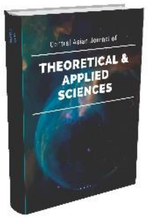

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PLC Laboratory Design for Online Education

Ubaydullaev Utkirjon
PhD, associate professor, Tashkent state technical university
utkir2005@gmail.com

Rahimova Mohira
3rd year student, Tashkent state technical university

Nosirov Khurshidjon
2rd year student, Tashkent state technical university

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Abstract: *The advancements in computer technology and the internet have revolutionized the landscape of education, particularly in the field of distance learning. In this context, remote laboratories have emerged as valuable tools that facilitate extensive use of university resources while supporting both professors and students. This article presents a remote laboratory specifically designed for practical work involving Programmable Logic Controllers (PLCs). The experiments conducted through this remote laboratory are explained, demonstrating how students can complete programming exercises at different locations and times on campus. The evaluation conducted indicates a positive experience, with students recognizing its value and appreciating the opportunity it provides.*

1. Introduction

With the rapid advancement of Internet technologies, new teaching methods have emerged, leading to a trend of replacing traditional local laboratories with open and remote laboratories [1]–[5]. Programmable Logic Controllers (PLCs) play a crucial role in coordinating complex tasks such as security monitoring, energy management, and control of automated production lines in the manufacturing industry. Consequently, there is a growing demand for engineers who possess strong skills and knowledge in this field[6].

Despite the inclusion of PLC topics in undergraduate courses at numerous educational institutions, students frequently encounter resource limitations that hinder their ability to develop strong PLC programming skills. Limited access to labs and a shortage of available equipment make it challenging for students to gain sufficient practical experience[7].

Among the various research efforts in remote laboratories, two major classifications can be identified. The first category relies on software simulation technology [2], [3], while the second category involves the use of hardware interfaces[3], [8]. Regardless of the method chosen, specific knowledge is typically required. However, it is often impractical for PLC instructors to possess extensive knowledge of every application.

To address these limitations, a well-known remote control software is adopted in this study to enable PLC remote operation, providing students with a realistic experimental environment[1], [9].

This paper proposes an open laboratory based on a LAN intranet, utilizing remote laboratory techniques. The course described herein is part of an electronic information engineering degree program and is an optional component of the student curriculum. The structure of this paper is as follows: Section II introduces the campus network model, followed by an explanation of the laboratory structure. Section III outlines the monitoring method, while Section IV discusses the evaluation of the remote laboratory. Finally, Section V presents a positive conclusion.

2. Infrastructure for Laboratory Realization

2.1. University Network Model

A campus typically refers to a defined geographic area within a university or college. Within this campus, a campus network is established, which comprises a collection of buildings interconnected into a unified enterprise network. This network infrastructure consists of multiple local-area networks (LANs) that facilitate communication and data transfer among various end systems.

The composite network model of a campus network is illustrated in Figure 1. The primary topology of a campus network revolves around LAN technology, enabling the interconnection of all end systems within the buildings. Commonly employed LAN technologies in a campus network include Fast Ethernet, Fiber Distributed Data Interface, Gigabit Ethernet, Ethernet, Token Ring, and Asynchronous Transfer Mode. These technologies ensure efficient and reliable data transmission within the campus environment.

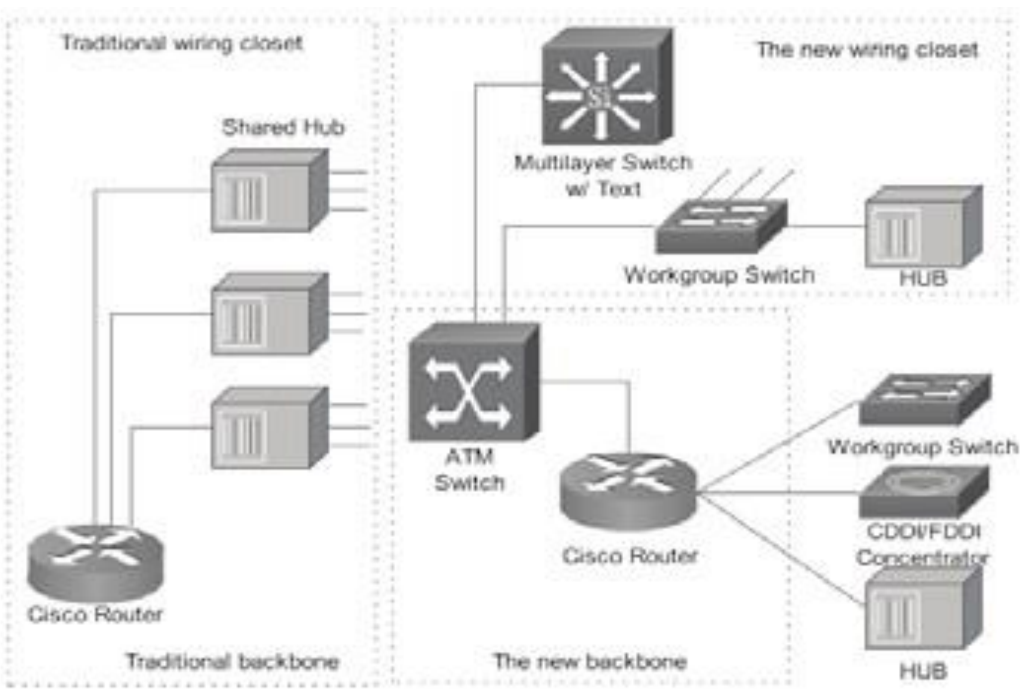

Fig.1. University Network Model

2.2. Laboratory Structure

The remote laboratory has been established based on the campus network, as depicted in Figure 2. This topology structure enables the connection of different PLC training models located in various places to the LAN via a local computer functioning as a web server.

On the laboratory server, specific programming and configuration software are installed. As a result, students have the capability to locally complete programming, debugging, and monitoring/control tasks of the PLC training models.

PC-anywhere is a highly effective software for remote access control. It allows one computer to remotely access and control another computer, establishing a one-to-one connection. The host components are installed on the laboratory server computer, while the remote components are installed on the computer chosen by the students as their remote access terminal. This software ensures reliable and secure remote connectivity. The Gateway functionality of PC-anywhere simplifies the process of finding hosts for remote users, even if the hosts are behind firewalls, routers, or have dynamic or private IP addresses.

With this structure in place, every computer within the campus network gains flexible access to the PLC laboratory. This scheme effectively overcomes the limitations of limited experiment resources. Students can access the PLC training models at any time and from anywhere on campus. They can program and debug the PLC training models remotely, as if they were physically present beside them.

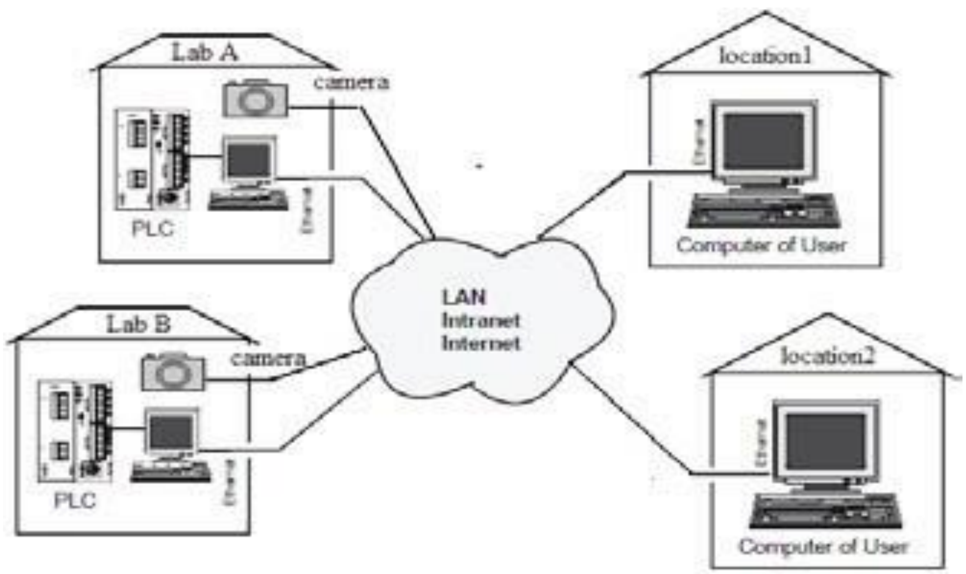

Fig.2. Topology of the Remote Laboratory

3. Supervision

To enable students to work with the remote laboratory, they need to install PC-anywhere on their terminals and configure the necessary settings. Additionally, they require a connection to the LAN to download programs to the PLC and utilize a camera for checking the functioning of the applications, as depicted in Figure 2.

In distance learning scenarios using remote laboratories, a visualization device plays a crucial role in allowing students to observe and supervise the correct operation of the applications when programming the PLC. This visualization aspect enhances the perception of a "real-world" experience for students, demonstrating that they are engaging in genuine laboratory work rather than simulations.

Each laboratory within the remote laboratory design incorporates the installation of a camera on the PC server. The camera's field of vision is focused on the PLC training model, providing monitoring and supervision capabilities for the educational system.

A fast and reliable internet connection is recommended to ensure an acceptable refresh rate for screen updates, allowing students to observe the functioning of the drivers in real-time. However, PC-anywhere has been used successfully with low-speed internet connections, demonstrating its adaptability.

It is important to note that while students receive feedback from the system through the camera, it is not the sole method of feedback. Additionally, students are encouraged to develop their own supervision screens where they can monitor and supervise the processes they are controlling, further enhancing their engagement and understanding of the laboratory work.

4. Results

The open PLC laboratory was subjected to testing by a group of 50 volunteer students who were divided into two groups: the local group consisting of 25 students and the remote group also comprising 25 students. All the students had an equal starting level, as none of them had previously attended a PLC programming course or worked with PLCs.

During the testing, students from both groups were able to successfully implement programs and operate the training models. However, they achieved varying levels of complexity in their programming tasks. Despite this, the overall feedback for the course was highly positive.

However, it is worth noting that three students from the remote group pointed out a major drawback, which is the requirement of a stable and high-quality internet connection for viewing the real-time camera feed at an acceptable rate. This issue affected their ability to monitor the laboratory activities in real-time.

Table 1: Students' Response Evaluation

Evaluation Aspect	Local Group	Remote Group
Course Interest	Positive	Positive
Usefulness of Material	Positive	Positive
General Course Rating	Good	Very Good
Laboratory Performance	-	Excellent

The survey results indicate that the students found the course interesting and believe that the knowledge gained will be beneficial in their future endeavors. The overall rating of the course is positive, with the remote laboratory receiving the highest score as students reported a smooth and problem-free experience. The analysis of the results demonstrates that the implementation of the remote laboratory significantly enhanced the course's quality. Additionally, the course methodology proved to be satisfactory, and students valued it accordingly.

Table 2: Assessment Results

Objective	Assessment Criteria	Average Value
Report Preparation	Students' submission of prepared reports	Satisfactory
Oral Presentation	Quality of oral presentation and discussion	Satisfactory
Final Exam	Performance in the final exam	Satisfactory

The course objectives were evaluated based on specific assessment criteria, and the average values are presented in the third column of Table 2. The results indicate that the objectives were satisfactorily achieved. However, further work will be conducted to improve both the laboratory environment and the course, focusing on the areas that received lower assessment results. In particular, attention will be given to improving the speed of photo file transportation in future research.

5. Conclusion

In this paper, we have introduced an open laboratory that operates on a campus network, along with an automatic remote learning PLC course. The laboratory setup and the structure of the course have been outlined. The primary objective of the course is to impart PLC programming skills to the students and equip them with fundamental knowledge in the field. This enables them to tackle various real-world scenarios commonly encountered in industrial settings.

Based on the feedback received through the survey, the students have expressed positive opinions about the course. Additionally, the results obtained from the submitted reports have been encouraging. Therefore, we can conclude that the overall experience has been positive and worth repeating in the coming years.

However, there are areas for improvement, and the main challenge lies in the speed of the internet connection. Enhancing the transmission speed of images would contribute to the refinement of the application and further enhance the learning experience. Addressing this challenge would be a key focus for future improvements in the remote laboratory setup.

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