

WEB-BASED LABORATORY EXPERIMENTS: CASE STUDIES

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1. Introduction

Facilitating access to a laboratory facility at a time and place convenient for students is a major challenge for engineering educators. This applies to both the traditional laboratory courses as well as laboratory courses as a part of distance learning programs. Traditional laboratory classes are scheduled only for specified time periods, 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 to gain sufficient experience through the process (Mott et al., 2002; Sears and Watkins, 1996). In some cases students like to perform additional experiments beyond their assigned tasks, but it is often difficult to arrange any additional laboratory hours because of lack of laboratory staff, while too much laboratory equipment lies idle during most of their usable lifetime (Patton and Jayanetti, 1996; Barnes et al., 2002). A web-based laboratory facility would address these problems by providing unlimited access to an experiment and hence maximize the use of available resources.

One of the major limitations of existing web-based distance-learning programs is their failure to deliver the laboratory-related courses (Henson et al., 2002; Palais and Javurek, 1996; Sears and Watkins, 1996). While simulation and multimedia provide a good learning experience for effective and complete learning, especially in applied engineering and technology programs, a mixture of theoretical and practical sessions is needed. Currently, students have to visit a campus to perform the physical laboratory sessions for these kinds of courses or there has to be an arrangement of mobile laboratories stationed at a few predetermined locations for a given period of time (Chumbley et al., 2002; Patton and Jayanetti, 1996; Safaric et al., 1998). With such arrangements, students get access to the hands-on facility for only a short period of time, which is usually insufficient to allow them to complete their learning cycle (Mott et al., 2002; Azad et al., 2003). Making the physical laboratory experiments accessible through the Internet would address this need (Malki and Matarrita, 2003; Sears and Watkins, 1996).

There are a number of initiatives that have been made to provide experimentation facilities over the Internet (Chumbley et al., 2002; Dabney et al., 2003; Gustavsson, 2003; Manasseh, et al., 2004; Malki and Matarrita, 2003). None of these facilities are designed to deliver a complete laboratory course that is a part of a regular educational program, due to the complexity in development; the higher cost; and the single server configuration that can provide access to only one experiment at a point in time.

This paper describes the development of a modular system that will enable students to perform physical laboratory experiments over the Internet. The hardware configuration required

for each individual experiment will be capable of being manipulated electronically over the Internet without any human intervention. Along with the initial input/output graphs, the data produced from these experiments will be made available to the students/users for further analysis. This unique of system has been developed and it is cost effective because of its modularity in design, its web security, its evaluation facility, and its extended functionality. The modularity of the system design will enable it to integrate with a large variety of physical laboratory experiments at minimum cost.

The next section describes the structure of the developed system by highlighting its main components along with interfacing hardware and software. Section three illustrates graphical user interfaces and web presentation details. Section four provides the structure for web delivery of the experiments. Section five provides a discussion and recommendation for further development. These are followed by the conclusions, acknowledgements, and references.

2. System Organization

The facility is developed in a modular structure so that each module can be changed and modified independently. Figure 1 shows a block diagram of the developed system. The modules are: a) Experiments; b) Interfacing; c) GUI and Web Publication; d) Server; e) Internet delivery; and f) Client computer.

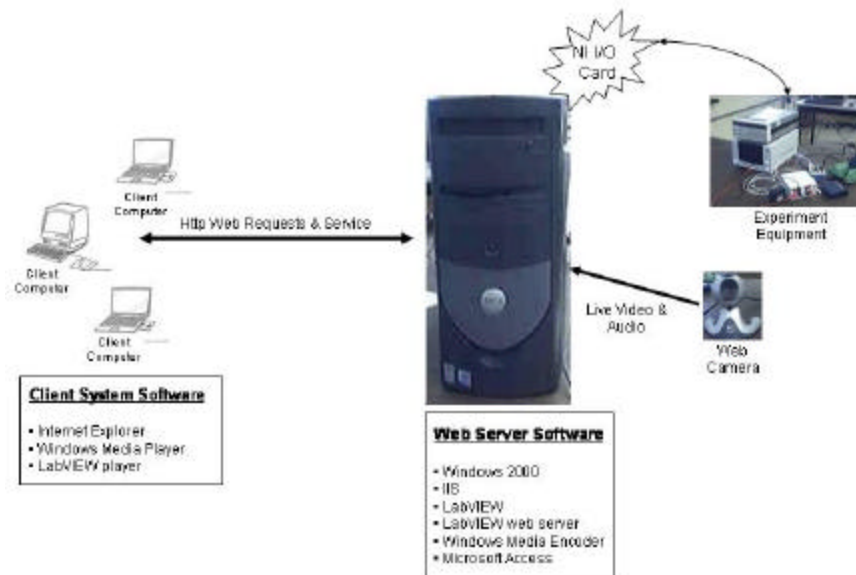


Figure 1: The system organization.

The individual experiments are developed according to the course and connected to the server through a suitable interfacing hardware. An Input/Output (I/O) card from National Instruments is used as the interface 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 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. A client can access an experiment by accessing the GUI (as a dynamic web page) within the server. A client PC should have Internet Explorer and LabVIEW player. 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 effectiveness of the system.

A web camera is directly connected to the server for live video and audio feedback to the client. Windows Media Player and Windows Media Encoder are used to provide the video and audio information to the server. The web server is developed on a PC using internet information services (IIS) with Windows 2000 as the operating system. Active service pages (ASP), html, Windows Media Encoder, and MS Access are used to develop web pages, integrate pre-published GUI, video and audio feedback, user account facilities, system evaluation, and web security. A clients' PC can access physical laboratory facility web pages through a web browser. The client PC should have an internet explorer, Windows Media Player, and LabVIEW player. In most of the cases, the first two are provided as a part of the Windows operating system. The LabVIEW player is a freeware and can be downloaded from the NI web site.

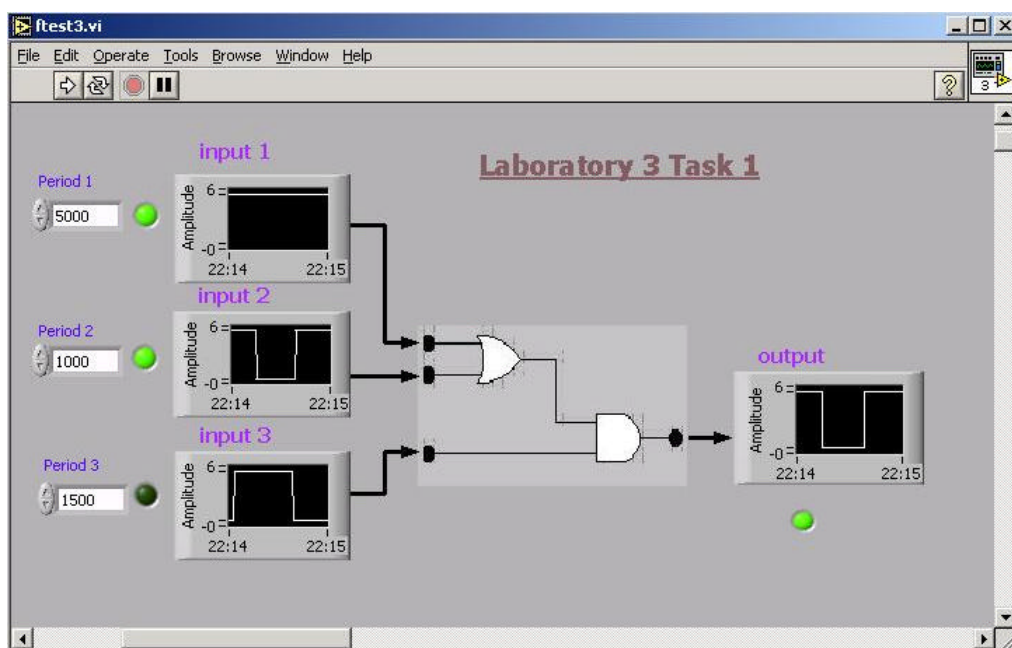


Figure 2: A GUI for 3-input 1-output system.

3. Graphical User Interface and Web Presentation

A GUI is serving as the media between the experiments and the students. It is important to provide a user-friendly and effective GUI that is to attract students while performing experiments without any physical supervision and assistance, which are usually provided during a traditional laboratory class. LabVIEW provides a facility to develop a GUI called virtual instrument (VI), which can serve both of the above purposes (Kariya, 2003). 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. Examples of two GUIs developed for two separate experiments are described as follows.

An image of a GUI developed for a digital laboratory experiment is shown in Figure 2. The left side of the GUI is showing all the 3-inputs that are generated within LabVIEW. These inputs could switch between two levels, logic 1 and logic 0. A user can change the time period between the switching. 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 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 passes the inputs to the experiment and receives corresponding output through appropriate ports of the I/O card.

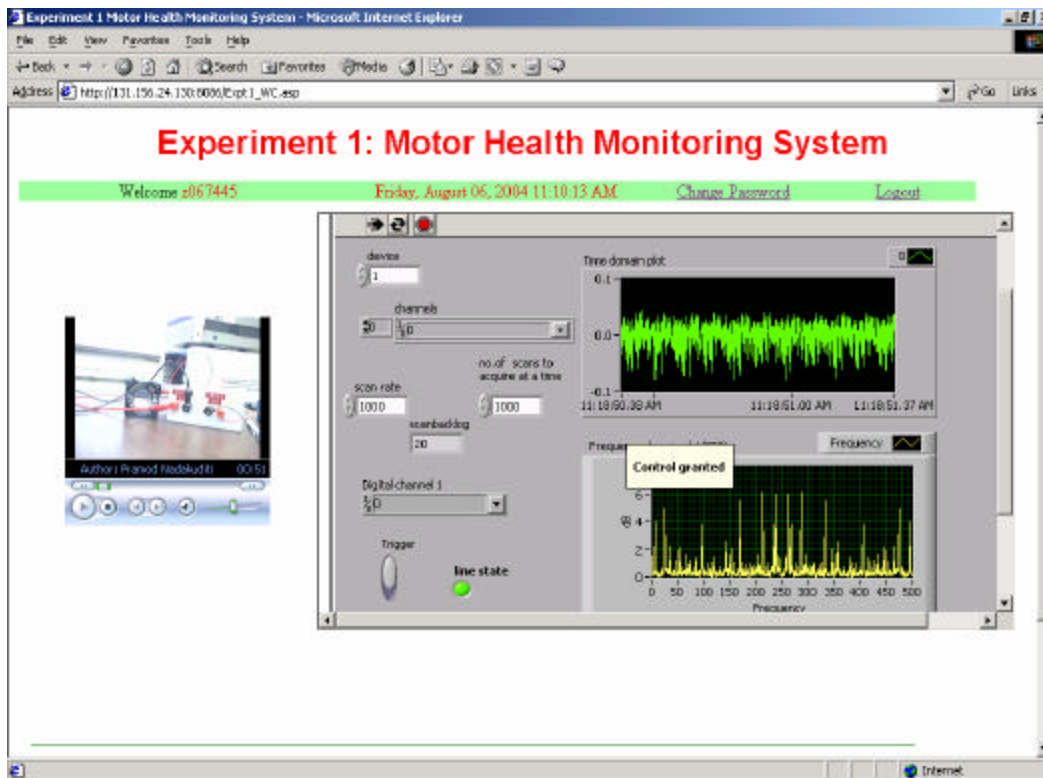


Figure 3: An image of the web page viewed by the clients from a remote location.

An image of the web page for a motor health condition monitoring experiment is shown in Figure 3. The web page consists of two individual entities. One is the GUI (with graphs and controls) and the other is the Windows Media Player panel. The GUI and the video panel are merged into this web page using the html frames. The graphs within the GUI are presenting time and frequency domain information that can be analyzed remotely.

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.

A web server is hosting the web site for the facility including all the applications and interfacing hardware and software, with a 3.6GHz processor, 2GB of RAM, 80 GB of HD, and a National Instrument's I/O card. 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.

4. Web Delivery

The Internet delivery part of this facility involves a number of issues: system access levels, user profile and password control, documentations, experiments, surveys, 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. Users 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 survey questionnaire. An administrator level of access will allow management of experiments and monitor and gather access profile and survey data.

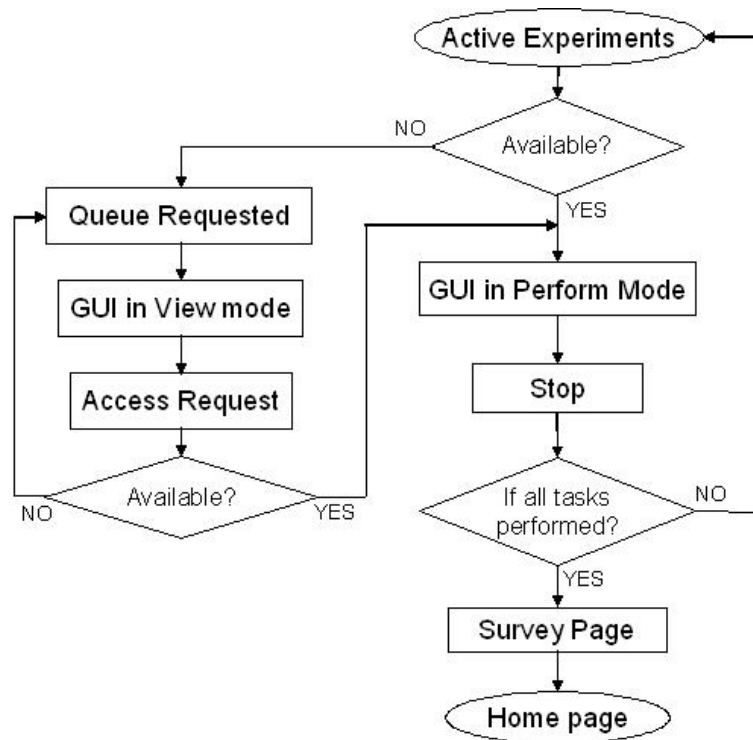


Figure 4: Level of access to the experiments.

A flowchart showing the browsing map for client and administrative levels of access is presented in Figure 4. Apart from the home page, the client level of access allows the users to have three areas to browse: Documentations, UserProfile, and Experiments. While for the

administrative level of access enables the activation and deactivation of experiments and the access to user profiles and weekly survey data.

The administrative level of access to the facility allows a user to have additional capabilities, such as maintenance of available experiments, 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.

5. Discussions and Recommendations

Performing physical laboratory experiments over the Internet is a relatively new concept. As discussed in the introduction section, researchers are pursuing this problem in an abrupt manner and are yet to come up with a sustainable solution. Any development in this area requires expertise in computer interfacing, data acquisition and control, computer networking, web security, and real-time control. For the experiments reported in this paper, the authors developed a modular system, which is cost effective, expandable, and sustainable to some degree. The uniqueness of this system is the combination of its ease in implementation, its modularity in design, its web security, and its student evaluation facility. The modularity in system design will enable it to integrate with a large variety of physical laboratory experiments with very little cost and effort.

Considering different kinds of physical experiments in terms of their nature of input(s) and output(s), speed of operation, data collection restrictions, and data presentation, a number of issues need to be addressed to develop an effective, versatile, cost effective, and sustainable system that is acceptable and feasible for general use. These issues are identification of modules, standardization for module input(s) and output(s), and collaboration between academia and industry. Currently, web-based laboratory systems in electronics and computer science curriculums are developed extensively, and need to be further customized and commercialized to maximize the benefits.

6. Conclusions

A web-based physical laboratory facility with video and audio feedback along with the provision of monitoring client access profiles has been presented. The system is developed using a modular approach, so that the system can be implemented for other experiments without much effort in terms of time and resources. Considering the ease of use, flexibility, and Internet adaptability, NI hardware and software are used to provide the interfacing between the experiment and a PC. Internet access is provided by using an IIS web server, ASP, ActiveX, MS Access, Windows media player, and Windows media encoder. Some are part of the Windows XP operating system, while the others are available as freeware.

A series of web pages have been developed for implementing the client access and for monitoring system use. The authorized clients will be allocated UserID and Passwords to protect the experiments from any mishandling. Only an authorized client can perform an experiment with a full control over the experiment through the Internet; while the others can view the experiment GUI. To obtain a meaningful outcome from an experimental run, only one authorized client can have control over an experiment for any particular period of time.

The provision of the administrator page allows the system administrator to assess the level of use of the system along with the students' learning behavior in terms of the length of their access time. This will allow the administrator to establish the usefulness of the developed system. The developed facility can be used as a stand-alone laboratory course within a distance-learning program as a complement a traditional laboratory course. It can also be used at the high-school level to provide an affordable laboratory experience that would better prepare students for college level courses.

7. Acknowledgements

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