Real-Time Remote Nondestructive Evaluation Laboratory

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Abstract

The Internet-enabled nondestructive evaluation (NDE) laboratory was developed for engineering technology (ET) students at Drexel University. This laboratory introduces students to fundamentals and industrial applications of ultrasound NDE techniques and procedures. Multiple instruction techniques, including Internet-based remote control of the real-time laboratory procedures, were developed and implemented for education and training for ET students, students of community colleges, and employees of companies wishing to obtain or improve qualifications in NDE. The students have access to the developed material in two modes: the traditional face-to-face classroom mode for those on Drexel’s campus, and a real-time, Internet-based mode for those attending classes at remote locations. Laboratory sessions are organized around current developments in the field of ultrasound NDE of materials. Measurement procedures and experiment descriptions are adapted and implemented from the NDE educational material for remote delivery via website. LabVIEW-based remote control, combined with an integrated computer image, simulates and mimics the appearance and operation of the actual NDE devices. Results of the calibration and testing can be saved from both local and remote computers. Pilot videoconference sessions of the remote NDE procedures with local community colleges were conducted and evaluated.

Introduction

This paper describes the innovating approach to teaching of the ultrasound NDE laboratory- and problem-based course using Internet Protocol (IP) networks\(^1\),\(^2\). Real-time remote laboratory procedures have been developed and tested with students of Drexel University and Burlington County College. Over the last decade, universities around the world have developed a number of laboratory procedures that could be fully controlled and monitored from remote locations\(^3\) utilizing Internet access to high-end equipment for other universities and community colleges. Many laboratory procedures can be remotely controlled, so that once the sample has been loaded, the industrial and educational equipment is completely computer controlled and acquiring, analyzing, and presenting the data can be performed via computer\(^4\). Thus, the experience of performing the experiment would be essentially the same for students in the room with the instrument or students at remote locations. Through remote operation, expensive equipment can be made accessible to institutions that cannot afford the equipment directly and which do not have faculties with the expertise in a particular area. The inter-institutional class sessions may be carried out utilizing high-speed wideband Internet2-based access to high-end equipment of an existing laboratory for other institutions and industrial organizations. Students involved in the “live” interaction with instructors are able to participate in small group discussions, share
documents, collaborate, and fully engage in the videoconferencing experience\textsuperscript{5,6}. Remote operation of equipment can be significantly enhanced by utilizing videoconferencing during the laboratory procedures. The implications of videoconference teaching are far-reaching as it relates to distance delivery of real-time interactive instruction between any remote sites using Internet Protocol (IP) networks. Instructor in the actual laboratory and students at the remote location can monitor each other in real-time and interact as they are in the same classroom or the lab. Laboratory exercises must be written and logistical issues resolved in order to utilize this mode of delivery with students and create environment of being in the actual laboratory.

The Rationale for the Project

The main goal of the project was to develop an Industry/University Cooperative Educational, Training, and Research Laboratory in NDE of materials. The laboratory provides an organized program of study in NDE at the undergraduate level using both face-to-face and real-time Internet-based instruction during lectures and laboratory sessions. The developed course EET 203 (Nondestructive Evaluation of Materials) introduces students to the engineering principles of NDE techniques by combining hands-on laboratory experience with lectures. Multiple instruction techniques, including Internet-based remote control of the real-time laboratory procedures, have been developed and implemented for education and training for engineering technology students, students of community colleges and middle and high schools in the Tri-State (PA, NJ, and DE) area, and employees of companies wishing to obtain or improve qualifications in NDE. The course was developed according to the requirements of the American Society for Nondestructive Testing in collaboration with industrial companies involved in NDE. The developed course consists of two parts: one that emphasizes the foundations of an ultrasound NDE modality, and the second one that focuses on specific NDE applications and techniques. These techniques are studied through experiments that closely simulate industry-relevant manufacturing and testing processes. One of the main objectives of the project was to attract students with an interest in NDE of materials to engineering technology and engineering programs by developing laboratory- and project-based course, which simulates commercial NDE processes and techniques in petrochemical, aerospace, nuclear, rail-road, and renewable energy applications using an in-depth case study approach. Both face-to-face and real-time Internet-based education and training in NDE were integrated during the development of the course. In addition, the developed technique could be utilized for NDE hazardous procedures in industries, in which the human presence is limited or restricted.

The role of NDE in assuring public safety is greatly increasing. The New York Times reports that more than a quarter of the nation’s bridges are structurally deficient or functionally obsolete and leaky pipes lose an estimated seven billion gallons of clean drinking water every day (Michael Cooper. U.S. Infrastructure Is in Dire Straits. \textit{New York Times}, January 28, 2009, p. A16). Similar issues exist in other areas, such as maintenance and diagnostic techniques for nuclear power plants and petrochemical industry. Aerospace designers and manufacturers too are frequently faced with the need to validate the integrity of structural parts for military and commercial aircrafts. Transportation equipment is highly specialized and safety sensitive; it is critically important that all aspects of a failure are investigated, not only to classify the failure mode but also to determine its cause from an engineering mechanics and design perspective.
Filling industry’s need for NDE personnel in the future constitutes a significant challenge to America’s colleges and universities. The developed laboratory and course expand the education opportunities for training specialists in this important and challenging field by reaching a different demographic with appropriate technology and educational approaches.

EET 203, Nondestructive Evaluation of Materials is a four-credit, forty-hour course that fulfills Levels I & II NDE in theory and training requirements, according to ASNT (American Society for Nondestructive Testing) Recommended Practice\(^7\,^8\). Laboratory sessions are organized around current developments in the field of ultrasound NDE of materials. Measurement procedures and experiment descriptions are adapted and implemented from the NDE educational material for remote delivery via website to other community college programs. During the laboratory sessions, the students work as teams conducting calibration and testing procedures and developing possible approaches to solving problems. Students are introduced to the tools, methodologies, and techniques used in real-world industrial applications.

**Remote Control of the NDE Procedures**

One of the main objectives of the project was to develop a videoconference teaching NDE facility, which would provide greater program delivery flexibility and offer non-traditional segments in education and training. Real-time remote control of portable ultrasonic flaw detectors USN 58L and USM 35X, as well as automatic water-tank-based system ULTRAPAC II, was completed and tested, including the videoconferencing option. The backbone of the IP-based videoconferencing consists of a Polycom VSX7000 system. The local site where NDE equipment is installed utilizes a Sony HDR-SR5 camcorder for capturing and recording the experiments, as well as several LCD or plasma monitors for visual display of the activities. GE Inspection Technologies’ UltraDoc software allows for control and data transfer to and from the portable ultrasonic flaw detectors. UltraVNC (Virtual Network Computing) software enables remote control and data transfer from the local computer connected to the flaw detectors and the camcorder simultaneously. Utilizing UltraVNC and UltraDoc control function and commands, one can remotely control and change any setting of the flaw detectors, such as calibration of the detectors and evaluation of test objects. This configuration of equipment and software packages allow students at the remote site to participate fully in laboratory activities. A technician’s or teaching assistant’s presence at the local site is required for initial set-up of the videoconferencing and NDE equipment and handling of the transducers. The block diagram of the remote NDE procedure including videoconference teaching features is presented in Figure 1.

The possibility of using a pick and place robotic system for handling and manipulating transducers has been also evaluated. A YAMAHA YK220X SCARA robot was utilized to manipulate the piezoelectric transducer of the NDE equipment. A developed transducer holder was connected to the robotic arm. Both the transducer and the couplant dispensing system were attached to the transducer holder. Robotic control software (VIPWin) executes instructions via a serial port connected to the robot controller, which facilitates the inputs and outputs for the robot. The program controls four individual motors, each controlling the displacement of the transducer fixture in \(X\), \(Y\), \(Z\) and \(\Theta\) directions. The robotic control of the NDE equipment will allow training and testing procedures to be carried out remotely eliminating the human presence in the restricted areas.
The experimental set-up for conducting real-time remote NDE procedures is presented in Figure 2. The equipment includes the following: Yamaha YK220X SCARA robot, piezoelectric transducer attached to a transducer holder, GE Inspection Technologies ultrasonic flaw detector (USM 35X or USN 58L), precision robot platform, couplant dispensing system, and step calibration block. The complete control of the equipment and NDE procedure is performed using the Yamaha VIP and LabVIEW (Laboratory Virtual Instrument Engineering Workbench) graphical programming language. The controller is capable of connecting to the Ethernet and can also be controlled using a PC server. Two web cameras are used for constantly monitoring the robot movement. All devices are connected to a local area network (LAN).
During the laboratory sessions, students are able to control NDE devices remotely via computers, allowing integration of the experiments with Internet-based automation technologies. The remote operation is established using the UltraVNC, which allows a user control of a computer from a remote location. A remote connection to the USN 58L ultrasonic flaw detector is established by accessing the USN 58L flaw detector under the LabVIEW control\textsuperscript{9-12}. All commands performed by the USN 58L correspond to similar commands performed under LabVIEW control from the remote computer (Figure 3).

The developed LabVIEW-based remote control allows for complete resemblance of the actual device (USN 58L or USM 35X) and simulated device on the computer monitor (Figure 4 and Figure 5, respectively).
The developed procedure allows remote control and changes any setting of the flaw detectors, such as calibration of the detectors and evaluation of test objects. Results of the calibration and testing can be saved from both local and remote computers.

The Internet-based remote operation of the ULTRAPAC II water-tank-based system (Fig. 6) is controlled by the full-featured ultrasonic C-scan software UTwin and Remote Desktop Client for Windows Terminal Services. The system allows for obtaining a plain view of the test object, over which the transducer was scanned, displaying the shapes and plain positions of the reflectors. Variations in color represent the depth of the reflectors (discontinuities) in the test object. The system can be controlled by the local or remote computers via Internet. The image on the monitor of the remote computer is presented in Fig. 7.
Internet-Based Real-Time Instruction of the EET 203 Course.

The pilot videoconference sessions of the remote NDE procedures were carried out with Montgomery County Community College (MCCC) and Burlington County College (BCC). The hardware and software necessary for remote control of NDE equipment was installed and set up. The goal of the pilot sessions was to develop effective presentation skills for fully-interactive videoconferencing to be sure that the speech is clear, loud enough to be heard in a regular situation, and slow enough to be easily understood. The lighting, as well as monitors, microphones, and placement of NDE equipment was carefully evaluated to ensure the best quality transmission and reception. High-speed wide-band Internet2 services using Internet Protocol (IP) networks were utilized for laboratory procedures. During the pilot sessions, the concept of fully-interactive IP-based videoconferencing of users at different locations was tested to optimize the parameters and locations of the equipment installed. All necessary adjustments were carried out by the network specialists of the Drexel’s School of Technology and Professional Studies (SoTAPS), MCCC, and BCC.

As part of these demonstration sessions, remote NDE experiments were taught from the Drexel’s NDE laboratory and participated by Drexel’s technical personnel, teaching assistant for EET 203 (Nondestructive Evaluation of Materials) course, and IT personnel of both community colleges. These pilot instructional sessions and associated laboratory experiments were remarkable successes and demonstrated great promise for continued development of courses utilizing Internet2 delivery. The developed NDE facility will allow SoTAPS to consolidate and teach classes spread across several Community Colleges reducing the cost of teaching and laboratory outfitting. Another benefit of fully-interactive videoconference teaching of NDE of materials course is that the classroom sessions can be recorded and integrated with WebCT. The pilot videoconference-based remote instruction of the laboratory NDE procedures is presented in Figure 8.
Figure 8. Remote control of the NDE procedure from the Montgomery County Community College site.

The monitor installed in the Drexel’s NDE laboratory displays the MCCC videoconference facility during remote calibration procedure, which is completely controlled from MCCC. At the same time, the big screen in the videoconference facility of MCCC projects in real-time the Drexel’s NDE laboratory with installed automatic flaw detector and calibration block during calibration procedure. The same image is displayed at the right lower corner of the monitor located in the actual NDE laboratory at Drexel. The pilot videoconference session with Burlington County College is presented in Figure 9.

Figure 9. Remote control of the NDE procedure from the Burlington County College site.

Based on the results of pilot remote laboratory procedures, necessary corrections and adjustments have been made. Audio and video components of the videoconference-based
During the fall and winter quarters of the 2009-2010 academic year, the EET 203 NDE of Materials course was offered twice. Both face-to-face and remote laboratory procedures were carried out by the engineering technology (ET) students of Burlington County College and Drexel University. The real-time remote laboratory procedure carried out by the students of BCC is presented in Figure 10.

![Remote laboratory procedure from Burlington County College.](image_url)

The students performed experiments, such as straight-beam, angle-beam, and area-amplitude and distance-amplitude calibration procedures using automatic flaw detectors USN 58L and USM 35X. During the laboratory sessions, instruction was performed by ET faculty from Drexel’s NDE laboratory. All calibration procedures were carried out by the students remotely (Figure 11).
Figure 11. Drexel’s students carry out remote angle-beam calibration procedure.

Figure 11 represents the students in the remote laboratory conducting calibration procedure. There are two monitors installed in the remote lab. The left monitor displays the students in the same remote facility. The right monitor displays Drexel’s faculty in the NDE laboratory providing real-time instruction to the students.

Summary

The NSF funded Nondestructive Evaluation of Materials laboratory and course were developed for engineering technology students of Drexel University. Several modes of instruction, such as face-to-face and real-time remote, were developed and tested from various remote sites. The described NDE procedures during the laboratory sessions were carried out from the actual NDE laboratory and remote locations. Remote procedures were developed using the graphical programming language LabVIEW. Data was exchanged between local and remote sites via wide-band high-speed Internet2 network. During the laboratory sessions, the students control NDE equipment remotely with the help of Graphical User Interface (GUI) that reproduces the front panel of the NDE instrument. After a short training, no differences were observed in conducting laboratory experiments for the students on-site compare to the students at remote locations, including time and accuracy of the procedures.

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Bibliography


Biographical Information

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