UDC 004

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INTERNET-ACCESSIBLE ADVANCED ENGINEERING LABORATORY

Abstract

Novel information technologies have had a profound effect on engineering education. Leading American universities provide global access to their theoretical courses via the Internet; however, this highly beneficial development does not offer the laboratory component crucial for quality engineering and science education. Our efforts address the inherent limitation of all Internet-based educational technologies by creating an infrastructure that provides remote access to advanced instrumentation. Unlike virtual laboratories, the proposed technology brings real hardware to the fingertips of students. It provides a basis for conducting pre-designed and open-ended experiments in the areas of digital communications, physics and electro-optics to the international community of engineering students.

Introduction

The amounts of knowledge expected at the baccalaureate and master's levels show drastic increase. Fortunately, the on-going revolution in information technology results in innovations in university education that can address these requirements. The system of engineering education is especially receptive to evolution of the Internet. However, there is one area in engineering education that is still dominated by classical teaching/learning methodology: the laboratory. This can be easily explained: the purpose of an engineering laboratory course is to teach students to interact with the "real hardware" in all its complexity and imperfection. Any attempt to replace the "real hardware" with the most elaborate simulation software can result in the loss of realism and prevents students from gaining important practical skills. The technology presented in this paper is not a virtual reality laboratory. It is a hardware/software infrastructure providing remote access to advanced instrumentation via the Internet. Developed under the National Science Foundation's funding, it brings real hardware to the fingertips of students. All aspects of operation of this hardware are controlled by a designated computer through a number of actuators and sensors.

Laboratory courses in engineering education

Laboratory courses constitute a very important component of engineering education. Authorities in the area of methodology of engineering education emphasize the role of student laboratory in achieving such educational goals as "experimental skills," "sense of real world," "taste of discovery," "understanding equipment," "motivation," "appreciation of the power of team work," "networking skills," "communication skills," and "the importance of independent learning," see [1], [2], [3], [4], and [5]. Indeed, only in a laboratory course can students design, implement, and later assess a plan of an experiment leading to the solution of the formulated problem, that includes development of an experimental setup, choosing a rational sequence of stimuli, recording, analyzing and interpreting data. Student laboratories provide a demonstration of the power of proverbial "poor contacts", second-order effects, hidden dynamics, measurement noise, effects of overheating, cross-talk between wires, etc. A well-designed laboratory experiment presents students with uncertainty, non-trivial outcomes, and an opportunity for discovering new, not mentioned in a textbook, properties and phenomena.

The system configuration

Any laboratory experiment is intended to provide the students with an opportunity to *visualize* the laboratory hardware, to *learn* about its components, their functions and principles of operation, to *establish the goal* of the experiment, to *design* the experiment, to *apply stimuli* to the laboratory setup, to *observe* the hardware in action, to *record data* featuring the stimuli and the response of the hardware, and, finally, to *process*the recorded data.

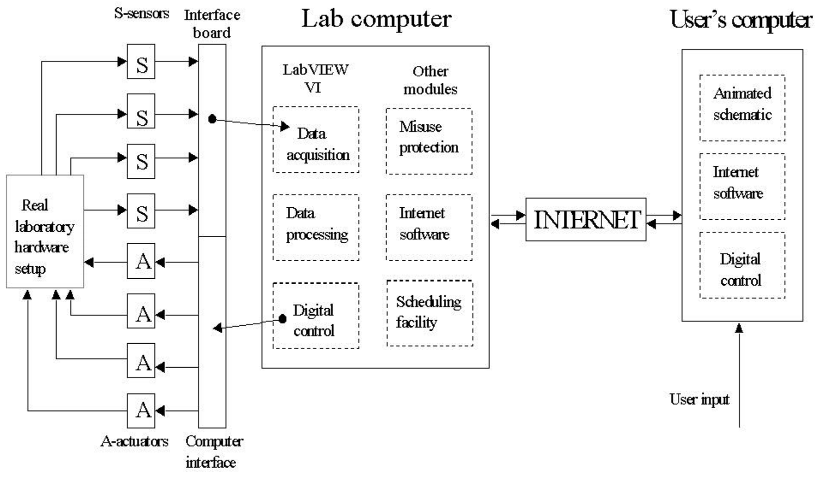

Figure1. System configuration

A schematic in Fig. 1 represents the overall configuration of a laboratory setup accessible via the Internet. It could be seen that a real hardware setup is interfaced with a lab computer that, operating through a system of actuators (A) and sensors (S), performs control and monitoring tasks.

The working prototype

Mounted on the roof tops of two buildings on the Binghamton University campus are two identical laser communication modules manufactured by fSONA(SonaBeam 1250-S). Data transmission rates for the device can be varied between 100 and 1448 Mbps. A dedicated computer is equipped with two Ethernet cards that are used to send and receive communication bit streams. Two media converters, which convert data from the Ethernet card form to optical and vice-versa, are used to connect to the link head's fiber optic communication channels, as shown in Fig. 2.

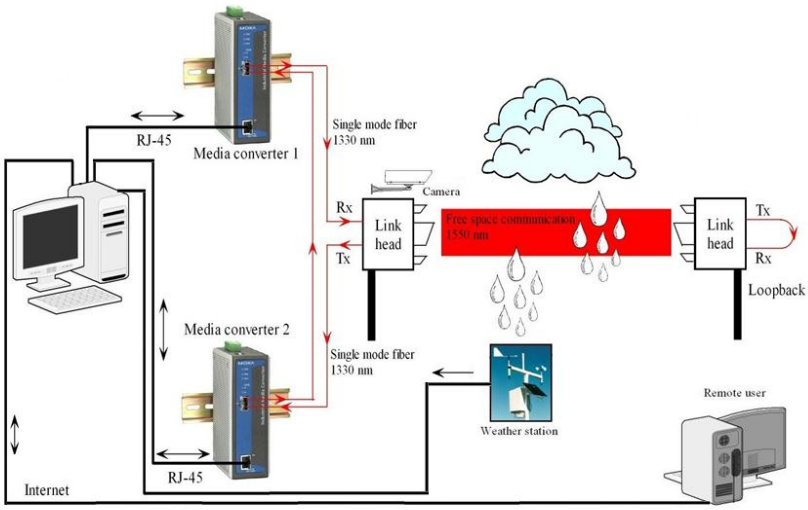

Figure 2. Experimental system

The data transmission to the link head from the media converter is performed using 1330 nm wavelength via a single mode fiber. The data is sent in free space from one link head to the other using 1550 nm wavelength and then it is looped back. Once received, the second media converter is used to convert the optical signal at 1330 nm back to electrical to be sent to the second Ethernet card on the same interface computer.

In addition, our system is equipped with a weather station, a collection of sensors to measure temperature, humidity, wind speed and direction in weather-related experiments and a video surveillance system intended to provide visualization of the link path and qualitative characteristics of the channel.

Recommended experiments

Characterization of a high-performance communication link is a task typical for a practicing electrical or communications engineer. While it is expected that the facility users will develop their own experiments, the following examples can be suggested.

Link analysis under various conditions.Measurements of the received power is a common and practical task in link budget analysis. Since all parameters of the laser communication system are known, this experiment requires students to perform calculations for a given transmitted power and verify if the results are reasonably close to the measured signal. This could be repeated for different values of the transmitted power and for situations when one of the two transmitter diodes is disabled, since all these options are available through our interface software. We intend to keep a sufficient data history on the server, so that it would be available to those users who did not spend enough time collecting their own experimental data.

Effect of transmitted power on error rates. This and all subsequent experiments explore the impact of various factors on the error rates of the system. Typically, this information could be obtained through textbook learning and computer simulation studies. However, most textbooks provide detailed description just of the additive white Gaussian noise, often disregarding many factors contributing to the bit error rate in real-world communication systems. This experiment provides students with a hands-on exposure to the realities of communication systems and will allow them to experience verification of the ubiquitous bit-error-rate curves presented in textbooks.

Effect of Transmission Medium on Error Rate. The experimental environment offers the luxury of having the actual and received information at the same time, and therefore is conducive to various error analysis studies, including the effectiveness assessment of various error mitigation technologies. Many conditions result in a random source of bit errors that are uniformly spread in time; such errors can be mitigated by binary error correction codes. However, other real-world sources can result in bursts of errors that can seriously reduce the effectiveness of correction codes effective for addressing random bit errors.

Conclusion

The-Internet-accessible engineering laboratory is a novel concept in distance learning. While laboratory classes are a necessary component of any engineering curriculum, it can dramatically enhance the quality of education on the global scale. An experimental setup featuring laser communication system operating within a special infrastructure facilitating full remote access to the hardware is described. The system offers a set of pre-defined and open-ended experiments.

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