

ARCHITECTURE FOR A REMOTE ACCESS LABORATORY WITH APPLICATION TO ELECTRONICS ENGINEERING TEACHING

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Abstract: This article presents an architecture for the development of Internet remotely controlled experiments with focus on educational applications. We use the Internet as the communication infrastructure; hardware and applications specific for computer based instrumentation; a system composed of an electronic board and applications for monitoring and controlling real experiments. The experiments created with the tools presented make it possible for a user with a computer connected to the Internet to control and get information about the experiment upon which he/she is acting.

1 INTRODUCTION

Remote laboratories are real equipment, which can be remotely operated and controlled by means of a graphical interface, usually employing the Internet as means of communication. A remote laboratory simplifies the logistics and infrastructure required for the operation of a conventional laboratory, such as equipment scheduling, physical space and professionals for surveying students' activities. From the educational point of view, when students have freedom to conduct experiments from any computer connected to the internet at the most convenient times for him/her, the learning process begins to take place as a function of the student's rhythm and availability of time (D'Abreu, 2003).

2 MOTIVATION

Besides the theoretical instruction based on traditional classes, the experience of doing things practically provided by laboratories are vital elements for the education of engineering professionals (Hua & Ganz, 2003). However, arranging and keeping available a laboratory for long periods of time may signify a high financial cost. With a remote laboratory it is possible to optimize the use of resources as it may be available for longer times and may be accessible to more than

one educational institution and consequently to a greater number of students, who may simultaneously participate on experiments at different places and times.

Another aspect to consider is that, as there is no need for the students to be physically present in the laboratory, there is no need of facilities with large physical space and this may signify a reduction in maintenance costs.

By providing them access to remote experiments, one can satisfy the existing demand for teaching students the use of complex technical equipment, introducing them to the state-of-the-art practices of their fields of study and fulfilling the expectations about what is expected in their education. In giving them access to experiments high cost and sometimes sensible equipment, one may expand the range of utilization of such equipment obtaining, in a certain sense, economies of scale (Schafer, Seigneur & Donnelly, 2002).

From the educational point of view, it is believed that all learning processes that may possibly be conducted within a local environment may also be realized remotely, an approach which, unlike the traditional classroom, involves communication and knowledge based on freedom, plurality and cooperation in the largest possible scale (Silva, 2000).

Several universities and research centers around the world have developed works concerning the remote control of instruments through the Internet.

Some, as Telelab (Casini, Prattichizzo & Vicino, 2002), AIM (Shen *et al.* 1999) and PEARL (Schafer, Seigneur & Donelly, 2002) were designed with educational goals.

The various remote laboratory systems studied exhibit a common feature: they were developed by researchers skilled on the several technologies related to the programming of Internet applications and with deep knowledge of hardware and of the network and communication protocols of the instruments entering their environments. Consequently, such systems are monolithic, offer little flexibility and are difficult to be modified by users.

3 OBJECTIVE

Our goal in developing a tool for creating remote experiments is to provide teachers with resources for designing their experiments, which may involve controlling instruments and activating relays, electronic switches and digital potentiometers, among other devices, without concern to the problems related to programming instruments, hardware communication and their integration to the Internet, being able to focus on the aspects related to the subject they want to explore.

The contribution of this work is the development of a platform for supporting experiments in the field of electronics, on which it is possible to perform, remotely and locally, several distinct experiments conceived and performed in real laboratories and satisfying the following characteristics:

- A low and decreasing per student cost: after the initial investment, the remote laboratory tends to become more economical as compared with the conventional one, as it can serve a greater number of students.
- Modularity, in the sense that it allows the addition of new experiments, equipments and applications.
- Experiments are performed in real time.
- Possibility of employing experimental procedures already existing in conventional laboratories, being easily integrated to other educational resources used such as textbooks and pictures, among others.
- Applicable in remote and local modes.
- Shared access to high cost equipments, rendering unnecessary their acquisition by each institution or laboratory.

- Flexible scheduling for performing the experiments, optimizing the students' study hours and the use of the equipments.
- Resources for integration to systems for creation and management of courses in E-learning such as Aulanet (2003) and Teleduc (2003).

4 ARCHITECTURE OF THE REMOTE LABORATORY

In order to achieve the objective proposed, the remote laboratory system, composed by an integrated set of applications and modules, has been implemented (figure 1).

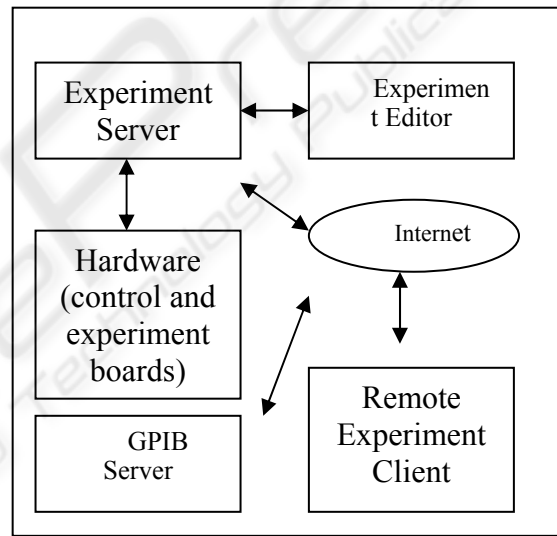


Figure 1: Diagram of Remote Laboratory.

In what follows we describe the main components of the remote laboratory's architecture.

- **Experiment Board** - An electronic board containing the electronic circuit that will be used for the experiment, it is endowed with connections for inserting the Electronic Blocks, which permit the variation of the various circuit parameters.
- **Electronic Blocks** - Electronic circuits playing the functions of the main components used in electronics, such as potentiometers, electronic switches and resistors, among others. The electronic blocks receive the commands originated in the computer and converted in the control board, and thus modify their states and values.

- Control Board - Electronic circuit connected to the computer through the USB port, it is responsible for receiving the activation and control commands which come from the application running on the PC and acting upon the electronic blocks on the experiment board.
- Experiment Editor - An application used by the developer of the remote experiment. It employs a graphical interface composed of a working area and a toolbar, and allows the user to select the Electronic Blocks and graphical objects that will be used in the experiment and to dispose them on the working area by dragging and dropping. Clicking the right mouse button opens a box in which it is possible to assign values to the properties available in each Electronic Block and graphical object.
- Experiment Server - It is the application responsible for receiving the commands coming from the Remote Experiment Client and for passing them over to the computer's USB port, to be used by the Control Board.
- Remote Experiment Client - An application running on a standard Web browser, responsible for providing a graphical interface to the elements created on the experiment editor and allowing the user to act upon those elements. For instance, clicking on a switch changes its picture to state 'open' or 'closed', providing to students a view similar to the real one. At the same time, it delivers a command for the Experiment Server to act upon the previously configured Electronic Block.
- GPIB Server - Experiments on electronics usually employ instruments such as oscilloscopes for depicting graphically the signals found on circuits. Most commercial oscilloscopes communicate with computers via the GPIB protocol in order to send data and receive control commands. In order to allow the experiment user to visualize signals and control the oscilloscope, it was developed the GPIB Server, which communicates with an oscilloscope's hardware and with the Internet, thus making possible its remote control by the GPIB Client.
- GPIB Client - Responsible for the communication with the network, receiving data and sending control commands to the remote Oscilloscope. The interaction with users takes place by means of a graphical interface composed of command buttons and a screen representing a real oscilloscope.

5 DEVELOPMENT OF EXPERIMENTS

With the set of components previously described it is possible to elaborate the experiments and perform them remotely. In a typical situation the teacher or the laboratory's technician will elaborate the experiment and the student will perform it. In what follows we describe a possible case of utilization for the elaboration of an experiment and its execution.

Experiment elaboration:

1. Assembling of the circuit on the experiment board.
2. Connection of the Electronic Blocks to the experiment's circuit.
3. Running the Experiment Editor application.
4. Insert the image of the electronic circuit's diagram. The image may be in BMP, JPG or GIF file formats.
5. Select in the toolbar the Electronic Blocks related to the experiment's circuit and place them on the working area. By clicking on the Electronic Block object one may change its properties such as its state, initial value and the port to which it is connected, among other properties.
6. After repeating step 5 for all the Electronic Blocks, it is possible to save the project and to evaluate it with the Remote Experiment Client.

Experiment Execution by the Student:

1. The student must open the browser and connect to the URL of the Experiment Server.
2. On the initial screen the user name and password are required for the login.
3. After logging in, the graphical interface is shown, containing the image of the electronic circuit's diagram and the graphical representation of the Electronic Blocks that take part on the experiment. Upon acting on the Electronic Blocks, commands are sent to the Experiment Server and are executed on the Experiment Board. The interaction with the Electronic Blocks is done by means of graphical objects like buttons which change their appearance, in the case of switches showing the On and Off positions, sliders for changing the values of potentiometers and selection boxes for choosing the oscilloscope channel to be used.
4. A button on the graphical interface opens the Client GPIB application window; it is used for visualizing signals and controlling the oscilloscope connected to the Experiment Board.

6 IMPLEMENTATION OF THE REMOTE LABORATORY ENVIRONMENT

The Remote Laboratory is constituted of a set of applications and electronic circuits. The premise has been assumed that it should be characterized by a modular architecture making possible its integration and favoring scalability with respect to software and hardware. In order to achieve such objectives, standard market technologies for data communication, controllers of peripherals, electronic components and network protocols have been adopted.

The applications running on the PC computer have been developed using Labview (National, 2004) and Microsoft Visual Studio (Microsoft, 2004). With these tools have been developed the functionalities related to the access to hardware device drivers (USB), the processing of information data from instruments and the client, communication through a TCP/IP network and the graphical user interface. Language C compiler PICC (Htsoft, 2004) has been used for programming the control board's microcontroller.

In what follows we present a general view of the implementation of the several modules of the Remote Laboratory.

- **Control Board** - This circuit is composed of a USB device controller and a microcontroller duly programmed to receive commands from the PC computer and to decode them and generate logical signals which, through the data bus and controls will act upon the Electronic Blocks used in the experiment.
- **Experiment Board** - This board is constituted of an area common to all experiments, on which there are some decoding electronic circuits, connectors for the data bus and the control, plugs for the oscilloscope probes, and the Electronic Blocks. Another area is free for the experiment's author to prepare the electronic circuit that will be provided to the remote user.
- **Electronic Blocks** - They represent common components of electronic circuits, such as potentiometers, resistors, capacitors and switches, among others. For these components to be controlled by the Control Board, auxiliary circuits have been associated to them. The potentiometer used is a digital model whose value is varied by means of

instructions sent by the microcontroller. The switches were implemented with relays and integrated circuits functioning as electronic switches.

- **Experiment Editor** - This application is composed of two main windows: the toolbar, on which the user selects the various objects available; and the working area in which objects are inserted and edited (figure 2).

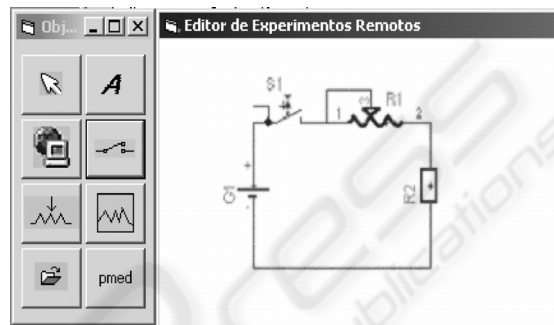


Figure 2: Experiment Editor.

Objects are divided in two groups: hardware objects, which are the electronic components that take part on the circuit, and auxiliary objects such as label, hyperlink and background image.

When an object is inserted in the working area, it can be positioned and its properties can be modified by clicking the right mouse button. For instance, the digital potentiometer has properties as resistance value, number of steps and identification on the experiment board. Such data about the potentiometer and also about the other objects are stored in an XML (Extensible Markup Language) file. This file format, universally accepted for information exchange among heterogeneous systems, favors integration among the distinct applications and makes development easier, as this kind of file is accessible to most present programming tools such as Java and C/C++.

- **Remote Experiment Client** - When this application is started from the Web browser, it establishes a socket connection and loads the XML file with the object definitions previously defined in the Experiment Editor. Next, the properties of each object such as its position on the screen, image, functionalities and values are configured and the application is enabled to receive the action of the remote user. For instance, when a switch is clicked it changes graphically from state open to closed or vice-versa and generates an event that captures the user action by opening a socket

connection that sends to the Experiment Server a set of instructions with the executed action.

- Experiment Server - This application is responsible for the communication between the Remote Experiment Client and the Control Board. The Experiment Server awaits a socket connection. When this connection is established, it captures the data and decodes them; if they are valid, it sends them to the USB port to which the Control Board is connected.
- GPIB Server - The communication between the PC computer and an instrument endowed with GPIB resources takes place through an interface in the computer; as concerns software, it happens by sending commands and receiving data and status information. The most common oscilloscope functions were implemented and made available to users through a graphical interface that seeks to represent a real instrument with its buttons and graphic screens. For the remote user to be able to access this oscilloscope, sending commands and receiving data, a module was implemented which establishes a socket connection with the GPIB Client.
- GPIB Client - Accessible from a Web browser, it shows a graphical interface (figure 3) which represents the real oscilloscope. A socket connection allows control commands to be sent to the GPIB Server and received data to be seen on the graphic screen.

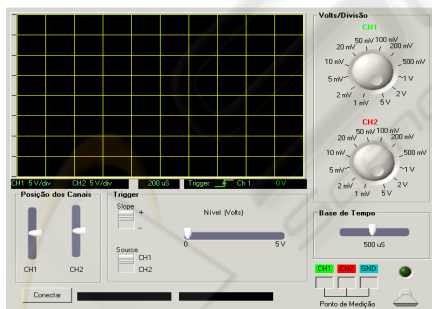


Figure 3: GPIB Client.

7 TEST AND EVALUATION OF REMOTE LABORATORY

In order to evaluate the system, experiments performed on the conventional laboratory of Industrial Electronics in the undergraduate course of the Faculty of Electrical Engineering - Unicamp,

were used. Experiment 4 of that course was wholly implemented on the Experiment Editor. The activities in this experiment involve turning switches on and off, acting upon digital potentiometers and making measurements with the oscilloscope in order to analyze signals. The user interface is composed of the experiment's circuit diagram that can be seen in figure 4.

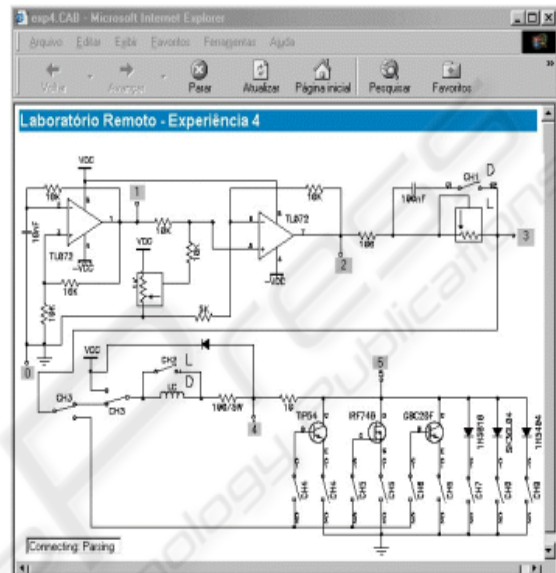


Figure 4: Remote Client Experiment.

The switches and the potentiometers of the real experiment are represented in the electronic circuit diagram, and when clicked, work as if the student were acting directly upon the conventional experiment, i.e., the components would be physically activated, i.e. switches will be turned on or off and potentiometers would have their value on the Experiment Board altered. For each user action a visible output is presented, thus providing a faithful representation of the state of the circuit that is being experimented. Figure 5 shows the details of a selection switch in the OFF position. When the picture is clicked, a command will be sent which shall close the switch on the circuit controlled by the Control Board.

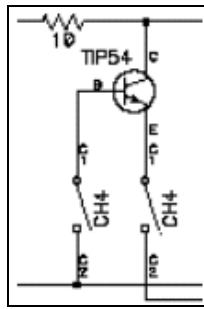


Figure 5: A detail of the graphical interface.

Employing the Experiment Client system, the user then modifies the switch image (figure 6) in such a way that it represents the closed switch condition, and sends a command to the Experiment Server, which passes it to the Control Board; this last one, after decoding, acts upon the Electronic Block switch on the Experiment Board.

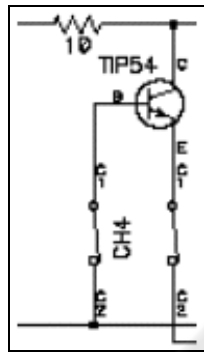


Figure 6: Result of an action on a component of the graphical interface.

8 FINAL REMARKS

In this article we presented the implementation of an architecture for constructing a complete system for remotely performing engineering experiments, together with its initial evaluation. With this remote laboratory architecture we plan to make available to students experiments that may be accessed full time, matching more easily the students' availability of time and being capable of serving a relatively larger number of users.

During the elaboration of the experiments, the Experiment Editor and the modular character of the Electronic Blocks made it possible to implement and modify experiments very quickly.

For this experiment we used a PC with a Celeron 800 MHz processor and 256 MB RAM running Windows 2000. To this computer we connected the

Control Board running the Control Board Server application. The oscilloscope, an HP 54403 model, was connected to a Pentium 233 MHz with 128 MB RAM and a National Instruments GPIB board, running the GPIB Server. Both computers were connected to the Internet.

A first evaluation of the remote laboratory according to the parameters initially proposed revealed the functionality, reliability and easy of use of the distinct technologies integrating this system.

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