Session 3613

24x7: Lab Experiments Access on the Web All the Time

Jim Henry
University of Tennessee at Chattanooga

Abstract

24 hours a day and 7 days a week, engineering laboratory equipment at UTC is for users via the World Wide Web. Users can conduct systems lab experiments from remote sites, anytime day-or-night, any day of the week. Additionally, "local" laboratory users have experimental data and response graphs posted for Web access (viewing and downloading). The hardware consists of distributed desktop computers connected to a variety of engineering laboratory equipment. The software is all implemented with LabVIEW.

With remote access, students need support in a different manner than with traditional laboratory courses. This paper discusses aspects of this situation and suggests ways to accomplish this student support.

The web address (URL) for the lab is http://chem.engr.utc.edu

Hardware and Software

The engineering laboratory at UTC for several years has been using desktop computers for data acquisition and control of engineering equipment. The data acquisition and control software is written with LabVIEW software.

The computers are all networked with ethernet and have internet (IP) addresses. A web-server program was developed which allowed users to conduct experiments using widely available web browsers. The users conduct the experiments either from computer labs on campus or from home computers via internet providers.

More details are given in Henry (1996, 1997, 1998a and 1998b).

Hardware Stations

Different stations for different laboratories are available. They are stations for controls systems experiments, stations for chemical engineering and environmental engineering and stations for mechanical engineering.

System Dynamics and Control Stations

- Flow
- Level
- Pressure
- Speed
- Temperature
- Voltage

Chemical and Environmental Engineering Stations

- Packed Bed Absorber
- Batch Drying Oven
- Flow through Porous Media
- Distillation Column
- Gas-fired Water Heater
- Forced-draft Evaporative Cooling Tower

Mechanical Engineering

- Kinematics of Piston an Cam in an Engine
- Heat Exchanger

Some of these are single-input, single output systems. All are inherently stable systems when run in open-loop configuration. That is, if you specify a fixed input value, the system will reach a constant steady-state condition.

More complete descriptions of these have been given before (Henry, 1993, and Henry, 1995).

Software

The systems are operated by student operators using the LabVIEW software on desktop computers at each station or by the Web user as described below. The software operates the equipment under the conditions of parameters as chosen by the student operators, either locally or remotely.

Experience with Remote Laboratory Operation

The "proof-of-concept" of web-access laboratory experimentation has been completed at UTC. Since mid-1995, one of the engineering controls stations has been accessible on-line. Four additional stations were added soon thereafter.

By Summer, 2000, at least two additional stations and possibly as many as four additional stations will be accessible. In addition to operating this equipment, Web users are able to listen to the sounds of the equipment (motors and valve operators) while they operate (with live, RealAudio streaming audio) and one station (Level control) is also viewable on the Web while it operates (with live, RealVideo streaming).

Figure 1 presents a diagram of how the system is connected. Numerous students can be interacting simultaneously with the system. The experiment requests are composed by Web-based "forms" and sent to the Web server at UTC. The Web server forwards the request to the appropriate lab station. The station parses the request, runs the experiments and returns the data to the Web server. The Web server then sends the data and graphical results back to the user.

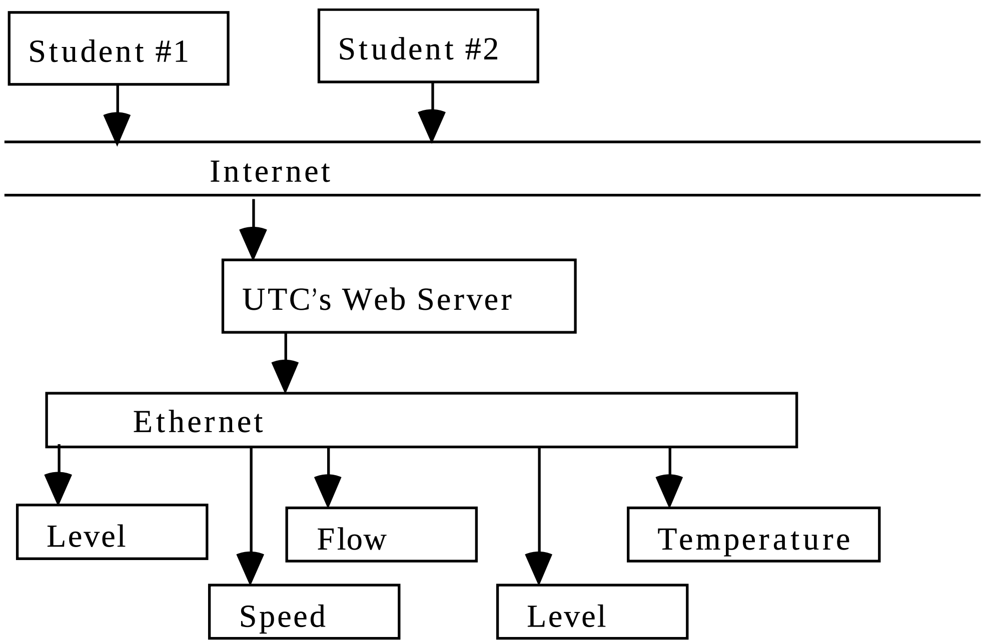

Figure 1: Schematic of communications with lab equipment

The software on the client machines is a widely available browser program (Netscape or Internet Explorer). Users will likely want to use a local copy of LabVIEW Student Edition or a spreadsheet program, also. The software on the UTC Web server and the lab stations has all been programmed at UTC in LabVIEW. These LabVIEW programs developed at UTC are available to other universities for use in non-profit activities.

All of these are inherently stable systems and have operated for several years safely with unattended operation. "Dead-man" timed relays are installed to prevent operation in the event of a computer "freeze."

Data Repository and Response Curves

Some of the laboratory equipment is not now Web-accessible in terms of remote operation. All stations are, however, networked in a manner that connects the station computers to a Web server. This Web server is also a file server for the labs.

The experimental data collected in the labs is saved as files on the server. Additionally, as the experiment progresses, periodic response profiles are constructed and posted on the server. This gives students at least four advantages: 1. their data is saved on a medium that has been shown to be more reliable and is has larger capacity than floppy disks. 2. their data is saved in a location that is known by them, their team members and the laboratory staff. 3. their data is easily shared with and reviewed by team members. And 4. as a longer experiment is in progress, the system response can be viewed periodically.

Student Support with Remote Laboratories

Educational Materials for Remote Laboratory Operation

Education materials for Web-based laboratory experiments includes the tutorials, assignments and supporting materials needed to assist learning on the part of the students. It also includes the teaching aids for use by instructors. The educational materials being developed at UTC include descriptions of the equipment, examples of experiments, procedures for conducting the experiments and sample topics for discussion. These educational materials will be on a Web site that has interactive programming, extensive photos and diagrams as well as video and audio components.

This project is developing and evaluating the materials for implementing extensive use of Web-based laboratory learning experiences. Another aspect of the educational materials will be an expert system that will monitor the use of the Web-based laboratory system. This system will monitor the performance of the users of the system and give suggestions and feedback to the users (students) and give reports to the faculty members.

Since 1996, some students in each school term have completed the laboratory portions of the Controls course by Web connections. At this time, a Web-site presents a series of directed assignments for the student to work through and report the results by e-mail with graphical attachments. The assignments are comprised of tutorial and suggestions. The report is guided by a set of questions for each assignment. Graphical and tabular results are sent as e-mail attachments. The instruction thus far has been largely by Web and text reading materials and by e-mail between the respective student and the instructor. More development of this area is in progress.

Expansion of the access to educational materials for engineering labs has already begun with a new Web site being developed. The site http://www.engineering-labs.net has been established (at UTC) as a resource center for engineering labs on the Web. This site is a starting point for faculty as well as students to find helpful resources. Faculty will find lab descriptions and instructions from other institutions. Students will find equipment descriptions and discussion points for experiments similar to what they may be conducting. Considerable development and expansion of this Web resource is a part of this UTC Program. This site will be for all engineering disciplines; not just chemical, as is the focus the rest of this paper.

The nature of many universities presents special problems and opportunities in conducting traditional laboratory learning experiences. For example, it is difficult for commuting, part-time, working students to bond and form groups. Implementing an asynchronous, Web-based program where there is teamwork and student-based learning facilitated on the Web could help establish a "community of learners." The UTC Program will incorporate current ideas in engineering education including increased cooperative learning and active problem-based learning strategies in the courseware. We are designing the features of the UTC Program to accommodate the full-time, part-time students and working students, addressing the broad range of preparation students have and insuring that they have full learning opportunities.

Vision for a Web-Empowered Laboratory

As a result of more Web-empowered laboratories as outlined here, we envision that:

-- Students will have access to on-line labs with a variety of experimental systems in chemical engineering

-- Students will be able to easily design and conduct experiments from home, dorm, computer lab or office

-- Students will be able to compare local lab experimental results with on-line lab results

-- Faculty will have materials to implement remote laboratory experiments in their own institutions

-- Faculty will have more diverse laboratory offerings available

-- Faculty will be able to easily use on-line labs in classroom demonstrations

-- Faculty will be able to easily use on-line labs in office consultation with students

Enriching the communication between asynchronous group members is one objective for the new software. Text, graphics, audio, video, and numerical data need to be communicated in a timely manner. In short, we seek to develop software that can diminish the sense of distance and time between team members and is fairly easily implemented and used.

Educational methods are being developed that involve change from directed instruction to a problems-based approach. Several characteristics of the "constructivist" approach will be observed in the teaching and learning process. These characteristics are based on cognitive learning theory and developmental theory, and are discussed in the work of Dewey, Vygotsky, Piaget, and Bruner (Grabe, 1998; Robyler, 1997). Implications for the development of instructional activities include the following:

-- Problem-oriented activities that are open-ended, and multi- or interdisciplinary
-- Visual formats that allow creation of mental models
-- A rich learning environment containing a variety of interactive resources
-- Cooperative group work, emphasizing shared intelligence
-- Learning through exploration and discovery
-- Authentic assessment, emphasizing the qualitative nature of student work

Important components in this teaching and learning model stress that what students learn and how they learn are not separate. This is currently practiced in many schools' face-to-face courses, and will be extended to these Web-based materials in an appropriate format.

A variety of learning activities will be included in the educational materials being developed. The varied activities in the student-centered approach will appeal to a wider range of learning styles and will present a more inclusive learning environment. This will aid in retaining under-represented student groups.

Mentoring-instruction combines cooperative learning and a situation in which the professor-expert provides assistance to the student-novice in the development of understanding and acquisition of knowledge. This assistance simplifies the learner's role, rather than the task, until the learner develops the capability for completing the task alone. Collaborative instructor-student and student-student activity is stressed. The professor stepping out of the role of content deliverer and into the role of facilitator of learning, mentoring and coaching the student as the student takes a more active role in his or her learning. The challenge is to develop software systems that will assist in this.

A database of usage of the Web-laboratories will be built. An expert observer system will be developed to give feedback and guidance to users of the system. This feedback will be timely. The "coaching" function of the software ("expert observer") mediates student functions by providing assistance during the planning, implementation, analysis, and application phases of the laboratory experimentation. There is a change in the courseware in emphasis from "What are the directions?" to "What does the student learn?" The latter is assessed through measures of student responses. We are incorporating problem-based learning in the educational material.

The expert performance monitor will aid in the mentoring, instruction, tutoring and assessment of students. The expert performance monitor will be a system to monitor weak or irregular performance by the students and give feedback to the students and reports to the faculty.

This system can collect information on what topic and when students need help. As such, it can be a powerful tool to develop better laboratory teaching materials. It will also be a powerful tool for the evaluation and assessment.

As faculty move from lecturing roles to auxiliary facilitator and coach roles, students engage as active participants in the learning team and also gather and study learning issues to share and present to the learning team. Problem-based learning is said to promote student motivation, relevance and context of the learning, higher order thinking skills, authenticity, and metacognition and self-regulated learning.

UTC is committed to continuing to develop and expand this Web-available laboratory. Extending the experiments to include thermodynamics, heat transfer and chemical engineering unit ops is in progress.

Acknowledgements

UTC's Center of Excellence for Computer Applications has supported this effort with a generous grant. Other support has been received from the UTC College of Engineering and Computer Science, National Instruments, Plant Engineering Consultants, Apple Computer and Analog Devices. Partial support for this work in the lab is being provided by the National Science Foundation's Division of Undergraduate Education, Instructional Laboratory Improvement (ILI) grant DUE #97-51024 .

Discussion with Drs. Jim Cunningham, Charles Knight, Ed McMahon and Karen Adsit at UTC have been especially helpful. The assistance of Don Eberhart, Karl Fletcher and Curtis Gossett has been valuable.

Bibliography

Grabe, M. & Grabe, C. (1998). Integrating technology for meaningful learning (2nd edition). Boston, MA: Houghton Mifflin Company.

Henry, Jim, (1993), "Engineering Controls Systems with LabVIEW," Scientific and Engineering Applications for Macintosh, Woburn, MA, August, 1993. Available via Web at http://chem.engr.utc.edu/Henry-Pub

Henry, Jim, (1995), "LabVIEW Applications in Teaching Controls Systems Laboratories," ASEE Annual Meeting, Anaheim, CA, June, 1995. Available via Web at http://chem.engr.utc.edu/Henry-Pub

Henry, Jim, (1996) "Web-based Controls Laboratory Hardware and Software," available via Web at http://chem.engr.utc.edu/Henry-Pub

Henry, Jim, (1998a) "Laboratory Teaching via the World Wide Web," ASEE Southeastern Meeting, Ireland, FL, April, 1998. Available via Web at http://chem.engr.utc.edu/Henry-Pub

Henry, Jim, (1998b), "Running Laboratory Experiments via the World Wide Web," ASEE Annual Meeting, Seattle, WA, June, 1998. Available via Web at http://chem.engr.utc.edu/Henry-Pub

Robyler, M.D., Edwards, J., & Havriuk, M.A. (1997). Integrating educational technology into teaching. Upper Saddle River, NJ: Merrill/Prentice-Hall, Inc.

Biographical Information

JIM HENRY

Jim Henry is Professor of Chemical and Environmental Engineering at the University of Tennessee at Chattanooga. He has also taught at Tulane University, Prairie View A&M University, the University of Jordan in Amman and the University of Edinburgh.

Dr. Henry received his Ph.D. from Princeton University. His B.S.Ch.E. was received from Rice University. He completed a postdoctoral year at Yale University.

Dr. Henry has also worked for a U.S. Department of Energy research lab, DuPont Company and Chevron Oil.

For the past 10 years, he has focused on developing data acquisition and control application in laboratories for controls systems, chemical and environmental engineering. He also teaches the courses in principles and in design of chemical and environmental engineering processes. His research is in the area of applied control systems, fuzzy control and distillation control.