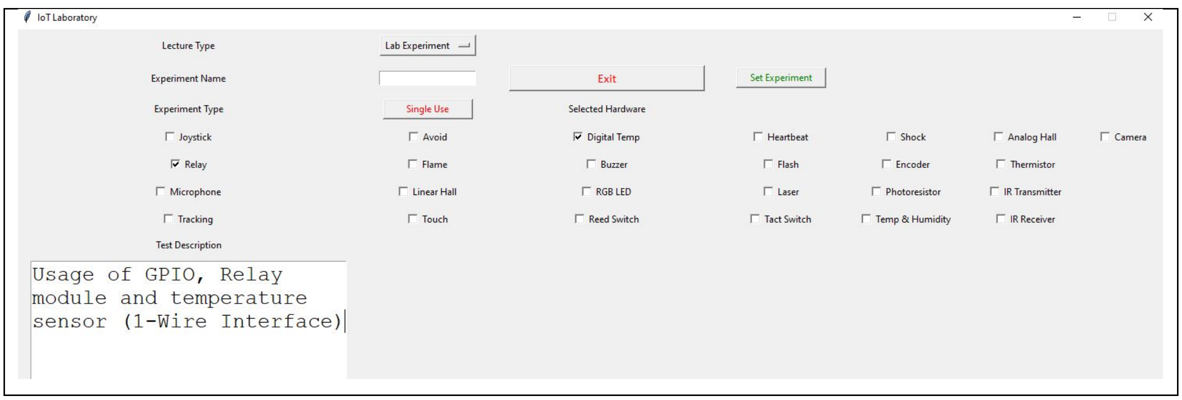

Figure 3. UI for practical experiment definition

Primarily Results

To demonstrate the system's capabilities, it manages real-time experiments. It collects data from sensors and controls equipment remotely. Users can monitor and interact with the ongoing experiment, with results continuously updated on the user interface.

The system's performance was assessed with a sample group of 12 students. Their feedback highlighted the significance of learning processes involving coding for IoT tools. They emphasized the need for continuous hardware and equipment use throughout the course. Users also appreciated the system's versatility, allowing for various actions beyond guided experiments.

Conclusion

In conclusion, the COVID-19 pandemic has accelerated the adoption of remote labs in higher education. This paper explores the design and development of a remote IoT laboratory, highlighting its potential in bridging the gap between hands-on learning and remote access. The primary results suggest that the system is efficient, user-friendly, and compatible with students' learning experiences. This research signifies the importance of innovative online class systems in the post-COVID-19 educational landscape and points toward the future of flexible and engaging laboratory experiences. Further research and development are needed to realize the full potential of this system in diverse educational settings.

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