Tele-experimentation: The Emerging Approach to Science and Engineering Lab Education

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Abstract

A project has been initiated to enable students and researchers to conduct Science and Engineering (S&E) experiments via the Internet as an answer to the dual needs for improved distance education in those fields as well as for more effective utilization of scarce research hardware resources, with the ultimate goal of having such experimentation become a ubiquitous component of distance education and research.

The first step towards this objective consisted of implementing, as a prototype, a method whereby students studying Control Systems are able to conduct experiments on a small wind tunnel system located in the UTEP Controls laboratory while off-campus via the Internet using only Web browser software and to view (near) real-time data from that experiment the same way. Specifically, this allows the remote user to vary the PID controller gains and then monitor the effect of such variations on the dynamic response of the air velocity in the wind tunnel.

The general approach and particular implementation, having now been established, can next be adapted to other S&E experimentation systems (for Biology, Chemistry, Physics and the various Engineering disciplines) on the UTEP campus and then elsewhere so as to result in a much broader impact, especially with the ongoing development of Internet 2. The intent is to eventually develop standardized (as much as possible) hardware and software platforms with generic modules for addressing various functions inherently needed by such experimentation systems, especially those used for instructional purposes.

Motivation

Two major events have shaped American society over the past decade and continue to exert an influence today. The first was the end of the Cold War, which has had an unfortunate side-effect of reducing Federal funding for NASA and University research and education activities. The second was the advent of the World Wide Web, which has led to the incredible popularization of the Internet as an alternate means of personal and mass communication, information assimilation and dissemination and, more recently, distance education and research.

With the above as motivating factors, a project was initiated at The University of Texas at El Paso (UTEP) aimed at providing a springboard for improved distance education in the fields of Engineering and the Sciences as well as for more effective utilization of scarce research hardware resources. Although the idea of tele-operation of hardware systems over the Internet is

not new (Web-controlled robots exist[1,2] and even a few Internet-based engineering laboratories[3,4]) one soon realizes that these systems were developed to be different from each other and also are difficult to duplicate by people not closely involved with those systems, if not impossible because of legal restrictions. What appears to be needed to popularize this concept and make tele-experimentation ubiquitous is the development of standardized (as much as possible) hardware and software platforms with generic modules for addressing various functions inherently needed by such experimentation systems, especially those used for instructional purposes.

The first step towards the objective state above consisted of implementing, as a prototype, a means of enabling a remote user to perform an Engineering experiment located in a UTEP laboratory via the Internet and to collect (near) real-time data from that experiment the same way. The project was a collaborative effort by the Electrical & Computer Engineering (E&CE) and Mechanical & Industrial Engineering (M&IE) Departments, and leveraged the recent development of a wind tunnel and the ongoing development of an NSF-funded multidisciplinary Dynamic Systems and Controls laboratory. Its immediate goal was to enable UTEP students studying Control systems (an interdisciplinary field) to conduct experiments on a wind tunnel system (see Figure 1) located in a UTEP laboratory while off-campus via the Internet and only a Web browser. The wind tunnel is not only an important research and design tool for studying the aerodynamic properties of various automotive and aerospace structures, it also provides an excellent platform for education in aerodynamics and control.

Figure 1 – Wind tunnel system

The approach, having been established, can now be adapted to other Science and Engineering experimentation systems on the UTEP campus and elsewhere thus resulting in a much broader impact, especially now that the institution is connected to Internet 2. Broader and longer-term goals include the following: to enable students and researchers who are off-campus to conduct experiments on systems located in any of UTEP's Science and Engineering laboratories via the Internet, and to have one or more NASA facilities Internet-enable some of their systems using the proposed approach so that UTEP students (and researchers) can conduct experiments on them via the Internet. The main purpose actually will be to study how readily portable the developed system is.

The following describes various system implementation details as well as this project's impact on students, researchers, the infrastructure for education and research, and the public.

Project Accomplishments/Implementation Details

First, a Web page[5] was developed to disseminate information pertinent to the project. It describes the project's goals and objectives, displays a timeline for the various tasks and a block diagram of how the different components relate to each other, and personnel contact information.

Also accomplished was the project's main task of enabling a remote user to conduct an experiment via the Internet through a Web browser running on his/her PC. This process is basically as follows. After accessing the home page for this tele-experimentation system[6], user commands entered through the browser are routed via the Internet to the PC controlling the experiment in the DSC lab. These commands are then processed by software and result in appropriate signals being sent, by a Data Acquisition and Control (DAC) card mounted within the PC, to the 2 electric motor driven fans that provide the air flow for the wind tunnel system. The objective of the experiment is to investigate how changing the parameters of the fans' Proportional-Integral-Derivative (PID) controller affects the behavior of wind velocity within the wind tunnel. The sub-tasks performed to achieve the above included installing the hardware/software necessary for an Internet connection, and developing the software (using National Instruments' Internet Toolkit that is compatible with the existing DAC hardware) for transferring information between the Internet and the experimentation system. A Virtual Instrument (VI) front-panel for starting, stopping and adjusting the parameters of the experiment was also developed.

Another task accomplished was to enable the feedback of experimental results to the remote user by transmitting wind velocity data obtained from the wind tunnel system to the remote user in (near) real-time for display in a graphical format (plot of wind velocity versus time as shown in Figure 2). This data is collected via the DAC card mounted within the PC that is connected to the experimentation setup. It is then processed (by software) before being sent to the remote user via the Internet, allowing him/her to view the experimental results with a Web browser.

An additional task accomplished was to address the issues of limiting and disabling access to the experimentation system. Access to this system is to be limited, based on user name and password, to only the group of approved users in order to prevent excessive wear and tear of

the system. The issue of 'gracefully' disabling system access during times when the system is in use either by people in the lab or a remote user was also addressed, the approach being to re-direct these potential users to a 'Temporarily Busy' Web page. Other issues addressed include the functionality to automatically detect simple fault conditions and disable subsequent system access to protect the system from significant damage.

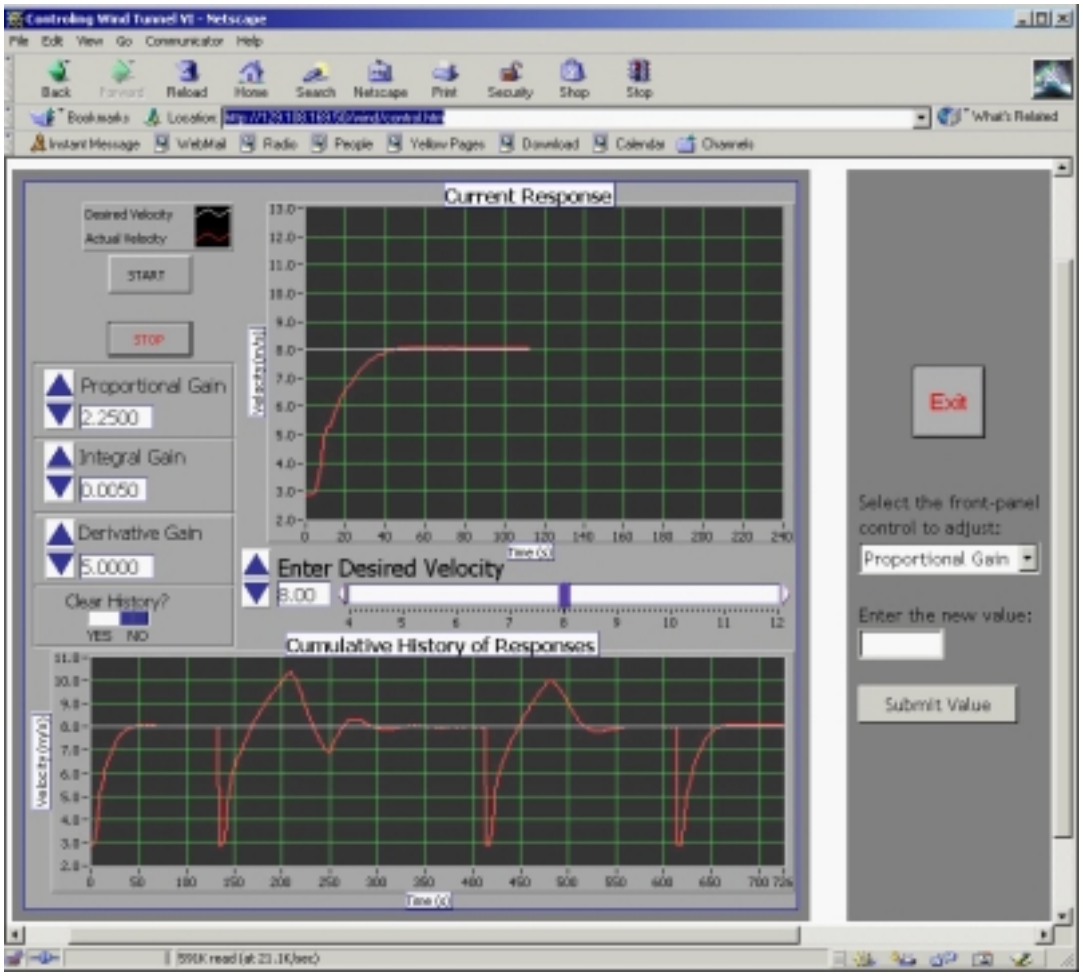

Figure 2 – Virtual Instrument front-panel for wind tunnel control and data display

The final task accomplished consisted of preparing a user's guide and also a (subsequent) developer's guide. Explanations of the wind tunnel system and the experiment, along with step-by-step instructions for the remote user have been prepared and published as Web pages linked to this project's home page. Documentation of the implementation details of this project was undertaken in keeping with the goal of enabling the developed software to be ported for use by similar systems or modified with minimal effort for various other systems adopting the same approach to remote experimentation. The various software programs (CGI, Java and LabVIEW) that have been developed for this remote experimentation project can be obtained upon written or e-mail request to the first author of this paper.

Project Evaluation

Evaluation of this project will primarily consist of soliciting student feedback on the ease of use, availability, reliability, clarity of instructions, and overall quality of this remote experimentation system. This will be accomplished through the course evaluation forms for the EE and ME Controls courses during the Spring 2001 semester. Feedback on similar issues will also be sought from the other students and researchers who are allowed to access this system using a Web-accessible evaluation form that is being prepared for this purpose. This data will be compiled at the end of the Spring 2001 semester.

Project Impact

This project makes a positive contribution to the infrastructure for research and education. In addition, both students and researchers have benefited, and will continue to benefit, from this project. It will also continue to have a positive impact on the public's awareness of how science and technology affects our daily lives. These points are elaborated upon as follows.

Impact on students

This project will impact students in the following ways. Firstly, it will immediately benefit an average of 37 Electrical Engineering (EE) and Mechanical Engineering (ME) undergraduate students per semester enrolling in the EE and ME Controls classes. This number should increase somewhat during the next decade because of the projected University enrollment increase in that same period and a steady improvement in retention rates. Those undergraduate and graduate students working on Senior Design or research projects related to the wind tunnel will also benefit from the results of this project.

In addition, the 3 undergraduate students who helped set up the hardware/software and develop the remote experimentation programs all gained valuable training and experience because of this project. They now possess the expertise to set up similar systems for their future employers.

Demonstrations of this tele-experimentation system will be conducted for visitors, including pre-college students, during Engineering Open House. Public dissemination of material concerning this project is already being done via the Internet by having the tele-experimentation system's home page linked to the Departments' home pages. These activities are being undertaken with the secondary objective of motivating lower-level Engineering students and influencing pre-college students everywhere, but particularly in the region (the majority of whom are Hispanic), to study Engineering.

Impact on faculty and other researchers

Firstly, the project director and co-director had the opportunity to investigate how to improve distance education using the Internet and to exercise their project management skills in carrying out a plan for doing so.

Furthermore, it is under planning for faculty and other researchers who are off-campus to conduct experiments on the wind tunnel initially and, eventually, on systems located in various

UTEP Science and Engineering laboratories via the Internet. By having other off-campus facilities (possibly NASA) Internet-enable some of their systems using the proposed approach, UTEP faculty (and other researchers) will then be able to conduct experiments on those systems via the Internet.

Impact on the infrastructure for research and education

The hardware and software system developed that comprises the wind tunnel tele-experimentation setup allows UTEP students studying Control systems to conduct experiments on a wind tunnel system located in a UTEP laboratory while off-campus via the Internet and only a Web browser. The system description, developed materials and evaluation results, made available through publications and over the Internet, will be useful for the development of similar projects elsewhere.

In the near future, enhanced versions of this prototype will allow students and researchers who are off-campus to conduct experiments on systems located in any of UTEP's Science and Engineering laboratories via the Internet. Additionally, we anticipate that other off-campus facilities will have their experimentation systems Internet-enabled using the same or a similar approach so that students (and researchers) can conduct experiments on them using only a Web browser. Such infrastructure enhancements will eventually enable tele-experimentation to become a ubiquitous component of distance education and research, and act as a means to maximize the availability of scarce hardware resources in an era of declining budgets.

Impact on the public

This newly developed remote experimentation setup provides additional opportunities to educate the public (especially young people) on how science and technology affects our daily lives. This is being achieved through demonstrations/presentations during public events such as Engineering Open House. Additionally, a broader impact on human society is being achieved by making information about this project, its products and its results, available at all times to the public through this system's Web-site and its links from other Web pages.

Conclusions

A first step has been taken towards the objective of improved distance education and research by implementing, as a prototype, a method whereby students studying Control Systems are able to conduct experiments on a small wind tunnel system located in the UTEP Controls laboratory while off-campus via the Internet using only Web browser software and to view (near) real-time data from that experiment the same way. The intent is to eventually develop standardized (as much as possible) hardware and software platforms with generic modules for addressing various functions inherently needed by such experimentation systems, especially those used for instructional purposes. This will then act as a springboard to enable tele-experimentation to become a ubiquitous component of distance education and research, and act as a means to maximize the availability of scarce hardware resources in an era of declining budgets.

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