

Evaluating Student Performance in Online Laboratories

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Abstract

This paper discusses a new online process control laboratory that provides an interactive process experience in a process control course that is structured as a conventional lecture course. Use of online simulations provides a low cost alternative to a laboratory and does not require a major change to the curriculum (i.e. adding a separate course or increasing the credit hours for the existing course). As in earlier works by the author, the online laboratory maximizes the capability of the web server by using JAVA applets to perform the simulations on the client (student) computers. However, the interactive modules in the new online laboratories are capable of reporting to the server how well students perform. The instructor can view these data over the Internet to monitor student performance. The software architecture provides information that the instructor can use to determine how well the course objectives are being met. Student response to this system has been positive. Additionally much valuable information about student performance (such as the time to perform an experiment) has been obtained and are discussed.

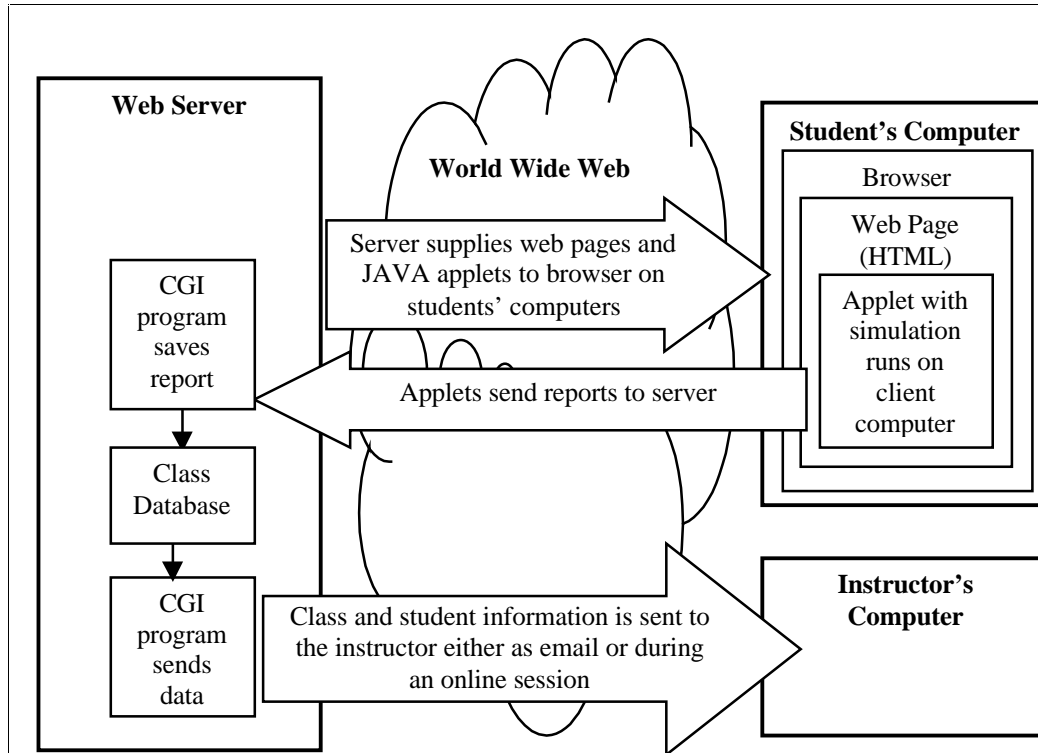
Introduction

The Online Widener Laboratories (OWL) are the result of an extended effort to incorporate interactive web-based instructional modules in a variety of courses. OWL consists of two laboratories that have similar organization and software architecture but different goals and uses. The first online laboratory, the Virtual Chemical Engineering Laboratory was the subject of previous papers (1,2, 3). This paper deals with the Virtual Process Control Laboratory and monitoring courseware that allows the instructor to assess performance.

The heart of each instructional module is an interactive simulation that recreates a process or experiment. The interactive simulations are contained in JAVA™ applets delivered by the web server to the client (user's) computer. Applets run on the user's computer in the browser window. This architecture (Figure 1, next page) reduces the server's workload by shifting computational load from the server to the client and eliminates delays to the users' responses caused by transmission delays between the client and the web server. Therefore the user sees a fast response and the server is able to

accommodate more simultaneous users than would be possible if it performed the simulations.

Figure 1
Structure of OWL Interactive System



A disadvantage of this method of delivery is that the applet must be transmitted to the user who may be connected to the Internet through a modem. Therefore, the size of the applet must be kept small. Otherwise, users might object to long delays when the applet is transmitted. A size of 60k was specified as a target for the size of the applet. This size typically requires between 10 and 40 seconds for a page containing the applet to load when connected to the site using a typical Internet Service Provider, such as AOL, over a 58.8 modem.

At Widener University, Process Control is taught in a standard three-credit course taken by both Mechanical and Chemical engineering students. This course does not have a regularly scheduled laboratory component. The Virtual Process Control Laboratory was constructed to allow students to have experiences tuning controllers and observing various control schemes in simulations that behave in manners similar to real examples. It is designed to supplement the lecture component by allowing interactive homework and in class demonstrations. This laboratory has been online for one and a half semesters.

The modules use examples of control of processes such as heaters and mixers that are understandable and relevant to both disciplines, therefore, the site can be used by a wide variety of engineering students. The Virtual Laboratory has the advantage that the

simulations use an accelerated time scale (1 second of real time ~ 4 seconds of simulated time) so that students may complete assignments more quickly than in a conventional laboratory. Additionally, the simulations all have a “Pause” button that allows users to temporarily halt the simulation to examine the simulations response or calculate the controller settings.

There are many other pieces of software that allow students to perform interactive experiments. A significant advantage of using the Internet to deliver such instructional modules is the ability of a web based system such as OWL to easily record student activities and report the data to the web server, so that the instructor can easily monitor and record student progress. The architecture of the OWL system is shown in figure 1. Note that the OWL system allows the instructor to monitor students’ progress through the web site itself rather than relying on student generated responses, such as written reports. Thus the instructor can observe the details of student work and more easily determine problem areas.

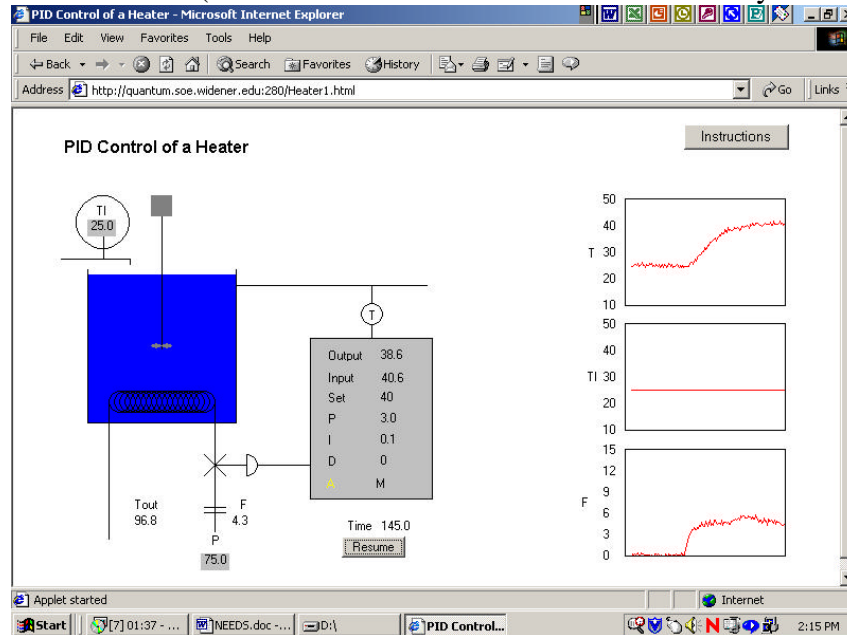
The Virtual Process Control Laboratory

The goal of OWL is to provide an interesting and realistic interactive experience that simulates important engineering concepts and supplements other instruction. The Virtual Process Control Laboratory provides realistic simulations that can be used in a variety of instructional ways (e.g. in class demonstrations, homework assignments and projects) that provide students interactive experiences with a variety of control schemes. The Process Control Laboratory uses a variety of control schemes to control identical simulated processes. Thereby, allowing the students to explore the merits of such control methods cascade and feed forward control in an environment that encourages active learning.

The design of user interfaces has been an important consideration in the development of OWL(4). The user interface of the modules is patterned after those generated with Factory Floor™ software, a commercial software product developed by OPTO22 for use with their programmable logic controllers. This software is used in Widener’s Chemical Engineering Laboratory to control real-world laboratory experiments. Therefore some students are already familiar with the interface. A sample screen from the Virtual Lab is shown in Figure 2.

Instructions on how to interact with the modules, along with descriptions of various tuning schemes, are provided in the “Instructions” section of the web site. Also, the instructor performs an in class demonstration of how to use the modules. Students have reported that the modules are easy to use. Data entry is patterned after Factory Floor’s™ data entry method. The plots on the right scroll automatically when module is running, simulating the plotting functions available on Factory Floor and other commercial process control software. All the modules have the capability of adding random noise to simulate a noisy signal. In a few of the modules, the user can control the amount of noise allowing students to explore the significance of signal noise in control.

Figure 2
Screenshot of “Heater 1” (a simulation of a water heater controlled by a PID controller)



The software provides a means of directly performing of graphical analysis of data. Users click on any of the dynamic plots with the mouse. This action causes the simulation to pause and a large plot to appear as shown in Figure 3 (next page). As described in the online instructions, students can then draw lines, measure values and determine properties necessary to tune the controllers or measure results.

The lines drawn by students are persistent objects, so that a student can draw a line on one graph to mark an event (such as the change in flow). When the student clicks on another graph, the lines he or she has draw reappear on the new large plot. In this way students may easily measure such items as dead time.

Uses of the Virtual Process Control Laboratory

Each simulation can be used for a variety of purposes. The instructor is free to use the modules as he or she wishes. The modules can be used as in-class demonstrations or as homework assignments because the site is available on a 24/7 basis and the server is capable of accommodating multiple simultaneous users. Students or faculty do not have to reserve time on the site, another advantage of the architecture of the OWL system.

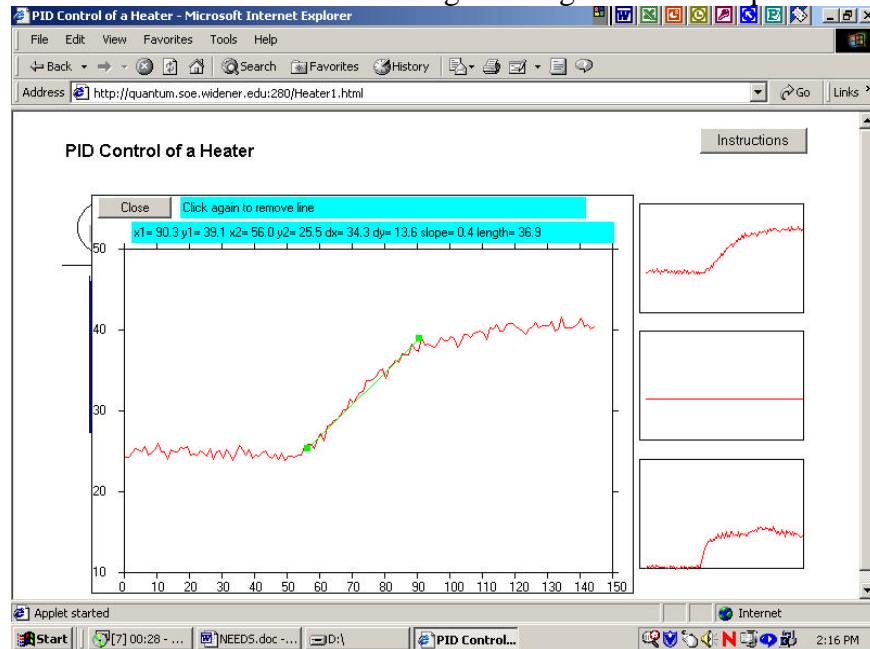
Examples

Building a Control Design

Several modules illustrate different control schemes used on the same simulated process to illustrate significant features of the design of control system. For instance, the simulated water heater shown in figure 1 is used again to illustrate cascade control to

accommodate changes in heating oil pressure and finally, feed forward is added in a third module to accommodate changes in feedwater temperature. At the completion of these modules, students have gained both experience in practical controller tuning and insights into how each enhancement improves response to upsets.

Figure 3
Screenshot of Heater 1 module showing the Large Plot for Graphical analysis



Experimentally Measuring Bode Plots

A module simulates the flow by gravity in two tanks connected in series. The “two tanks” simulation of a prototype experiment in the Chemical Engineering Laboratory has the ability of causing a sine wave input to the simulation. A sine wave generator can control the feed valve position while a PID controller controls a tank level by adjusting the drain valve setting. This module has been used to experimentally determine a Bode plot over reasonable frequencies for this process. Thereby providing a practical introduction to frequency response.

Multiple Input-Multiple Output (MIMO) Processes

Students can explore MIMO processes using a model that simulates a perfectly mixed tank combines two streams having different concentrations of a solute. The purpose of the control scheme is to regulate both the flow rate from the mixing tank and the concentration of solute in it.

Dynamic Matrix Control (DMC)

DMC control is used to control the same process model as conventional PID control schemes. Thereby allowing detailed comparisons of model predictive control to more traditional PID control schemes.

Monitoring software

A significant advantage of interactive web based instruction over other media is the ability to use the server to record and assess student performance. Beginning with the Fall 2001 semester, students using OWL are issued identification codes and passwords so that the instructor can monitor individual performance. The instructor has password access to both class summaries (Figure 4a) which show tables summarizing the performance of each student, and the class performance on each module. The summary page also has a table summarizing each report from the modules. The user can examine a detailed report of any run by clicking on the “Details” button for that run (Figure 4b). This courseware can conveniently keep the instructor informed of problem areas as they occur.

Figure 4a
Instructor's Summary

Experiment	Number of Runs	Number of successes	Average Time	Maximum	Minimum
Two Tanks	6	6	6 min 49.8 sec	21 min 42.1 sec	19.94 sec

Figure 4b
Detailed Report of Module

Detail module report from Ch E 427

Prepared for Chuck Nippert
Date: 9/22/2001 11:59:23 AM

Name:

Module: Two Tanks

Status: Success

Started at: 9/17/2001 10:06:45 AM

Reported at: 9/17/2001 10:13:04 AM

Run Time: 21 min 42.1 sec

Time 9/17/2001 10:06:45 AM Since start = 6 min 10.04 sec

CV1 = Size

Time 9/17/2001 10:06:45 AM Since start = 6 min 12.29 sec

CV2 = Level 2

Time 9/17/2001 10:06:45 AM Since start = 6 min 22.37 sec

PID CV2 setP = 80.0

Time 9/17/2001 10:06:45 AM Since start = 6 min 26.35 sec

Time offset = 50.0

Preliminary Results (*It was fun!*)

The monitoring software was first tested in the Fall 2001 semester. An early example of its power in assessing the effectiveness of this software occurred its first week of operation. A team of students was assigned a problem that required the students to run a module. The instructor software indicated that they had run the experiment successfully a total of 17 times, when asked why they had run the module so often, the students replied, “It was fun”. The conventional monitoring software included in most servers would only report the number of runs and not who had run the modules or whether they had been completed correctly, thereby giving the instructor a much different picture.

The students’ response supplements the results of the first semester of operation (Spring 2001). On average, ninety percent of the students during that period were successfully able to tune controllers (i.e. achieve approximately the same tuning settings as those obtained by the instructor using the same tuning method). Additionally, student response was positive as summarized in Table 1.

Table 1 Summary of Student Attitudes

Statement	% Agree or Strongly Agree
The Virtual Laboratory helped me learn to do Process Modeling	77%
The Virtual Lab helped me understand process control.	77%
The in class demonstrations help me understand process control issues	70%
The simulations in the Virtual Lab seemed realistic	60%

All students who attempted the modules reported that they were easy to use and felt that the modules were a worth while experience.

Refereneces

1. *"Interactive WEB Based Virtual Laboratory"*, A.I.Ch.E. Annual Meeting, Los Angeles, CA, Nov. 12-17, 2000
2. *"Development of a WEB Based Virtual Laboratory"*, A.I.Ch.E. Annual Meeting, Los Angeles, CA, Nov. 12-17, 2000
3. *"Using Web based Supplemental Instruction for Chemical Engineering Laboratories"*, *Proceedings of the 2001 American Society of Engineering Education Annual Conference and Exposition, Albuquerque, NM.*
4. *"On-Line Tools for Data Analysis of Virtual Experiments"*, Middle Atlantic Regional Conference ASEE, Glassboro, N.J. April 21, 2001

Charles R. Nippert

Prof. Nippert has been on the faculty of the Chemical Engineering Department of Widener University, Chester Pa. since 1980. He is a graduate of Lehigh University and worked for several years at Kawecki-Berylco (now Cabot Specialty Metals). His current interests include process simulation, process control and the development of web-based instructional materials for use in a variety of engineering courses. The material is contained in "The Online Widener Laboratories", found at www2.widener.edu/~crn0001/VirtualLab.html. The site is open to all for examination and use. He is married and has two children.