Development of Remote Laboratory Experimentation through Internet

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Abstract

Current technology enables the remote access of laboratory equipment and instrument via Internet. This can be especially useful in engineering education; part time student and remote student can conduct laboratory experiment remotely. Such remote laboratory experiment method can also enable student to use expensive laboratory equipment, which is not usually available to students. In this paper, we present a general method of creating a web-based Remote Laboratory Experimentation, which enables Electrical Engineering (EE) students to control the real instruments through Internet and conduct oscilloscope experimentation remotely. Oscilloscope experiment of remote laboratory in the department of Electrical Engineering, National University of Singapore, was created based on this method and announced on March 3 1999. Until now more than 180 persons have conducted this experiment and there are more than 1500 hits on the home page of remote laboratory (http://vlab.ee.nus.edu.sg/vlab). Based on this general method, other applications and remote experiments can be developed, we only need to develop the program using LabVIEW for controlling different instruments locally and then design the procedure and content for the new experiment quickly and smoothly.

1 Introduction

Distance education is being introduced at the university level because it improves flexibility in university education. [1] At Politecnico di Milano, a university distance lesson system has been operating for three years. The distance teaching system provides three basic services: lessons, seminars and tutoring. A Virtual Classroom [5] was constructed in University of Erlangen-Nuremberg, which uses hypertext mark-up language (HTML) and hypertext transfer protocol (HTTP) to introduce the capabilities and possibilities of VHDL, simulation and synthesis tools. It can be used to teach students at any computer terminal in the world. Benjamin demonstrated the interactive and computational capabilities of Java through a simple matrix assembly Java applet. [4] With this applet, students assemble element equations into the global equations for structural analysis using the bar element. The matrix assembly applet features a graphical user-friendly interface, on-line help and interactive feedback. Remote labes [2] are actual laboratory experiments that are run remotely via a web interface. This type of lab is well suited to distance learning courses where students need not be physically on campus. Parameters can be set on the web, then a software interface converts those parameters to a form that is accepted by the local computer running the experiment.

The Remote Laboratory Experimentation represents an extension to the ways in which people utilise the Internet. A remote laboratory for engineering education should realise an integrated environment for user controlling the real device in

the remote site and conducting the actual experiments in the remote laboratory through a computer network. The core of the Remote Laboratory is a cluster of general-purpose and/or specialised instruments interfaced to a set of personal computer systems connected to the Internet. With the ability to configure instruments and data analysis remotely via software, the laboratory will facilitate the sharing of expensive instruments and equipment, and may well be the next important step in remote distance learning.

This paper shows the method of how to create remote laboratory experimentation, based on LabVIEW by National Instruments [3] and other WWW techniques, such as CGI, Javascrpit, HTML and so on. An interface architecture is proposed between LabVIEW and WWW server, and a demonstration of remote laboratory experiment (oscilloscope experiment) will be introduced.

2 The System Architecture

Computers in the Remote Lab are connected to engineering instruments like oscilloscope and function generator. When students log in to these machines over the Internet, they are able to control both the computer and the equipment. A video camera can also be used to live broadcast what is happening in the physical world. It does not matter if the student is in a nearby dorm room or on the other side of the world. To achieve that mentioned above, a client-server distributed environment was designed, as shown in Figure 1.

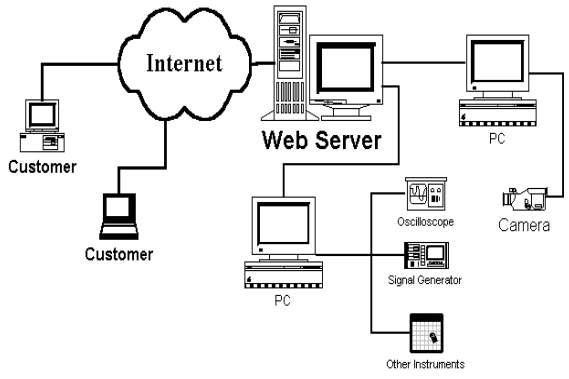
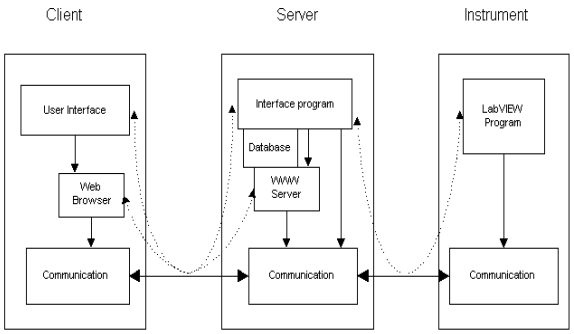


Figure 1: Hardware Structure of Remote Laboratory Experimentation.

- IBM compatible PC computer with data acquisition card, GPIB interface card and Ethernet card. The computer is connected to Internet through the National University of Singapore network NUSNET.
- Programmable Instruments, such as Oscilloscope and Function generator, with GPIB cable.
- IBM compatible PC computer with a video camera and an Internet-based video server, (This is very important, because the user will feel that he/she controls the real instruments remotely instead of simulators.)



- LabVIEW programming environment with Internet Developers Tool-kit.

Figure 2: The double client/server software environment

The software structure of the remote laboratory, both on the server and the client, is shown in Figure 2. In our realization, the server is implemented by using PC running Red Hat Linux 5.2 with TCP/IP protocol, the mSQL database by Hughes Technologies, and the Apache HTTP server. The clients are IBM-compatible personal computers running MS-windows95; the WWW browser is Netscape Navigator 4.0 or higher, because we use server push technology by Netscape Company to transmit the video image, which currently isn't supported by MS-Explorer. The remote laboratory experimentation on the server manages the requests from clients and sends the parameters to LabVIEW program, which controls the real instruments in the actual laboratory. And the remote laboratory

experimentation on the client is some graphic user interfaces for controlling the remote instruments and seeing what has happened in actual laboratory.

3 Creating Experimentation in Remote Laboratory

To create a remote experiment, firstly, we need implementation of local instruments control and secondly implementation of remote instruments control through Internet.

3.1 Local instruments control using LabVIEW

To implementation of instrument control via computers, LabVIEW environment was adopted. LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a powerful instrumentation and analysis programming language for PCs running Microsoft Windows and various operating systems [4]. LabVIEW integrates data acquisition, analysis, and presentation in one system. For acquiring data and controlling instruments, LabVIEW supports RS-232/422, IEEE488.2 (GPIB), and VXI, including Virtual Instrument Software Architecture (VISA) functions, as well as plug-in data acquisition (DAQ) boards. The GPIB card is connected to the instruments, which support SCPI (Standard Commands for Programmable Instruments) command structures defined in IEEE488.2. A maximum of 15 device loads can be connected to each bus, with no less than two-thirds powered on. Figure 3 illustrates the software and hardware environment in this case.

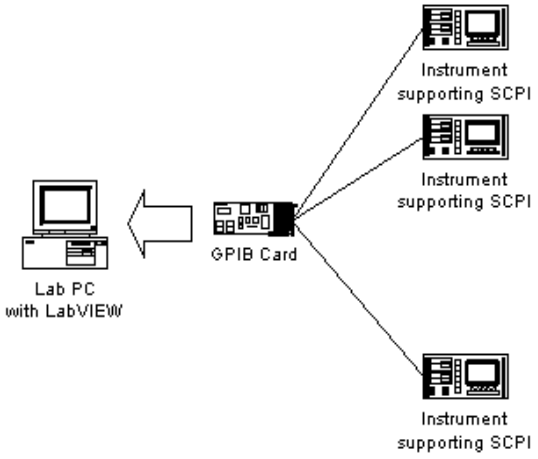


Figure 3: Environment for local control

Now the instruments can be controlled by lab PC in LabVIEW environment since LabVIEW provides available drivers for them. The only job for a local user is to send command strings to different GPIB ports. According to the GPIB port number, the command strings will be transferred to corresponding instruments, which can interpret the commands and take the expected actions. If there are any data resulted from the action, they are collected by DAQ (Data Acquisition) board for further analysis and presentation.

3.2 Remote Instruments Control through Internet

To implementation of remote instrument control, an interface architecture between WWW server and LabVIEW is developed, as shown in Figure 4.

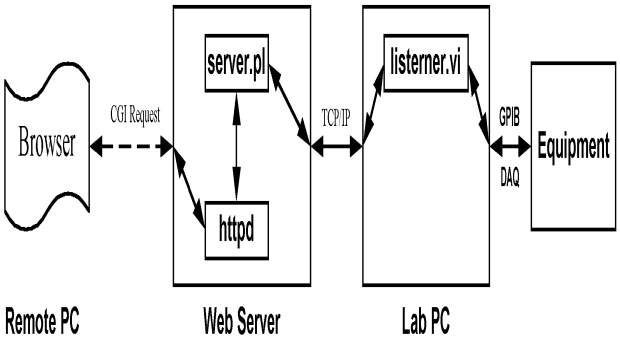


Figure 4: Double client-server architecture

CGI and TCP are two major tools for communication between users and WWW server , WWW server and the program running in other machines. An interface software can be developed for remote instrument control.

One web page is provided to enable user send instrument parameter. WWW server accepts parameter. WWW server activates CGI program and transmits instrument parameter to CGI program (server.pl by Perl 5). Then CGI program establishes a TCP connection with listener.vi (by LabVIEW G Language) on the Lab PC, and passes the parameters to listener.vi. The listener.vi on the Lab PC activates the local instrument control VI and passes

the parameter to it; finally the control VI sends command string to the attached instrument. Then the TCP connection will be released and CGI program returns some information to remote side. Any instruments can be control remotely through the interface software, only if the local control program supports specification of the interface software.

3.3 Implementation of remote laboratory experiments

After implementation of remote instrument control, we can set up the remote laboratory by designing the experiment content, such as user interface of remote laboratory and instructions. The user follows the instructions to conduct the remote experiment. For the time being, the system doesn't allow users to create the experiment by them and conduct it, the user only can do the available experiments designed in advanced. If this function could be fulfilled in future, the system will be more flexible and user-friendly.

The user activates and conducts the remote experiment by performing the following steps:

- Connect to home page of web-based Remote laboratory,
- Identify the user authorization in web server side and obtain a valid session ID of the remote laboratory,
- Select the available experiments in the remote laboratory,
- Show the corresponding web pages,
- Conduct the remote experiment and view the real-time image in the browser,
- Terminate the session by releasing the server connection and the session ID.

Oscilloscope experiment, which is MODULE EG1106 in Electrical Engineering department of National University of Singapore (NUS), is the compulsory experiment course for all the EE students. So we choose this experiment as a demonstration to implement the remote laboratory using the method mentioned above. The objective of this demo is to teach the first year students in EE department of NUS:

- To study the basic functions and controls of a dual trace oscilloscope by voltage and time measurements.
- To measure phase using an oscilloscope.
- To study the frequency response of a low pass filter.
- To study the transient response of a series RC circuit.

When the user connects the home page of WWW server using a WWW browser, a welcome page will appear and ask the user to select an available remote experiment to do. After the user enter the remote oscilloscope experiment, the user can see the relative introduction and documents. Figure 5 is the oscilloscope experiment home page. When the user activates the experiment by pressing the 'Conduct Expt' key, a logon page asks the user to provide the username and password for authentication. After the user successfully passes the authentication, the user interface home page for controlling the real instruments (both oscilloscope panel and signal generator panel) in remote laboratory will appear, as shown in Figure 6. The real time image will be shown on the left top of the oscilloscope panel. Currently, each user only have 30 minutes to conducts the experiment, after 30 minutes the session will be terminated by system. In the right top of user interface, the left time to conduct the remote experiment will be shown. The user can press the 'quit' button to exit the experiment, as he/she will. After user logoff the system, the session is terminated and connection is released.

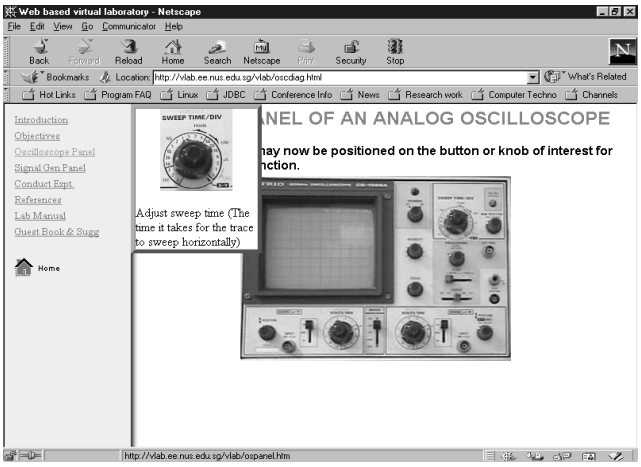


Figure 5: The home page of oscilloscope experiment

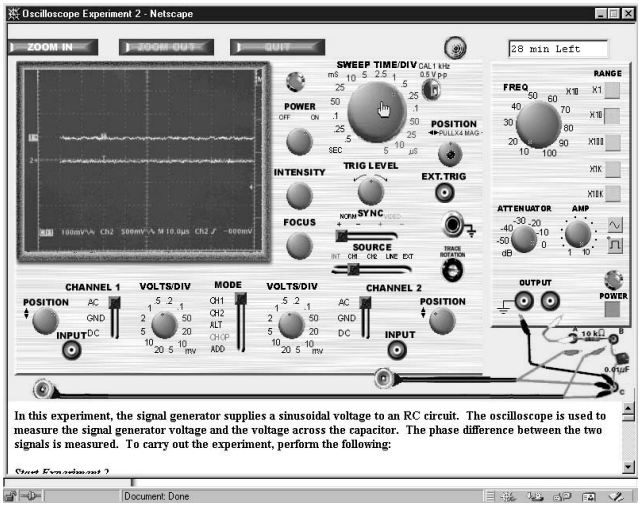


Figure 6: User interface on client side

4 Conclusion

This paper presents a general method to create web-based remote laboratory experimentation. LabVIEW environment is adopted for implementation of local instrument control. To implement remote instrument control through Internet, a double client-server interface structure between WWW server and LabVIEW program was proposed. Commands and parameters can be submitted to the LabVIEW program via interface software using any graphical browser. Remote users can control the real instrument and view the real time result of experiment at the same time.

Remote laboratory experiment can be used in following fields;

- Distance learning for part time and remote students without time and distance limitation,
- Pre-experiment for undergraduates before they go to the actual laboratory,
- Enable students to use expensive laboratory experiments which they actually have no access,
- Share expensive laboratory equipment with other university

References

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