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Design of a real-time remote-access engineering laboratory using integrated Web service and wireless technology for distance learners

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ABSTRACT: Web-based distance education has enabled university programmes to increase diversity within the student body by allowing non-traditional students and satellite campuses the ability to access a standard college education. However, for engineering distance education, students only have limited access to laboratory equipment to gain hands-on experiences. In this article, the authors present the results of their study on designing a flexible distance learning system that allows distance students access to an automation laboratory in real-time from a remote location. This system eliminates the difficulties of transportation of automation workstations, the installation of costly software on multiple computers, and gathering distance students at a central location at a specific time in order to conduct their laboratory experiments. The system design incorporates integrated Web services from logmein.com and 802.11g wireless technology that permits remote users to program the PLC controlling the pertinent automated laboratory station, while also providing visual feedback through the use of wireless Web cameras.

INTRODUCTION

For more than a decade, distance education has been proven to be an effective method of learning for non-traditional students. Recent leaps in Internet technologies has furthered and broadened the realm of distance education. A survey conducted by the National Centre for Education Statistics (NCES) of the US Department of Education showed a 72% growth in distance education programmes from 1994-1995 to 1997-1998. The survey further showed more than 1.6 million students enrolled in distance education courses by 1997-1998 [1].

The overall quality of distance education has improved greatly due to technology advancements and the increased popularity of Internet usage. The quality of distance engineering education has also seen significant improvements due to interactivity, virtual classroom environment, and other new technologies introduced to distance education, such as video streaming. However, for engineering and technology distance education programmes, the experiential exploration aspect of engineering and technology education has remained an area for further improvement. The need for the transportation of bulky equipment, the installation of costly software on multiple computers, and the requirement of distance learners to access experiment facilities at a certain time in a dedicated laboratory, all make conducting engineering laboratory experiments more difficult for distance learners.

A great deal of efforts has been undertaken by researchers and educators to address these issues. A real-time, remote-access network-based laboratory can be developed at a cost that most institutions may not be able to afford [2]. In an effort to search for alternatives, some other solutions have been proposed and developed. One solution is to utilise interactive multimedia-based educational materials and technology to incorporate practical examples and engage illustrative materials [3].

However, while this method enriches students' learning experiences through interactivity, engineering students do not gain real-life experience as they would in a laboratory. Another solution to this issue is the creation of virtual laboratories. Examples include *LabView*-based virtual instrument and self-developed Web-based virtual laboratories [4][5]. This approach enhances students' learning experiences through a simulation environment, but still does not provide the knowledge and skills that could be gained from being physically present in the laboratory.

This article presents results of designing a flexible distance learning system using an integrated Web service and wireless technology that addresses the above described issues. Some preliminary results have been reported elsewhere [6]. Using the remote access software, *LogMeIn Pro*, from 3am Labs Inc., integrated with an IEEE 802.11g wireless Web monitoring system at the experiment facility, educators can easily give practical demonstrations from a remote site, while distance learners can easily experiment and monitor the results in real time.

The results include user-controlled live video and snapshot pictures of a laboratory experiment, as well as data collected by the remote users for their reports. This eliminates the need for transporting bulky equipment to a remote location. Because the remote computer only acts as an agent to access resources on the master computer at the experiment facility, there is no need to install costly application software on each individual remote computer.

This approach demonstrates its simplicity, cost-effectiveness, and user-friendly accessibility. Furthermore, with secured access provided by *LogMeIn Pro*, educators and distance learners can use the facilities from home or on the road, which adds even more flexibility to teaching and learning.

DESIGN RATIONALE AND ISSUES ADDRESSED

This design is implemented through the Programmable Logic Controller (PLC) laboratories for an automation course. Initial successful implementation has demonstrated the feasibility, flexibility and effectiveness of this design. Further efforts have been undertaken in order to improve the user interface of this system. It is expected that this design will greatly improve teaching and learning effectiveness and have a broader impact upon a distance engineering education approach.

Figure 1 shows the block diagram of the system design. A main computer was installed in the Automation Laboratory at the Western Carolina University (WCU) campus, Cullowhee, USA. *WIN32* software is used to control a Programmable Logic Controller (PLC). Via LogMeIn.com remote-access Web service, the forward link allows remote users (instructors and distance learners) to access the main computer from anywhere at anytime.

The dedicated application software, such as *MicroWin* for PLC ladder logic programming and *VideoMail* for Web camera control, resided only on the main computer. Remote computers act as authorised clients to utilise these resources. In the automation laboratory, wireless Web cameras from *LinkSys* are installed to monitor the automated laboratory stations that are activated by the remote users. The Web cameras provide real-time visual monitoring, live video capture, and snapshot-taking capabilities to the remote users to observe and control an experiment process. The captured laboratory results can be fed back to the users through an IEEE 802.11g wireless link.

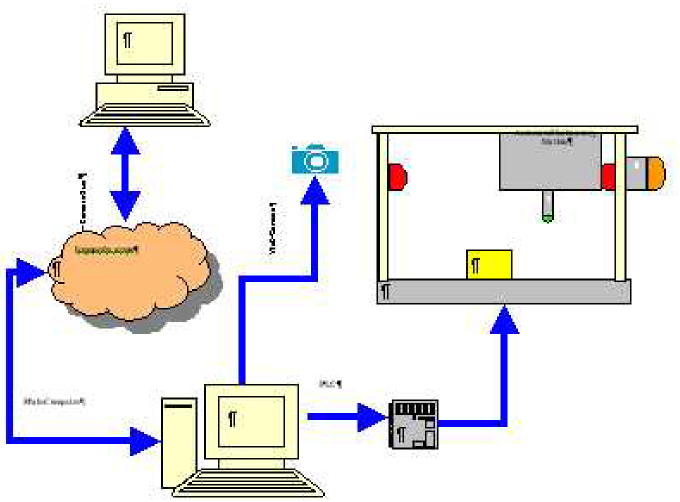

Figure 1: System design block diagram.

During the implementation stage of the project, several standard automation laboratory exercises were adapted from an automation course offered at Western Carolina University for the purpose of verifying and demonstrating the feasibility of this design concept. The following is a brief description of the standard laboratory exercises.

The first of two laboratory exercises used was the *PLC control of an alarm system*, in which the students were introduced to PLC ladder logic programming using the Siemens 224 series PLC and its related software, *MicroWin*. Students were introduced to PLC ladder logic programming, which covers ladder logic, editing rungs and simulating circuits. These skills enable students to develop a control program for an alarm system using standard functions such as basic inputs, outputs, latches and timers. A simulated control of the system is implemented at the WCU Automation Laboratory, allowing students to verify their program execution by downloading their developed program to a pre-wired Siemens S7-224 programmable logic controller (PLC), which enables the manipulation of the alarm system work station.

The second laboratory exercise used was *PLC control of a measuring system* in which the student was required to control an X-Y positioning table and sensor to measure the width of a part. The movement of the table is controlled by a stepper motor, which, in turn, is controlled by their ladder logic program. Once the program is developed, it is transferred to a Siemens S7-224 programmable controller for simulation.

The ladder logic for each laboratory experiment requires a few minor changes from the conventional format so as to facilitate the remote control of the PLC. For example, a remote user does not have the capability to physically control any physical inputs such as a system *START* button or a system *OFF* button.

Therefore, a technique known as *forcing a bit* was employed to address this issue. This technique consists of entering the relevant bits address into *MicroWin*'s status chart feature and entering a one for *START* or zero for *OFF*. This modification gives the remote users complete control of operating an experiment station at any time.

DESIGNED LABORATORIES AND EXAMPLE RESULTS

Figure 2 shows the dedicated laboratory set-up for this research. The main computer is located at the far end of the laboratory with individual laboratory workstations placed in front of it. When a user activates a laboratory session from a remote location, he/she accesses the application software and other resources on this computer.

Figure 2: The dedicated laboratory.

Web cameras are directly positioned in front of each workstation allowing the user to monitor the laboratory station and experiment processes. A central Web camera is situated to give the user a broad view of the entire testing area. When this camera is activated from a remote location via the Internet, it also turns on a halogen lamp to provide sufficient lighting in the laboratory. If there is no activity sensed by the camera for a preset length of time, it turns off the light automatically. This feature allows the remote users to work at night when all other lights are off. It is worth mentioning that this added value provides remote users flexibility in choosing a time when the network traffic is not as congested so as to conduct their experiments and, therefore, improves the reliability of a chosen laboratory session.

Figure 3 shows the view on a remote user's desktop when the user accesses *MicroWin* software installed on the main computer. As can be easily observed from Figure 3, the user can utilise this software as if it were installed on his/her desktop computer. When multiple licenses are provided, multiple remote users can utilise the same software to conduct the same experiments at the same time. In addition to all authorised resources on this main computer, the remote user can utilise other features, such as file transfer provided by *LogMeIn Pro* software.

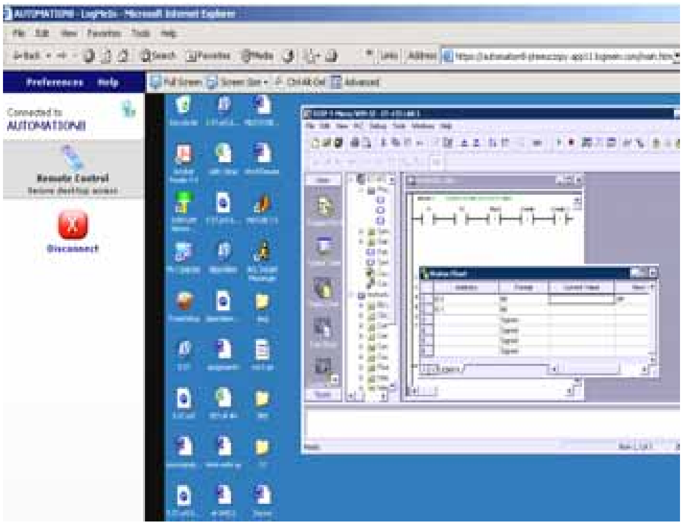

Figure 3: Desktop view of a remote user using *MicroWin*.

Figure 4 presents a snapshot of the first laboratory, PLC control of an alarm system, as described in the previous section. A remote user took the snapshot using the Web cam. In this laboratory experiment, the system is armed after downloading the correct ladder logic program. Thereafter, any movement activates the motion sensor, which, in turn, enables the strobe and siren. The remote user can monitor this experimental process via live video that can be temporarily stored on the main computer for later review, and take snapshots as shown for inclusion in the laboratory report.

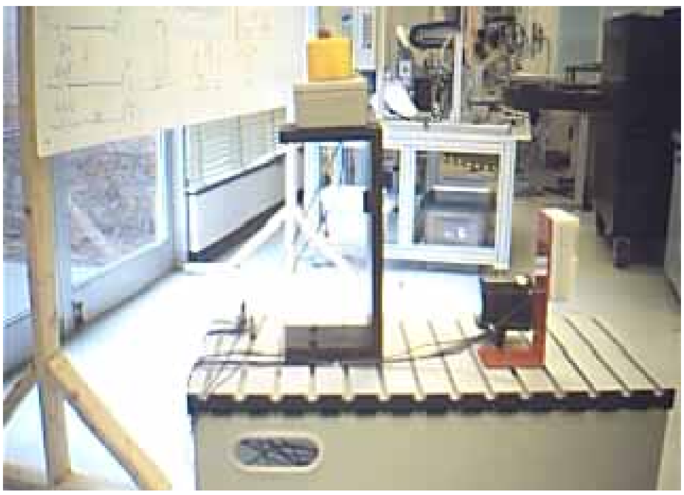

Figure 4: Snapshot of laboratory 1: PLC control of an alarm system.

Figure 5 shows a picture of the second laboratory experiment, PLC control of a measuring station. As in the previous section, the image was also captured from the Web cam by a remote user. The correct ladder logic program executes the horizontal travel of the measuring sensor, while a continuous flashing strobe warns of the impending motion. The measurement data can be acquired by *MicroWin* software and later transferred to the remote user's computer for data analysis.

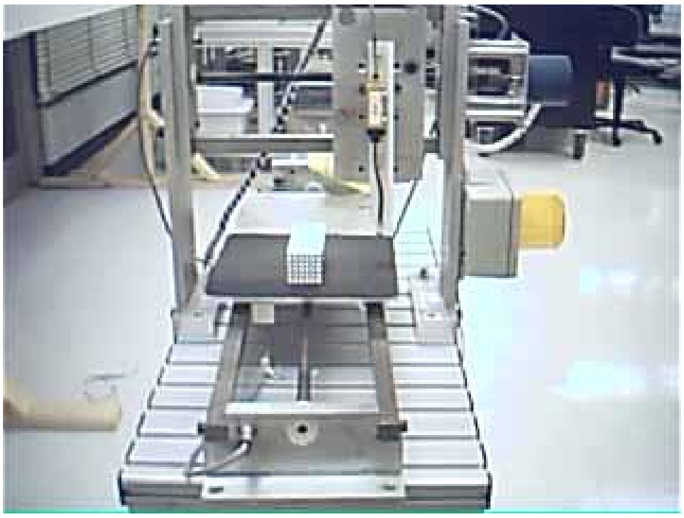

Figure 5: Snapshot of laboratory 2: PLC control of a measuring system.

In addition to the above system implementation, further considerations were given in order to address related issues, including occupational safety, multiple user access and live video quality for dial-up modem users.

Within any automation environment, safety issues are of a paramount importance. During the testing stage, all system executions were verified with a complete knowledge of class schedules, personnel movement and a restricted laboratory. A visual warning of the system's impending operation was activated during each test, while a Web cam enabled a visual check.

Furthermore, a lock-out tag-out system greatly enhanced the safety measure and was implemented in this fully functional system. This can easily be achieved by simply enclosing the laboratory stations within a restricted area that employs a dead-man switch system, allowing immediate deactivation of the stations if the barrier or door is opened.

One problem of using the remote access software is that the software allows a second remote user to access the main computer by disconnecting the first remote user without any warning. This problem can be solved by creating a simple counting script that counts the number of remote users logged into the system. When the maximum number of users has been reached, the system does not allow additional remote users to log in until seats become available. To avoid the potential problem that a remote user may stay online for too long without conducting an experiment, a simple software script can be developed to disconnect the user after a certain period of time when no activities are detected.

Dial up users are at an obvious speed disadvantage compared to broadband users. A slow connection rate will cause a delayed video refresh rate, creating the appearance of a choppy video feed. This issue can be addressed by buffering the video at the remote user end and introducing a delay of about 10 seconds for video replay.

FEATURES OFFERED BY *LOGMEIN PRO*

LogMeIn Pro offers a number of features suitable for this remote laboratory system design. These features include remote access control, secure file access and transfer, file sharing and multi-layered security. A brief description of the applications of these features in this design is given below. More details and features can be found at 3am Labs' Web site at www.logmein.com, and their white papers [7][8].

Remote access control allows a user to completely take control over the main computer from a remote location. This feature was utilised to enable students to use the application software installed on the main computer, and eliminate the need for installing costly software on individual computers.

File access and transfer serves two purposes in this design. Laboratory notes and other reference materials are accessible to students through the file access feature. Experimental data, live video and snapshots of the experiment process can be transferred at the student's request for inclusion in his/her laboratory reports.

CONCLUSIONS AND FUTURE WORK

The integrated approach of using Web-based services and wireless technology has provided engineering and technology students with an effective means of gaining experiential knowledge by conducting laboratory experiments from a remote location. This is especially important for distance learners to gain *hands-on* experience.

However, the effects of being able to control a computer remotely far extends past the realms of distance education. For example, using this approach as a model, a shareware or timeshare technique can be employed for the control of costly engineering software and equipment, such as parametric modelling software or coordinate measuring machines. The broader impact of this project can be extended into many other engineering disciplines where experiential exploration is an important component.

The successful demonstration of this cost-effective design has helped secure some funding from the University. The future work related to this project includes the following:

- Design of a guided user interface based on students' level of understanding for a specific experiment;
- Investigation of secure data transfer;
- Assessment of the effectiveness of this system in engineering education.

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