AC 2007-891: IMPLEMENTING A REMOTE-ACCESS ENGINEERING AND TECHNOLOGY LABORATORY THROUGH A GRADUATE-LEVEL TEAM PROJECT

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Implementing a Remote-Access Engineering and Technology Laboratory through a Graduate Level Team Project

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Abstract:

For many distance engineering courses, labs are either accomplished by gathering students at a central location or are comprised by requiring students to perform computer simulation. Aimed at improving learning effectiveness for the students, Kimmel School graduate students are set out to implement a real-time, remotely accessible engineering laboratory for an undergraduate automation class based on the previous research results [1], [2]. Designing a remote-accessed engineering laboratory can eliminate the unnecessary need for transportation of laboratory equipment, reduce the cost of software licensing, and to provide flexible scheduling for student laboratory exercises.

This project consists of four major components: remotely controllable lab equipment, student knowledge assessment tools, information transfer over the networks, and a relational database and user interface design. The project is carried out by four graduate student teams, and each team is responsible for one of the four tasks. One graduate student takes the leadership of overseeing the project progress, coordination among teams, time-line management, and system integration.

The first team is composed of three graduate students with engineering technology backgrounds. Two of them are working students who use PLC programming at their jobs. This team designs and programs the lab stations and makes them suitable for remote laboratory exercises.

The second team is responsible to develop student tutorial materials and assessment tools. Assessment tools include a "background theory test" and a "pre-lab knowledge test." Team members are first year engineering technology graduate students whose course knowledge on "Automation Systems" is still current.

The third team focuses on information transfer over the networks. The information includes remote access methods, monitoring methods in the lab, and delivering methods of lab results. Both team members possess telecommunications engineering technology background and are familiar with computer networks.
The fourth team is composed of two students came from an electrical and computer engineering technology background. They possess moderate programming skills. This team designs a relational database for data storage and a user interface for navigation and data collection.

In this paper, we will report our findings from this applied research project. Our focus will be on the successes and lessons learned from the implementation process. Special emphasis will be given to the issues encountered and solutions found. Educational merits will be discussed, and preliminary assessment results will be addressed.

Introduction

For many distance engineering courses, labs are either accomplished by gathering students at a central location or are comprised by requiring students to perform computer simulations. To improving learning effectiveness for the engineering students, Kimmel School graduate students set out to implement a real-time, remotely accessible engineering laboratory for an undergraduate automation class based on the previous research results [1], [2]. By designing a remote-accessed engineering laboratory it will be possible to eliminate the unnecessary transportation of laboratory equipment, reduce the cost of software licensing, and provide flexible scheduling for student laboratory exercises.

The remote-accessed engineering laboratory project is implemented through the use of Programmable Logic Controller (PLC) laboratories for an automation course. During the implementation stage of the project three automated workstations were adapted from the automation course from Western Carolina University to demonstrate the feasibility of the design concept. [1] The three laboratory exercises were used for the implementation of the design, including a PLC controlled alarm Station, a PLC controlled stepper motor, and a PLC controlled measuring station.

The project was carried out by four graduate student teams; each team was responsible for one of the following major components:

(1) Remotely controllable lab equipment
(2) Student knowledge assessment tools
(3) Information transfer over networks
(4) A relational database and user interface design

The PLC team was composed of three graduate students with engineering technology backgrounds. Two of them are working students who use PLC programming at their jobs. The PLC team was responsible for the design and programming of automated workstations and to make them suitable for remote laboratory exercises.

The Assessment team was composed of two graduate students who were responsible for developing the student tutorial materials and assessment tools. The Assessment tools included a background theory test and a pre-lab knowledge test. Both the background theory test and pre-lab knowledge had to be successfully completed before the students were allowed to attempt the practical lab.

The Networking team was composed of two graduate students who focused on information transfer over the networks. The information included remote access methods,

monitoring methods during the labs, and delivery methods of lab results. Both team members possessed telecommunications engineering technology background and were familiar with computer networks.

The User-Interface & Database team was composed of two graduate students who came from an electrical and computer engineering technology background. They possessed moderate programming skills. They were responsible for designing a relational database for data storage and a user interface for navigation and data collection.

Design Rational and Architecture

As previously stated the remote-access engineering laboratory was composed of four main parts. By using *LogMeIn.com* from any remote computer, the student gains access to the user-interface, which guides the student through the laboratory system. The user-interface is linked to a relational database that handles the student assessment information and records student data. Each of the PLC automated workstations was assigned to an individual computer. A *Linksys* camera system was also networked to the each assigned computer. The *Linksys* cameras were used to monitor and record the lab processes.

In order to implement the user-interface, a relational database was used for data handling and storage, PHP, HTML and *MySQL* programming languages were used to connect the database to the user-interface. The infrastructure for the three laboratory workstations and *Linksys* cameras used for this project were set separately for each work station. Figure 1 below shows the detailed hardware and software diagram of the completed project. [6]
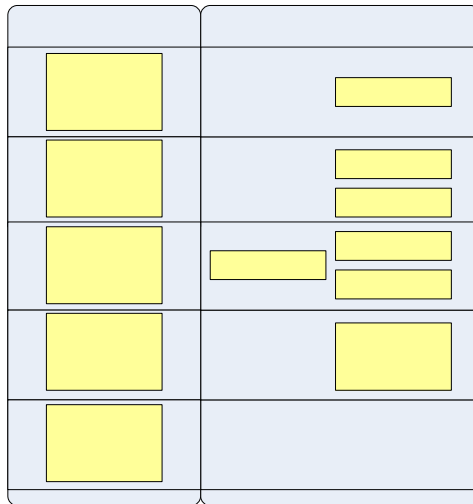

Figure 1: Hardware and Software Diagram

Currently, the remote-access engineering laboratory system is running on the local university network. Four computers have been setup to service the remote access labs,

one main computer acts as server to host the user-interface and database that contains the student assessment tools. The other three computers are dedicated to one of the three remotely controlled lab workstations as seen in Figure 2.

Figure 2: Remote-Access Lab Setup

Using the *LogMeIn.com* software a student can access the database computer to complete the background theory test and a pre-lab knowledge test. To access the database computer the student enters their user name and password and selects the *Quizzes* option to remotely log into the computer. After logging into the database computer, the student again enters their user name and password to gain access to the test material. The student then begins their background quiz. When the student has finished the quiz and is successful, the quiz is submitted and a time-and-date stamp is recorded in the database for administrative purposes. The process is repeated for the pre-lab quiz.

The background theory test must be completed successfully before the student is allowed to go on to the pre-lab test. If a student is unsuccessful, they are allowed two more chances to retake the quiz. If they are unsuccessful on their third attempt they are directed to the courses review materials and locked out of the system. They must then contact the administrator to regain access to the test. The same process applies to the pre-lab knowledge test. Once the student has successfully completed both the background theory and pre-lab quizzes they may take go on to complete the practical lab.

The administrator uses the same process to gain access to the database computer. Once the administrator enters their username and password they are granted access to the database field which records the student information and time-and-date stamps.

After the student has created his/her PLC code, they will again use *LogMeIn.com* to access whichever lab he/she is running. Once the student has logged into *LogMeIn.com* they will enter their user name and password and select the lab they wish to run. The student will then be granted access to the assigned workstation computer. After accessing

the lab, a timer will be started that gives the student one hour to enter their student information, download their PLC code, run, and verify their lab. A warning message will be displayed 30 seconds prior to time running out. If the student fails to complete the lab before the time is up they will loose access to the lab and the computer will restart. Once the student has entered their information a time-and-date stamp will be recorded in the database for administrative purposes. Figure 3 shows the user interface and lab format designs.
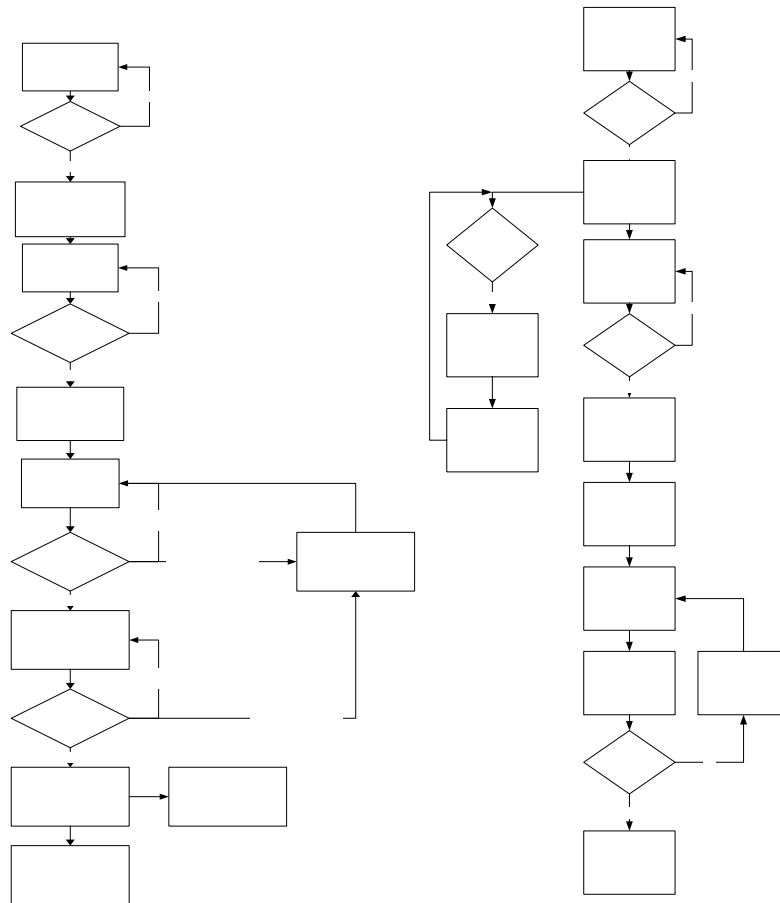

Figure 3: User Interface and Lab Format Design

Design Results and Solutions to Problems Encountered

PLC Team

(A) Design Results

During the implementation stage of the project three automated workstations were adapted from the automation course from Western Carolina University to demonstrate the feasibility of the design concept. [1] The three laboratories exercised used for the implementation of the design include a PLC controlled alarm Station, a PLC controlled stepper motor, and a PLC controlled measuring station.

The first laboratory exercise 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 the *Micro Win* software. The alarm workstation consisted of a motion detector that when activated, triggered a warning light and a siren. The PLC program was downloaded to the Siemens S7-224 PLC and run to verify the program execution. The PLC controlled alarm station is shown in Figure 4.

Figure 4: PLC Controlled Alarm Work Station

The second of three laboratory exercises was the PLC control of a stepper motor. The purpose of this laboratory exercise was to control the direction and speed of the stepper motor. Data bytes were used to define the sequence bit pattern for the steps of the stepper motor. This lab also required students to use timers and counters to control the speed and track the steps of the stepper motor. Once the PLC program was written, it was downloaded to the Siemens S7-224 on the workstation for simulation. Figure 5 shows the stepper motor work station.

Figure 5: PLC Controlled Stepper Motor Work Station

The third laboratory exercise was the PLC control of a measuring station. The students were required to control an X-Y positioning table and sensor to measure the width of a

part. The movement of the table was controlled by a stepper motor, which is controlled by the PLC program. Once the PLC program was written, it was downloaded to the Siemens S7-224 on the work station for simulation. Figure 6 shows the PLC controlled measuring station.
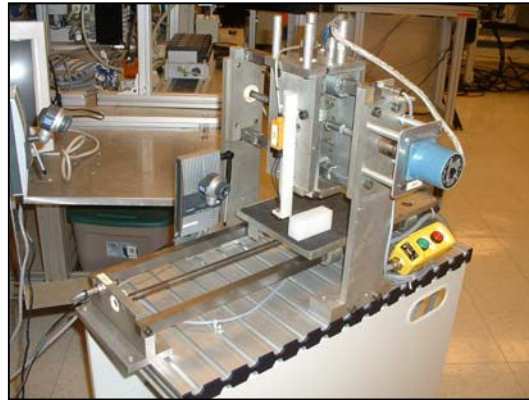

Figure 6: PLC Controlled Measuring Station

(B) Problems Encountered & Solutions Found

The ladder logic for each laboratory experiment requires a few minor changes from the conventional format for it to be successfully executed remotely. For example, a remote user does not have the capability to physically control any physical inputs such as START buttons of system OFF buttons. [1]

To remedy this situation, a technique known as forcing a bit was employed. The technique consist of entering the relevant bits address into *Micro Win's* status chart feature an entering a one for START or a zero for OFF. This modification gives the remote users complete control of operating an experiment station. [1]

Another issues encountered was the warning light on the PLC controlled alarm work station. Initially the light flashed, which made it hard to view the light over the web. The light flashed a rate that was faster than the refresh rate of the *LogMeIn.com* software. This problem was remedied by replacing the flashing light with one that did not flash. Replacing the light made it much easier to view the light over the web and verify the PLC controlled alarm work station was functioning properly. [3]

Assessment Team

(A) Design Results

The Assessment team developed a total of ninety questions for all three laboratories, thirty questions for each lab. Half of the questions developed focused on background

theory and the other half were focused towards the pre-lab knowledge. The questions were presented in the form of multiple choice and true or false.

Once a student had completed a test, the answers given by the student were compared against the correct answers in the assessment data base. The student was then given a report informing them of how many questions were answered correctly and if they had passed or failed the quiz.

(B) Problems Encountered & Solutions Found

The Assessment team encountered two minor problems while developing the assessment tools for the remote-access engineering laboratory. The first problem dealt with developing questions that were not redundant. They found that when developing the background theory questions along with the pre-lab questions, many questions were repeated. The second problem encountered by the Assessment team dealt with deciphering between questions that met the theoretical requirements for the background test versus questions that met the practical requirements for the pre-lab test. [4]

It was decided the Assessment team that the best way to remedy the repetitive questions developed by the group member was to split the labs up between group members giving them soul ownership of comprehensive materials for that lab. To better assess the bias between the theoretical and practical questions the assessment materials were reviewed by an instructor before being entered into the database. [4]

Networking Team

(A) Design Results

The remote-access engineering laboratory system is currently set up with all devices directly connected to the campus network through a hub. There were six cameras, three workstations, and one server, all with individual assigned network addresses from the campus' DHCP server. Five *Linksys* cameras were mounted to their appropriate automation stations. Two cameras were mounted to the PLC controlled alarm workstation, one camera was mounted to the PLC controlled stepper motor work station, and two cameras were mounted to the PLC controlled measuring work station. Each camera was given a logical name that coincides with the workstation it was assigned to. For example, there were two cameras mounted to the PLC controlled alarm workstation. The cameras names' were chosen as Alarm1 and Alarm2. [5]

Each workstation and the server were configured under Windows XP Professional. The *Linksys Viewer and Recorder Utility* was installed to allow the user access to the cameras, where the user could view and record live video of each workstation. Only the cameras appropriate to that lab were added to the viewer utility on the workstation. [5] *MicroWin* software, used for PLC programming, was also installed on each workstation. Each workstation also required the *LogMeIn* software to allow remote access. In order to limit access to the computers, the *Poweroff* software was also installed, which is configured to automatically restart the workstation after one hour of use. When the user

logs into the workstation, the *Poweroff* software and a log-in screen for recording each user's activity are started automatically. *Deepfreeze* was used to remove any newly saved data on the workstation after each restart. [5]

The initial plan for the system was to allow each automated workstation to be on separate networks. Wireless *Linksys* routers were to be used to separate each workstation and the corresponding wireless web cameras together. Each network was to be connected to another *Linksys* router, which then would be connected to the campus network. [5] The separation of networks allowed for added security and limited access to the automation workstations. Also, the amount of cabling would be reduced by almost half by allowing the cameras to connect to the routers wirelessly, which also allowed for greater mobility and easier direct access to the equipment

(B) Problems Encountered & Solutions Found

The largest setback while implementing the system occurred through campus IT services. Newly added policies forbid the use of any device creating new networks within the campus' network. [5] Our system called for one new network with three sub networks to be created. In order to work around this problem, the wireless functionality of the system was abandoned and the networks were dissolved. All connections were created using the campus' network.

Other minor issues arose throughout the project. First, the *Deepfreeze*, the software used to remove new data added to the system was installed on the computers we planned to use for the project. Spare computers were found and used to remove the issues caused by *Deepfreeze*. Second we solved the issue of logging students off the computer after a predetermined time limit, by using the *Poweroff* software. A batch file was created to run the program when the user logs in to the computer. The final issue encountered by the Networking team was getting all the right programs to run when a user logs into the computer. The computer startup file was used, and all the required software and batch files were inserted into it. [5]

User-Interface & Database Team

(A) Design Results

The user-interface and database provide means for gate-keeping, storing and accessing data information, and the overall implementation of this Remote Accessible Engineering Laboratory project. [6] The user-interface consists of a series of web pages. This interface acts as a liaison between the students and the databases, as well as a gatekeeper between the students and the lab equipment. PHP codes were used to link the web pages with the database. Using *MySQL* statements, data was effectively inserted and or modified depending upon user input. [6]
In order to be able to run in real-time, a web browser that supports PHP was required. To implement on the local-host, the software *XAMPP Control* was used to acquire connection between the *MySQL* database and the user-interface. [6] By running *XAMPP*

for the apache and *MySQL,* the connection was established between the web pages and the database.[6]

The database software used for this project was *MySQL Front*, which is an open-source product. The actual database design was accomplished using the GUI of this software to set up tables and fields. Each field had its own data type which is established here.

The database stores data for the background theory and pre-lab test that help fulfill the students' learning objectives. This database also consists of several fields that will contain the student information, their ID number, lab number and their scores from the exercises for assessment purposes. The time elapsed for conducting one lab is also recorded by using a time-and-date stamp implemented with PHP code. This information will be used to provide statistical data to assess the students' learning effectiveness over time. [6]

Two databases were designed in this project, including *users* and *questions*. The *users* database contains information for the students, including their ID numbers, passwords, quiz scores, time-and-date stamps, and the status of each lab. The *questions* database includes the answers for all the quizzes of the three labs. These two databases are relational, they interact with each other for recording and storing information accordingly to the students progresses. In order to insert information into the database from the user-interface a *SQL* statement was used.[6]

(B) Problems Encountered & Solutions Found

In order to implement the user-interface, programming languages such as PHP and HTML had to be learned and utilized. One specific problem that was encountered was some security issues. The first issue was the use of the back button using an internet browser. The back button feature had to be disabled; otherwise a user could take a quiz, and then go back and take the quiz again. This was disabled using some HTML code.

Unlimited use of the URL was another security issue. The problem was that a user could type the address for any quiz into the URL and take the quiz, defeating the purpose of having a controlled environment in which to take the quizzes. The solution to this was the use of specific HTML code.

Another security issue that was encountered was a user function. This first attempt to solve this problem was to allow the student to create an ID number and use that number every time that they took a quiz. However, this was not effective. Essentially, a user could create a false account, take all of the quizzes and find out the answers. To resolve this problem, the user would be assigned an ID and a password by the administrator.

Administrative security measures had to be put into place. These security measures prevented unauthorized persons from gaining access to the actual database. This is very

critical; if an unauthorized user gained access to the administrative data base they would have access to student information such as students' grades.

Conclusions and Future Work

Future work for the remote-access engineering laboratory includes mounting a lighting source to each of the PLC controlled workstations. The light source will be activated when a user gains access to the workstation. As of now, there are no review materials for the student to access once they have failed the test. These review materials will be developed and added to the database.

The security and gate-keeping functionality will be improved. The database design will be implemented in a more efficient manner. Randomly generating questions using a question database/test bank. Therefore, the design for the quiz web pages will be much simpler once only one web page is needed to display various sets of questions.

A more user-friendly administrative function will be designed; focusing on easier access of the student scores. Finally, an alert-email would be sent to notify the professor when a student fails all of the pre-lab and background theory quizzes. Therefore, he can contact the student to ascertain what the problem is and to determine the student's progress on the project. [6]

In conclusion, the remote-accessed engineering laboratory has provided engineering and technology students with an effective means of gaining experimental knowledge by conducting laboratory experiments for a remote location. [1] By designing this remote-accessed engineering laboratory it will be possible to eliminate the unnecessary transportation of laboratory equipment, reduce the cost of software licensing, and provide flexible scheduling for student laboratory exercises.

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