A Java-based Remote Laboratory for Distance Learning

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Abstract: This paper reports the establishment of a Java-based remote laboratory for distance learning. Many US institutions of higher education have successfully reported their establishments of Web-based education environments where the instructors and students participate in learning activities while geographically separated from each other. The success, nevertheless, has been primarily in the form of virtual classrooms that either electronically simulate conventional classroom settings enabling interaction among instructor and students in real time via a network, or provide instructional materials prepared in advance for students to access according to their own convenience in a non real-time fashion. Laboratory experiments that conventionally require on-site participation and manual movement of instruments have not been a focus of virtual classrooms until recently. Reports with respect to conducting laboratory experiments remotely, however, have been primarily on software simulations, rather than authentic laboratory experimentation. Due to the fact that laboratory experiments are a crucial aspect of the educational process for Engineering students, efforts have been made by faculty at the Department of Computer Science and Engineering, Florida Atlantic University, to develop a remote laboratory to be used by their students via the Internet. A prototype that features a Java-based remote laboratory environment enabling users to conduct experiments on actual hardware setups via the Internet has been developed. This environment includes both Java-based software for user interface and remote instrument control. Dry runs regarding electronic elements characterization using actual hardware components such as resistors, capacitors, diodes, transistors for circuit setups have been performed with success by students via the Internet. Courses that can find actual use of this construct include Electronic Circuits, Logic Design, etc.

Keywords: Remote Laboratory, Distance Learning.

1. Introduction

During the past few years, many American institutions of higher education have successfully established Web-based environments where learners can pursue their higher education via the Internet or other alternative distance education modalities [1,2]. The success, however, has been predominantly in the realm of the virtual classroom, an environment in which learning and teaching are conducted via a computer-mediated-communication (CMC) system [3]. Nonetheless, many learners whose courses are heavily lab-dependent (i.e., electronics, logic design, chemistry, etc.) are not able to enjoy the multidimensional benefits of a real laboratory experimentation via the virtual classroom due to its technical and instructional limitations [4]. Most of the tools employed to train students over the Internet are primarily simulation software that is also known as “Virtual Experimenters”. In these types of environments the knowledge gained by the student depends primarily upon the authenticity, constraints, and capabilities of the simulation software as created by the manufacturer. A review of literature, existing web sites, and surveys indicates that students are only free to perform experiments in a “Restricted Environment” [4]. These restrictions that are imposed by limited pre-designed inputs and predicted outputs restrain an individual’ s creativity to experiment in natural settings without pre-designed software limitations [5].

In contrast to the simulated laboratories, this paper provides a conceptual proposal of implementing an unrestricted environment where authentic lab experiments can take place via the Internet through remote scenarios. Students have unrestricted freedom to apply any inputs and acquire resulting outputs as though they attend the experiment in person [4]. During their physical presence in the labs, students are merely staging certain inputs to an electronic circuit, for instance, and observing the resulting outputs. If these learning behaviors are successfully performed remotely via the Internet, the online real laboratory is materialized — thus, becoming a reality. These actions are simply the I/O part of the experiment, which are administered by a special local computer interface with a proper instrumentation device. This local computer is then setup as a web server so that, any computer on the

Internet can log in and perform these I/O operations. Such a method can liberate students from physically attending the lab and, hence, engineering or science experiments can take place through distance learning facilitation software. The objective here is not to only replicate the essential elements of the face-to-face conventional laboratory, but, to some extent, to also utilize the power of the remote lab system to better what commonly take place in the conventional laboratory environment. The use of a host computer in these instances should not be confused with software simulation since students are still physically manipulating the electronic parts of an experiment. In addition, they are still having the freedom and the choice to set up any connections and/or parameters they might need. The computer; thus, simply acts as a front-end interface in this case.

The rest of the paper is organized as follows. Section 2 gives a general overview of the proposed remote lab operation model. Section 3 describes the design and implementation aspects of the system. Section 4 reports some remote lab experiments using a prototype implemented in Java with actual hardware setups. Section 4 concludes the paper.

2. Remote lab operation model

The operation model of the proposed remote lab is depicted in Fig. 1. It is envisioned that students located in different geographical locations can access a remote lab and perform desired lab experiments via the Internet. Required hardware setups for an experiment are located in a remote lab. Multiple experiments can be performed concurrently by different individuals. Students can do their lab experiments according to the times that are made available to them. All experiments results are stored in a database that can be retrieved and analyzed later.

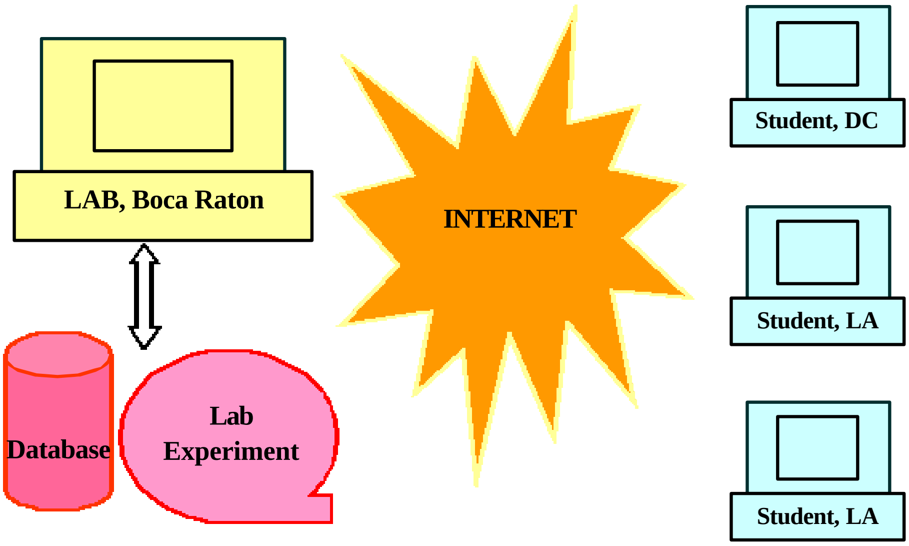

Fig. 1 Remote lab operation model

3. System description

The software design for the remote lab system focuses on a Java-based, client/server type software model whose functionality is primarily for interfacing with the user and controlling of the actual lab experiments. Fig. 2 below shows the major software components of the Java-based remote lab system. The underlying communication infrastructure is constructed using Remote Method Invocation (RMI), the Java implementation of the Remote Procedure Call. Through RMI, a client process can access an object on a remote server where the accessing of the real hardware and the storing and retrieval of experiments results are performed. The RMI registry is used to link logically together a client process to an object on the remote server. The thread manager is responsible for creating, managing, and terminating threads that are each created for a specific task on the server. The stub and skeleton are the mechanism used for invoking server services from a client process. The JDBC module is used for communicating with different underlying database systems. In addition, what is not shown in this figure is the Java native method that is included in interfacing with the local hardware setups.

The complete software system is composed of two parts: client and server. The client end consisted of the user interfaces, which are designed in the form of applets. The applets in turn have panels consisting of buttons and text fields, which help the students in accessing the right experiment and providing valid input parameters for the experiments. At the server side, interface has been provided for client to access the different object sitting on the server. The stubs and skeletons of the interface are generated using the Java compiler. They can be used by the remote client to access the server objects. Clients can talk with the stub. The stub in turn will communicate with the skeleton. A skeleton knows where the availability of the actual remote methods. Skeletons in other words, allow the clients to interact with the server objects. Server object replies back to skeleton and skeleton in turn will respond to the client. Using JDBC the server objects are allowed to talk with the database. Any client who wants to talk with database can do so by talking with the stub, which in turn interacts with the skeleton. This will in turn talk with the actual object. Only server objects are allowed to interact with the database directly. The server code is implemented using Java threads so that many users can concurrently access the remote lab setup. The server code interacts with the database to store and retrieve experiment results.

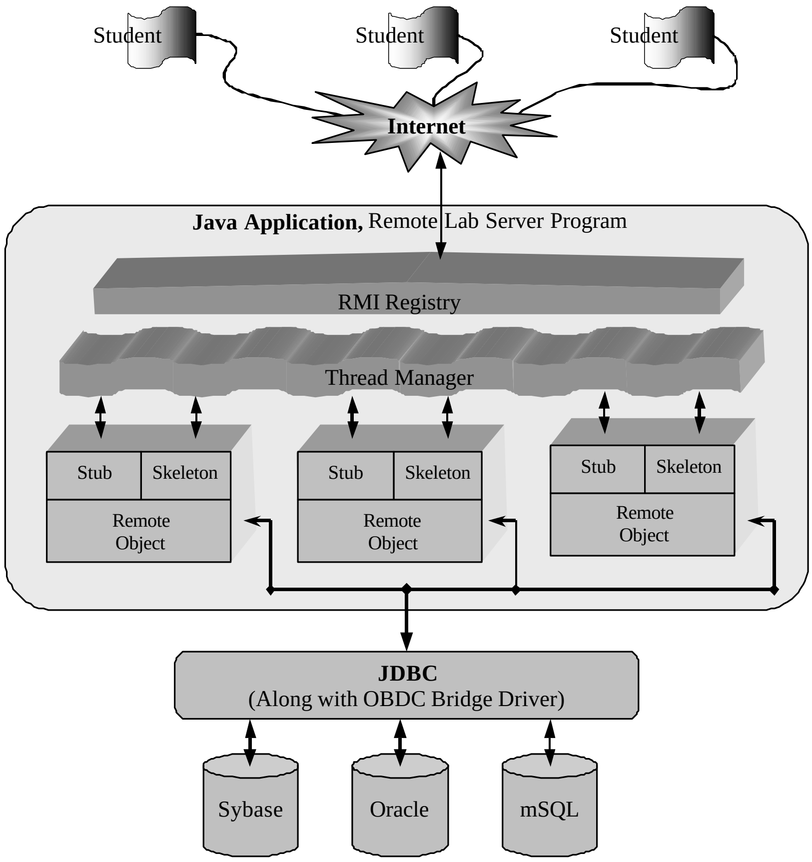

Fig. 2 RMI working environment model for the remote lab system

4. Actual remote lab experiments – electrical elements characterization

To realize the concept of the proposed real laboratories, after a prototype of the proposed remote lab system has been implemented in Java, a simple electrical circuit of the following configuration has been set up in one of the departmental labs. The actual hardware is composed of basic data acquisition and control board with an 8-bit digital I/O port, an analog input module, and an analog output module. The digital I/O lines are used to turn on the lights in the lab, turn on some testing equipment, and/or to select one of the resistors under test (say 100 ± ohm). The students logged on remotely, can enter a series of current values (say 10.005, 15.050, and 20.200 mA) to be injected through the selected resister. Current injection is carried out by the analog output module (programmable current source). For every current value injected through the resister, the corresponding voltage drop is read from across the resister (say 1.0007, 1.5053 ±, and 2.0217 ± V) by the analog input module (voltmeter) and transmitted back to the remote student. The student can now plot the IV (current/voltage) characteristic graph which is the voltage curve corresponding to different current values. If the curve is a straight line, then the student concludes that the resistor has a linear coefficient. If at high current values, the curve starts to bend, then the student concludes that the resistor loses its linearity due to thermal effect. If a temperature sensor is add to sense the resistor temperature, then more information can be concluded about the IV curve which then includes the thermal behavior. The readers can try this simple electric element characterization at http://jupiter.cse.fau.edu/directory.html. Use guest/guest for user ID/password or register own you name (say sam/sam). The actual values are always different from the theoretically computed ones using the assumed known values for the elements. The reason for the difference is that the true values of the electric elements are not guaranteed. The picture of Figure 4 shows a screen snapshot of a remote computer where a student is performing the experiments using the GUI interface that is part of the Java implementation of the prototype.

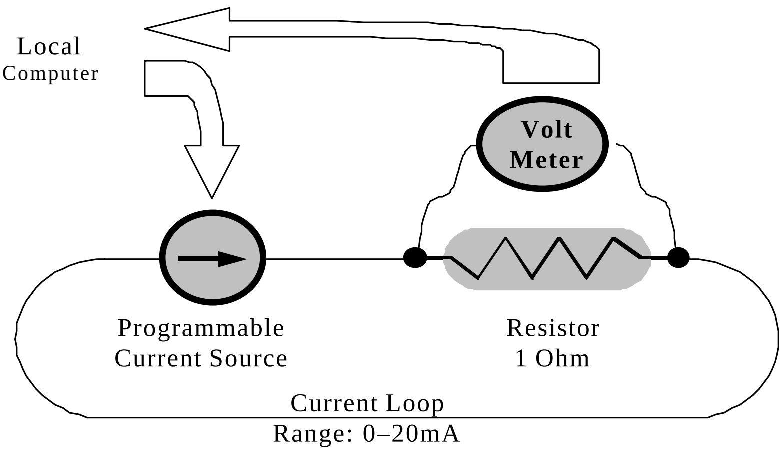

Fig. 3 Hardware configuration for electronic elements characterization

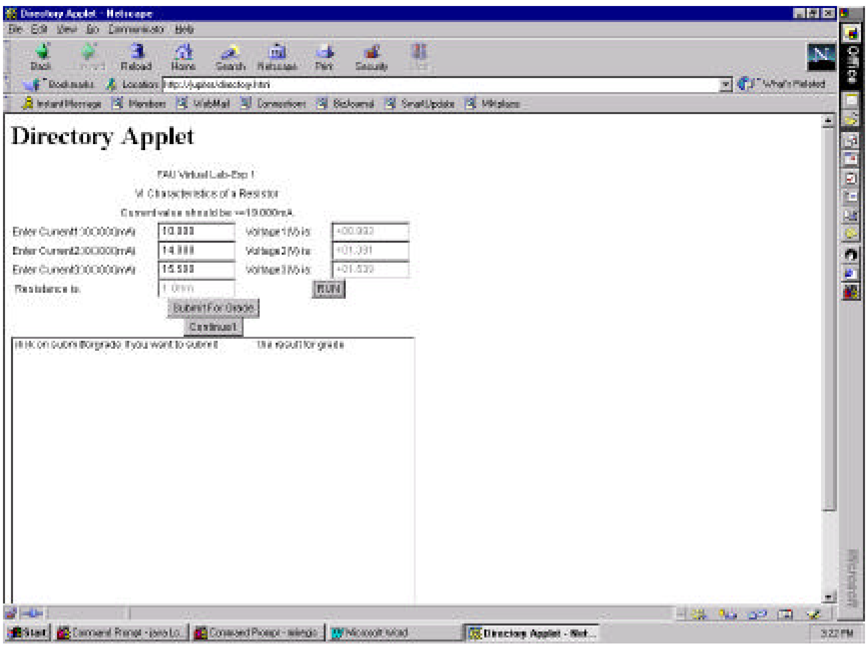

Fig. 4. Experiment Applet

5. Conclusion

The concept of real laboratories over the Internet has been proposed and realized. A prototype for the software controlling portion has been implemented in Java. Experiments with an actual hardware setup have shown that a remote real lab environment provides students the freedom of times and locations to conduct experiments, collect needed data, categorize and synthesize the experiment results, and create his or her own conclusions based on data collected from the experiment without physically attending a lab.

6. References

[1] Murray Turoff, "Designing a Virtual Classroom", 1995 International Conference on Computer Assisted Instruction (ICCAI '95), Mar. 7-10, 1995, Hsinchu, Taiwan, http://www.njit.edu/CCCC/VC/Papers/Design.html

[2] Linda Harasim, Starr Roxanne Hiltz, Lucio Teles, and Murray Turoff, *Learning Networks: A Field Guide to Teaching and Learning Online*, The MIT Press Cambridge, Massachusetts London, England, 1995.

[3] Atsusi Hirumi and Andrea Bermudez, "Interactivity, Distance Education and Instructional Systems Design Converge on the Information Superhighway," *Journal of Research on Computing in Education*, vol. 29, no 1, Fall 1996.

[4] Bassem Alhalabi, Sudeep Anandapuram, and M.Khalid Hamza,"Real Laboratories: an innovative rejoinder to the complexities of distance learning," *Open Praxis, The Bulletin of the International Council for Open and Distance Education*, U.K., vol. 2, 1998.

[5] Murray Turoff, "The Marketplace Road to the Information Highway," *Boardwatch Magazine*, 1994.

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