HARDWARE-BASED NDE REMOTE LABORATORY EXERCISES

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ABSTRACT

Real-time remote Internet-based procedures have been developed for Nondestructive Evaluation of Materials course. The four-credit, hands-on course introduces students to the fundamentals, methods, and techniques of ultrasound nondestructive evaluation (NDE) of parts and materials. NDE applications are presented and applied through real-life problems, including calibration and use of the latest ultrasonic testing instrumentation. The course can be delivered in several modes, including face-to-face, on-line, and real-time videoconferencing. The Internet-based videoconferencing mode also allows students at community colleges collaborating with Drexel University as well as employees of the companies involved in NDE participation in lecture/laboratory activities remotely. Remote real-time laboratory procedures have been developed using the graphical programming language LabVIEW\textsuperscript{TM}. During laboratory sessions, students are introduced to tools, methodologies, and techniques used by the NDE specialists in real-world applications. Industrial case studies in laboratory environment enhance the fundamentals taught in classroom sessions. The videoconference-based instruction of the NDE procedures and techniques can be implemented between any remote sites using Internet Protocol (IP) networks.

Keywords: Nondestructive Evaluation, Engineering Technology, Videoconference-Based Instruction.

1. Introduction

A laboratory-based course EET 203 entitled “Nondestructive Evaluation of Materials” with a problem-based learning approach to nondestructive evaluation of materials has been developed for engineering and engineering technology students [1]. The work in the laboratory enhances the fundamentals taught in the classroom sessions. The stated objective for the project is in tune with the more general ET program educational objectives according to the criteria established by the Accreditation Board for Engineering and Technology (ABET). Based on discussions with our industrial collaborators, we concluded that the industry has a strong interest in the development of training and certification programs in NDE. There is a growing demand for trained personnel in NDE for the petro-chemical, nuclear power, and aerospace industries [2].
Students are introduced to the tools, methodologies, and techniques used in the real-world industrial applications. Students carry out experiments and describe the results of the experiments in individual reports for each laboratory session. The simulation of the NDE applications used by companies in industry is implemented. A qualified evaluator from industry determined the success of the course based on the students’ course evaluation, laboratory reports, the final report, and the final presentation upon completion of all laboratory sessions. Based on these recommendations, evaluation reports, and students’ course evaluation forms, the necessary changes in the course guidance and laboratory procedures were implemented. In addition, the industrial partners, in collaboration with the Drexel’s faculty, developed real-world industrial problems and provided instruction during the laboratory sessions. The NDE procedures have been developed for face-to-face or real-time remote Internet-based delivery.

2. Laboratory procedures

EET 203 course has been developed as a quarter-based (eleven weeks) forty-hour course consisting of lecture and laboratory work each week to fulfill Levels I & II NDT in theory and training requirements, according to ASNT Recommended Practice [3]. Measurement procedures and experiment descriptions were adapted and implemented from the NDE educational material for the website remote delivery to other community college programs. Labs are organized around current developments in the field of ultrasound NDE of materials. Students carry out experiments, evaluate their results using various methods and techniques, and describe the results of the experiments in individual reports for each laboratory session. During the laboratory sessions related to understanding of the fundamentals of ultrasound NDE, the students carry out the following experiments using the ULTRAPAC II water-tank-based system:

- Measurements of the sound velocity in water [4, 5]
- Measurements of the sound velocity in other materials [5]
- Directivity Pattern Measurements [6, 7]
- Measurements of the attenuation coefficient of the ultrasonic waves [5]

All procedures can be controlled remotely using the LabVIEW™ Virtual Instrument (VI) controller [8, 9]. In addition, LabVIEW™ controller is used for data acquisition and analysis. The second part of the course is dedicated to NDE techniques and procedures that implemented for in-class or remotely-controlled experiments [10-14], such as

- Calibration of automatic flaw detectors using straight-beam and angle-beam probes
- Evaluation of homogeneity of various materials used in industrial applications
- Detection and localization of discontinuities in the materials, such as flaws, cavities, layers, and holes
- Weld testing
- Evaluation of the dimensions and shapes of various discontinuities

3. Internet-based NDE procedures

One of the main objectives of the project was to develop an Internet-based educational/research laboratory, which will provide greater program delivery flexibility and offer remote options in education and training [15-17]. The real-time inter-institutional class sessions can be carried out utilizing Internet2-based access to the equipment of Drexel’s NDE laboratory for other universities and community colleges. The ultrasonic portable flaw detectors USN 58L and USM 35X, PHASOR XS and OmniScan MX Phased Array-based devices, and a 3-D (C-scan) automatic scanning NDE system ULTRAPAC II are utilized for laboratory experiments. Real-time remote control of the USN 58L, USM 35X, and ULTRAPAC II instruments, was completed
and tested from the remote site. A Polycom system is utilized for IP-based videoconferencing. The local site with portable ultrasonic flaw detectors 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. The block diagram of the remote NDE procedure is presented in Figure 1.

The remote control of USN 58L and USM 35X using a pick and place robotic system for handling and manipulating transducers was developed and tested, including the transducer holder connected to the robotic arm [18]. Both the transducer and the couplant dispensing system were attached to the transducer holder. Robotic control software (VIPWin) allows execution of instructions via a serial port connected to the robot controller, which facilitates the inputs and outputs for the robot. The developed robotic control of the NDE equipment will allow carrying out training and testing procedures automatically.

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 a step calibration block. The complete control of the equipment and NDE procedure is performed using the Yamaha VIP and LabVIEW™ software. 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. A remote connection via Internet2 to the USN 58L and USM 35X ultrasonic flaw detectors is established by accessing the flaw detectors under the LabVIEW™ control. All commands performed by the USN 58L and USM 35X correspond to similar commands performed under LabVIEW™ control from the remote computer (Figure 3).

The Internet-based remote operation of the ULTRAPAC II water-tank-based system (Figure 4) 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 3-D image on the monitor of the remote computer is presented in Figure 5.

### 4. LabVIEW™-based control of NDE equipment

LabVIEW™ 11.0-based application was developed to remotely control the GE Inspection Technologies USN 58L and USM 35X portable flaw detectors. Remote control of each device is achieved by sending a set of short codes to the devices. The codes are sent one at a time through a serial port. Each code represents a particular command. The example of the structure for controlling the USN 58L device is presented in Figure 6.
Fig. 1: Block Diagram of the Internet-based remote NDE procedure.

Fig. 2: Real-time remote NDE procedure.
Fig. 3: Calibration procedure controlled by LabVIEW™ remotely via Internet2.

Fig. 4: ULTRAPAC II system.

Fig. 5: Remotely obtained 3-D image of the test object.

Fig. 6: LabVIEW™ program structure.

Fig. 8: Call (request) of a particular subVI.

All four subVIs (virtual instruments) are used for changing the value/setting of a particular function of the flaw detector. The subVIs consist of a Boolean control and a Stacked Sequence Structure. Frame 0 of the Stacked Sequence Structure assembles the CODE and Value from the Case Structure into a command string that is sent to the device. For example for USN 58L,
SubVIs and Main VI utilize “USN 58L Global Variables” VI, which contains all global variables used in the program. Each button on the front panel of the flaw detector is replicated by a corresponding OK button located on the Front Panel of the Main VI. When a particular subVI is called by pressing the OK button, the code string for that particular key is applied to the global variable “CODE” (Figure 7). At the same time, each increment or decrement of the controlled value, which corresponds to the particular key function, is represented by a certain numerical value. This value for both flaw detectors is set to “1” by the device manufacturer. This numerical value “1” is fed to the global variable “Value”. The call (request) of a particular subVI for both flaw detectors is presented in Figure 8. The subVI then executes the function by pressing a corresponding key on the front panel or turning the left or right knob of the flaw detector.

Videum 1000® VO Plus hardware board was installed on the local PC. This board operates under the software “Sample Capture Application” and allows capturing of the video signal from the flaw detector to a local PC. The board supports both PAL and NTSC video sources (composite and S-Video), such as cameras, DVD players, and video recorders. Once the video from the screen of a flaw detector was successfully streamed by Videum, ActiveX container from LabVIEW™ is used to stream the video on LabVIEW™ 11.0 Front Panel. Similar remote procedure was developed for controlling the USM 35X flaw detector.

![Diagram of LabVIEW程序](image)

Fig. 7: Frame 0 of the subVI demonstrates how CODE, Value, and Precision are applied to the subVI.

5. Summary

The paper presents the LabVIEW™-based development of real-time remote NDE laboratory integrated with a robotic system. The Internet-based NDE process allows the calibration and testing procedures to be performed locally where the flaw detectors are installed and remotely using the equipment and techniques described in this paper. This technique could be utilized for education, training, and real-life NDE procedures, which in turn would lead to significant cost reduction for companies involved in NDE and educational organizations. The developed
Internet-based NDE laboratory allows for collaboration among universities, community colleges, and training schools specializing in particular testing techniques and willing sharing their equipment remotely with other schools and industrial sites.

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6. References