

2006-1421: INTERNET-BASED PHYSICAL EXPERIMENTS: APPLICATION WITHIN A LABORATORY COURSE

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INTERNET-BASED LABORATORY EXPERIMENTS: APPLICATION WITHIN A LABORATORY COURSE

1. Introduction

Engineering educators are faced with a challenge for providing students with an adequate laboratory experience at a time and place convenient for them. This applies both the traditional laboratory courses as well as laboratory courses as a part of distance learning programs. Traditional laboratory classes are scheduled only for a specified time period, when students attend a laboratory class located within their academic institution. Considering the mixed ability level of students, the allocated time is often not enough for all students to complete their tasks satisfactorily and also gain sufficient experience through the process^{1,2}.

To address these issues, there are a number of initiatives that have been made to provide experimentation facilities over the Internet^{3,4,5,6,7,8,9}. None of these facilities are designed to deliver a laboratory course that is a part of a regular educational program. In addition to these, all these suffer from one or more of the three main drawbacks. These are: a) complexity in development; b) higher cost; and c) single server can provide access to only one experiment at a point in time. Although the Internet-based laboratory facilities have a number of potential benefits, these drawbacks hinder the process of gaining their popularity.

The paper will describe the design, development, and evaluation of an Internet-based laboratory facility that will be used to deliver an undergraduate digital electronics laboratory course within an engineering technology program. The system is developed through a grant from the National Science Foundation (Course, Curriculum, and Laboratory Improvement program). The uniqueness of the developed facility is its modularity in design and the use of commercially available hardware and software technologies. This approach is adopted to address the drawbacks identified earlier.

The next section describes the Target Laboratory Course. Section three illustrates the structure of the developed system by highlighting its main components. Section four illustrates the evaluation process in terms of usefulness of the system and learning outcomes. These are followed by the conclusions, acknowledgements, and references.

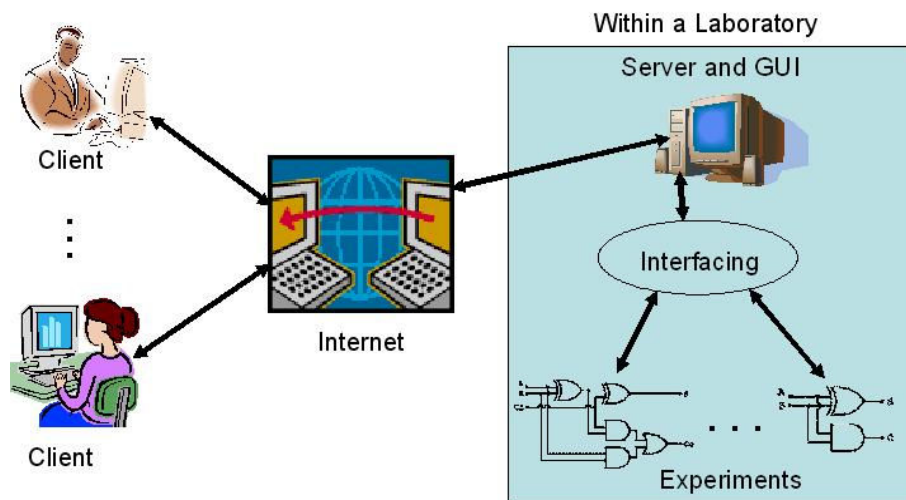


Figure 1: System structure.

2. Developed System Structure

This section will address the overall structure of the developed facility. As mentioned earlier, the facility is developed in a modular structure so that each module can be changed/modified in an independent manner. Figure 1 shows the different modules and their interaction. The modules are: a) Experiments; b) Interfacing; c) GUI and Web Publication; d) Server; e) Internet delivery; and f) Client PC.

The individual experiments are developed according to the course and connected to the server through a suitable interfacing hardware. A number of experiments can be connected to the server depending upon the capability of the interfacing hardware. Each of these experiments can be controlled (manipulated) via an individual GUI residing within the server. The GUIs are developed by using National Instrument's LabVIEW software package. The GUIs are subsequently transformed to dynamic web pages and stored within the server. These GUIs (as dynamic web pages) are linked with a web application that hosts the developed facility. The clients with appropriate UserID and Password are able to access the facility and manipulate the GUIs to control an experiment. With this facility, a number of experiments can be delivered simultaneously; however, only one experiment can be accessed by a single client at any point in time. A client can access an experiment by accessing the GUI within the server. A client PC should have Internet explorer (web browser) and LabVIEW player (freeware). In addition to performing experiments, the Internet delivery part of the facility provides documentations, user profile and password control, client access information, and weekly surveys to assess the system and its effectiveness.

2.1 Interfacing hardware and software

The first step towards the Internet-based physical laboratory facility is to establish an interfacing between the computer and the experiments. The computer will be the gateway to the Internet, while the experiments are the facility that needs to be accessed/operated over the Internet.

A digital I/O card from National Instruments is employed as the interfacing hardware^{10, 11, 12}. The software part of the interfacing process was implemented by using LabVIEW, which is also from National Instruments. The LabVIEW software has much more flexibility for data acquisition and control over the Internet. This can also be used along with other third party software, making it more attractive for development applications such as this one. Apart from these, the other reason for choosing LabVIEW is for its inbuilt server facility that can be utilized to publish a GUI for Internet access to the experiments^{13, 14}.

2.2 GUI and Web presentation

One of the main components of the Internet-based laboratory facility is the GUI. This is serving as the media between the experiments and the students. LabVIEW provides a facility to develop a GUI called virtual instrument (VI), which can serve both of the above purposes¹⁵. The concept of VI is to create more powerful, flexible, and cost-effective instrumentation systems using a PC. A VI can easily export and share its data and information with other software applications.

An image of a GUI developed for a 3-input 1-output experiment is shown in Figure 2. The particular experiment is Laboratory 3 and Task 1. The left hand side of the GUI is showing all the 3-inputs that are generated within LabVIEW.

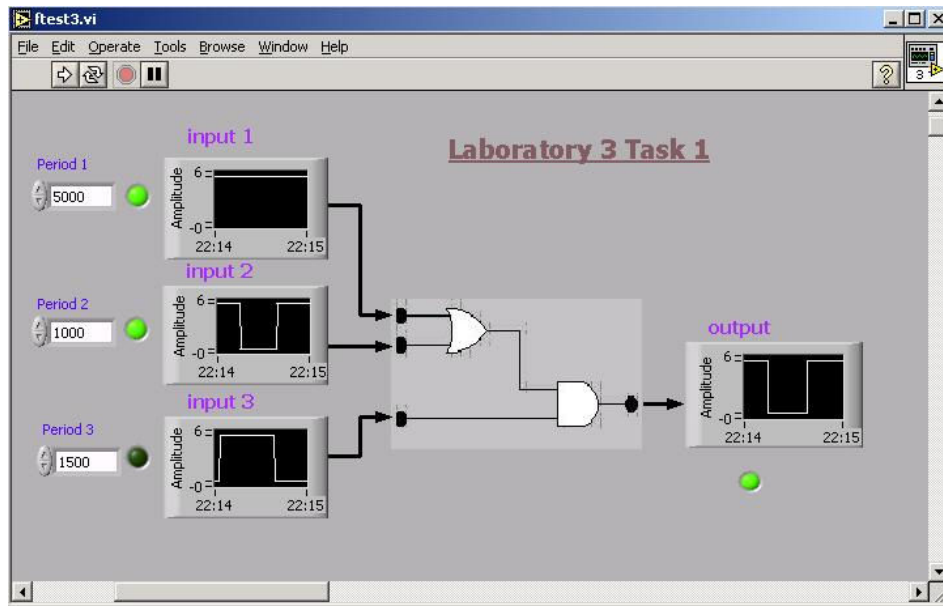


Figure 2: A GUI for a 3-input 1-output system.

A user can change the time period between the switchings. The state of an input can be monitored, either through an LED or on a graph window. The graph windows are labeled as input 1, input 2, and input 3. The state of output can also be monitored through a graph window as well as through an LED, which is shown on the right hand side of the GUI. The logic diagram between the two sets of graphs is the hardware system that has been used for the specific experiment. The GUI passed the inputs to the experiment and receives corresponding output through appropriate ports of the I/O card.

For the target course, inputs and outputs are digital in nature. This allows grouping the experiments in terms of the number of inputs and outputs and develops a single GUI for each group. A GUI for one group can be used for all the experiments of that group, with only minor modifications. For the specific course, there are a total of 10 reusable GUIs that will handle all 37 tasks for 12 laboratory sessions.

Presenting a GUI over the Internet involves publishing the GUI as a dynamic web page. The published GUI is stored within the server at a particular location, and a web application can point the location and filename for access to the GUI. LabVIEW allows multiple numbers of GUIs to be published at the same time, thus allowing the system to handle multiple experiments simultaneously.

2.3 Web Server and Software Tools

A web server is hosting the web site for the facility including all the applications and interfacing hardware and software. In terms of hardware, the web server is having a 3.6GHz processor, 2GB of RAM, 80 GB of HD, and National Instrument's I/O card. For the software part, it has Windows 2003 Server (OS), LabVIEW, Internet Information Services (IIS) server, .NET, XML (EXtensible Markup Language), XSLT (EXtensible Stylesheet Language Transformations), and SQL server 2000.

LabVIEW is used for data collection and visualization. The IIS provides the services to the http requests coming through the Internet. This is a component provided within Windows 2003 server. The IIS makes it easier to share documents and information over the Internet.

Web-publishing, security, administration, and applications can work together to increase performance and reliability, while lowering the cost of ownership and also improving the web application environment. Only an authorized client with a valid password can access the system. This requires password protection and a dynamic web page. This has been implemented using ASP.NET.

2.4 Internet Delivery

Internet delivery of this facility involves a number of issues: system access levels, user profile and password control, providing documentations, performing experiments, weekly survey, and administrative activities. All these issues are addressed within the facility to make this as effective as possible. Similar to the other modules, the Internet delivery module is independent of other modules and can accept any form of experiments without any change. The only thing that has to change is the experiment related documentations.

The system access level controls the level of access by a facility user. There will be two levels of access to the system. One will be as a client and the other as an administrator. Students will be allowed with client level access. With this status, one can perform or view an experiment, change password and demographic details, and complete the weekly survey questionnaire. An administrator level of access will allow management of experiments and monitor and gather access profile and survey data. An image of the homepage with client login is shown in Figure 3.

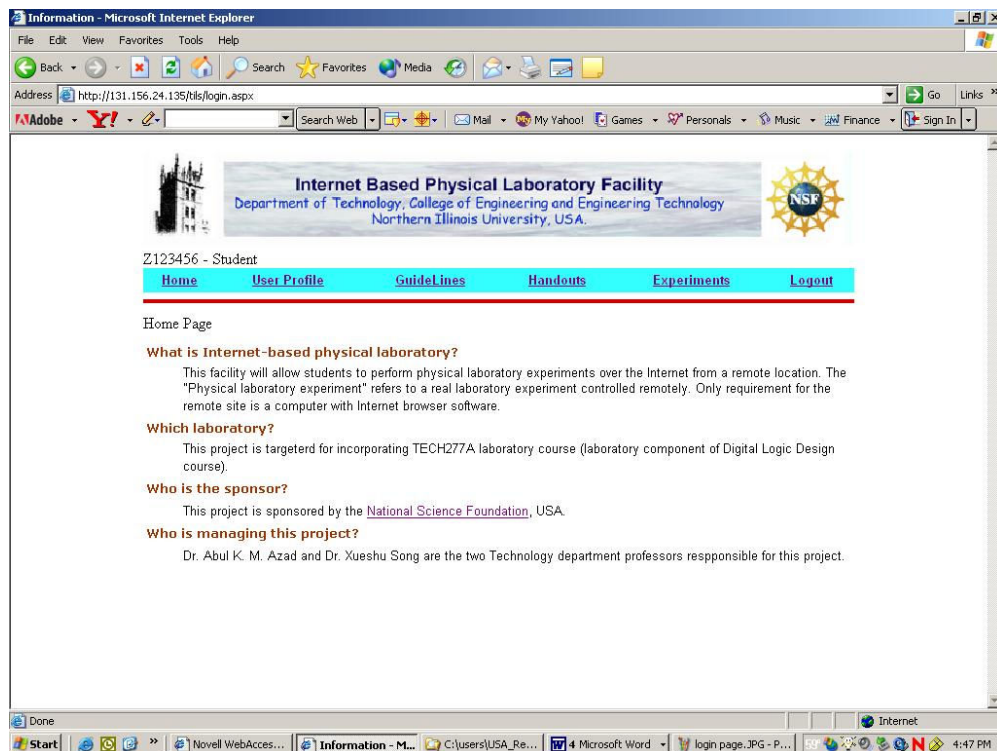


Figure 3: Homepage with client login.

The UserProfile button allows the user to access demographic and contact information, the password changing facility, and computer and Internet usage information. During the first login, every user needs to answer few questions regarding level of computer and Internet usage.

This is to establish a background profile for every user. A user can change contact information and password during any login session.

There are two documentations that are provided through the web page: guidelines and handouts. The guideline document provides a brief description about the facility, its working principle, and steps to follow to perform an experiment. The handout document will provide instructions for experiments along with pre-laboratory guidelines. For the target course, the experiments and handouts are going to change every week in accordance with the delivered experiments. As a pre-laboratory, students need to study the circuit and develop a truth table before performing an experiment.

Student can access to the experiments by clicking on the Experiment button within the home page. The experiment page will provide the students with a list of tasks that need to be completed during a given week. An experiment can be performed by a single user at any point in time; while other users can only view the experiment without any control over it. Depending upon the availability of an experiment, a client may get access either as a performer or as a viewer. An image of performer web page is shown in Figure 4. Only a performer is able to change the input status for an experiment. The viewers are put into a queue to get their turn as a performer on a first come first serve basis.

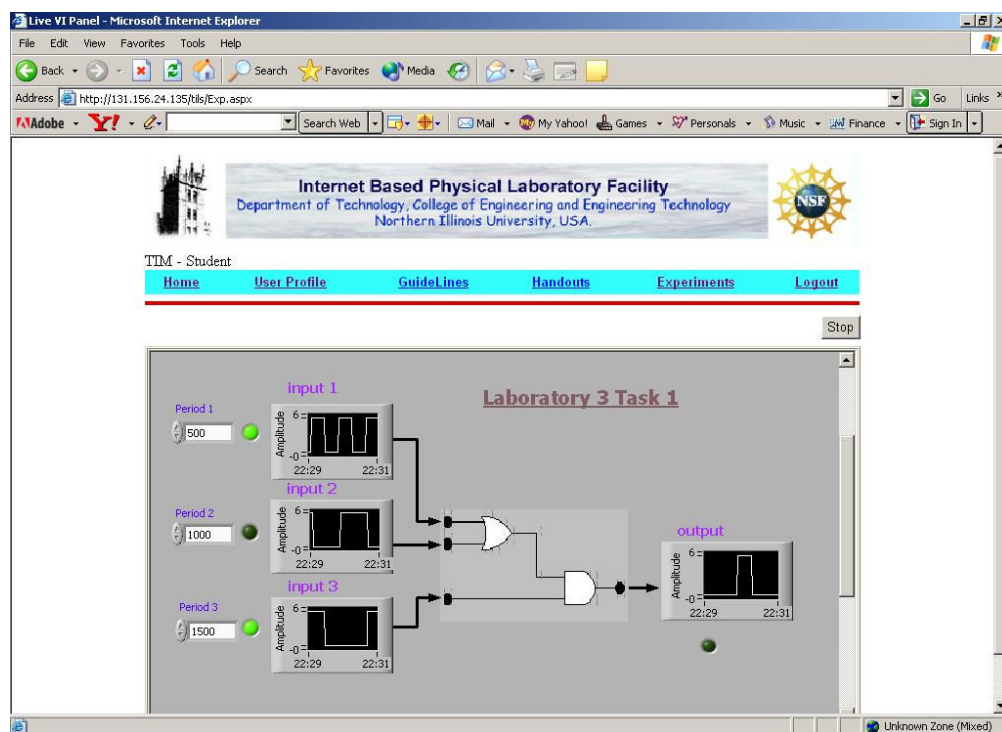


Figure 8: Image of a performer web page.

The administrative level of access to the facility allows a user to have additional capabilities, such as maintenance of available experiments and gathering user activity data, and results of weekly surveys. These application features allow an administrative user to activate or deactivate a given laboratory session or a specific task within a session at the Internet level. Activation of any experiment should be followed by loading of appropriate GUI and connecting the hardware experiment with the facility. All these need to be synchronized to make a specific experiment available through this facility.

Considering this is 24/7 facility, the system can be accessed any time from anywhere. To understand the user access profile, the system is provided with a provision to gather user activity data in terms of client login time, logout time, and performance duration for each client for a given experiment task. These data can be accessed by an administrative user through an application. Similar to the activity data, the weekly survey data can also be gathered by an administrative user and exported to Excel for analysis. These data will allow the course administrator to use this information (in addition to other course data) towards assessment and also to study the students' learning behavior using this facility. These will also enable the administrator to assess the usefulness of the developed facility and adjustments/changes to make the system more efficient and effective.

3. Evaluation

The evaluation will be performed to assess the effectiveness of the facility in terms of its usefulness and also for achieving learning outcomes. Both of these evaluation issues are considered from the very beginning of the project. Some of the assessment activities are incorporated within the facility as web applications, and data will be collected as the facility will be in use.

An independent evaluator approved the evaluation criteria and questionnaire with interactions with the authors. The results obtained from the evaluation process will be jointly analyzed by the evaluator and the author. In addition to these, three members of the program industrial advisory board will also be involved to assess the cost effectiveness feature of the facility.

The Internet-based laboratory course is a new concept, and evaluation of the facility for its usefulness will provide an understanding in terms of students' point of view. Towards this, a weekly survey is incorporated within the facility that students need to complete at the end each laboratory session. The survey will prompt automatically, and to ensure the data collection, the web application is programmed in such a way that a student can not continue with next week's experiment without completing the survey after the prior experiment.

In addition to the weekly surveys, the facility is equipped with collecting facility usage data. These data will allow the facilitator to know the level and timings of use of the facility and hence provide a broader understanding of the students' behavior in terms of use of the facility.

While implementing the project, students' learning outcome is another important factor that needs to be assessed. Towards this effort, the class will be divided into two groups (control group and test group). The control group will attend the traditional laboratory and will not have access to the developed facility; while the test group will attend the laboratory class using the developed facility. The control group and the test group will be formed with even distribution of gender, ethnic minorities, and achievement levels.

Both groups will be given pre- and post-tests at different stages of the course, and differences between the pre- and post-tests will be compared between the control group and the test group with both descriptive and inferential statistics. In addition, before, during, and after the proposed environment is developed, departmental faculty, and program industrial advisory board members will be completing questionnaires on: a) the usefulness and user-friendliness of the environment and b) their overall assessment of the management of the proposed project.

4. Conclusions

The paper presents the development of a modular Internet-based laboratory facility for offering an undergraduate introductory digital electronics laboratory course. Offering a laboratory course over the Internet as a part of a regular program is a unique initiative. In addition to access to the experiments, the facility has in-built evaluation and maintenance facility and a provision for monitoring client access profiles. In terms of hardware and software, the facility is composed of five independent modules: experiments, interfacing, GUI, sever, and Client access. The modular approach allows the facility to be used for other courses/experiments without much change.

For evaluation there are two approaches: one is to evaluate the system itself in terms of its user friendliness and effectiveness and the other is to evaluate students' learning outcomes. The first approach of the evaluation is incorporated within the facility as web applications. While the second approach, involves formative and summative evaluation using a control group and test group.

5. References

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