# Web-Based Remote Experimentation

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From the angle of computer based education, the Internet extends the power of personal computers (PC) from being a standalone machine to one that is connected to the world with uncountable resources. Applications such as library access, information search, educational material download, on-line tutorials and even examinations can now be routinely carried out by a low cost PC with Internet connection at any time from practically everywhere.

Most applications are however software oriented and do not involve experimentation through remote access to physical hardware or equipment. While it is natural and easier for more flexible software to establish links and communicate with each other, these setups do provide a good learning experience in many situations. However, as pointed out by Antsaklis at al (1999), it is commonly recognized that effective and complete learning, especially in engineering and science, requires a mixture of theoretical and practical sessions. In particular, to appreciate and use theoretical knowledge to solve real world problems, practical exercises are indispensable.

From the angle of evolution, once problems involving software and communications protocols and standards have been established, the next stage of Internet development may see more applications where hardware can be controlled or accessed, enabling us to have a better working, living and learning environment.

This article gives an overview of the design and use of Internet remote experimentation for the purpose of education. Following a brief survey of some related systems and their design philosophies, the architecture for a typical Web-based laboratory will be presented. The important software and hardware components and subsystems that are needed to develop a user-friendly system will be discussed, followed by some example implementations where the impacts of using such setups on remote technical education will be highlighted.

## OVERVIEW

### Internet Education

Developed within the midst of universities and government agencies, the Internet has been used for a variety of purposes in education. It serves as a convenience multimedia communication channel between teachers and students, scholars and research centers, and has hosted many new, immersing and innovative ways to enhance learning and expand educational opportunities. Distant education and non-traditional classrooms can reach more students with specialized instruction and self-paced learning, while student projects, virtual field trips and online journals may complement available local resources.

In general, the Internet can be used for education in the following manners:

- Delivering content from a course web site where various teaching materials and course management functions are hosted.
- Delivering programs where multimedia animation or simulation is provided to replace physical experiments.
- Providing access to a Web-based laboratory that enables students to set up parameters and undertake experiments from a remote location.

### Web-Based Course

This is the simplest and most common way in which the Web is used for education. In fact, most universi-

ties in the world have systems that utilize the Internet as a general communication tool and aid for material download and general learning.

In particular, Simione (1997) presented a user-centered web page construction and maintenance model to develop web-based course materials, while Pascoe (1997) developed several methods, including interactive exercises, course note annotation and automatic tailored feedback, to enable students to interact with the course site to enhance learning. Rosenblum (1996) described some web-based collaborative learning communication tools through a CGI program that provides instructors with private course discussion areas. With an intuitive chat interface, these areas allow the instructors to give students a platform-independent ability to communicate in as many groups as is needed by the class.

Recently, Tartaglia et al (2002) explored a web-based evaluation system for technical education, while Ko et al (2004) designed and developed a secured web-based test system where a camera at the client computer is used to capture and deliver images of the student's face and postures at random intervals during the assessment. This scheme overcomes the hurdle of verifying the identity of the student by using just a simple user id and password.

## Internet Simulation Laboratory

This is the second most common way to utilize the Internet for education, and is especially beneficial in helping students to obtain a deeper understanding of hard-to-grasp topics. As an example, the concept of frequency components in a time-domain signal can be much better appreciated by using an interactive multimedia approach where students download and run a program from the Web, play around with the amplitudes of the various spectral components of an audio signal, view the resulting waveform and listen to it at the same time.

Software based demonstrations can be passive or interactive. The former is simpler in structure but only allows student to playback prerecorded audio or video. The latter is more interesting from a learning viewpoint, but is also more complicated to be developed. It can in general be divided into those that need to be downloaded for execution on a local machine running software such as MATLAB, or those that run directly on the web using Java applets.

Numerous demonstration-based laboratories, such as those by Crutchfield et al (1997) and Tilbury et al (1998), can be found on the Web on a variety of topics all over the world. A good example is the simulation laboratory developed in Carnegie Mellon University, where an effective paradigm to use the web for tutoring students on the use of MATLAB and SIMULINK is provided. Students are expected to run MATLAB or SIMULINK in one window of their own computers and a web browser in another. While surfing the tutorial, the student can download examples from the web page and run them locally. This helps students learn how the analysis and design of control systems can be carried out.

## Web-Based Remote Laboratory

The above setups provide students with useful theoretical and simulation materials. However, in science and engineering especially, it is universally recognized that effective and efficient learning requires a mixture of both theoretical knowledge and experimental work or exercises. Essentially, effects due to non-ideal operating conditions, practical components, noise and interferences just cannot be taken into full consideration in any simulation. Simulations are based on the use of models that by and large approximate real physical systems. Even the most complicated models, such as those used for pilot training, assume certain operating parameters and conditions which may be violated in actual operation or flights. In fact, the most important stage in the design of a good simulator is to study the actual system for the purpose of extracting the most important essence that need to be taken into account in the simulation. From this angle, a Web-based experiment is much more valuable than a Web-based simulator. It is impossible for the latter to derive the former, but it will be a very valuable experience to design a simulator from getting actual data from a Web-based experiment.

Nevertheless, some basic resource issues have to be resolved in conducting laboratory-based experimentation sessions. Firstly, physical space must be available for developing the experimental setups and for students to carry out the experiments in a conductive environment. Secondly, technical manpower has to be deployed to ensure safety and proper equipment handling. Thirdly, appropriate time scheduling has to be in place to ensure maximum usage of the laboratory.

In the context of teaching where the various topics