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Wireless Mobile Platform: A Tool to Implement a Distance Learning Laboratory for Teaching Computer-based Instrumentation and Control*

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Offering courses through the World Wide Web is becoming the modality of choice for distance education. While using tools such as WebCT has made the creation of lecture courses straightforward, laboratory intensive courses are more difficult to implement. Currently, the Electronics and Telecommunications Engineering Technology programs at Texas A&M have an ongoing effort to develop a distance learning laboratory for a computer-based instrumentation and control course. The goal is to create an instrumentation platform that allows students to design experiments remotely and then upload and test their work in real time over the Internet. This paper describes the progress to date, lessons learned, and presents the new distance learning curriculum currently being implemented.

INTRODUCTION

ENABLING DISTANCE LEARNING is becoming increasingly important to the mission of today's institutions of higher education. Much work is being performed to offer online courses that make education accessible to those who do not fit the model of the traditional full-time student [1, 2]. Tools such as WebCT^{TM} make the task of offering a typical lecture course via the Internet straightforward [3]. Unfortunately, while this works well for lecture courses, educational programs that rely heavily on a hands-on learning approach must develop meaningful laboratory experiences that can be delivered via the World Wide Web. Currently, many universities have ongoing efforts in this area [4, 5].

The Electronics and Telecommunication Engineering Technology (EET/TET) programs at Texas A&M University are currently evaluating methods for offering distance education laboratories. To accomplish this, a subset of the programs' laboratory-intensive courses is being evaluated and tested by the student body. One course in particular, Computer-based Instrumentation and Control, has offered unique challenges requiring innovative solutions. In this course, students learn the basics of computer-based instrumentation including analog and digital data acquisition, software-based signal conditioning, and industry standard instrumentation platforms.

Members of the EET/TET faculty have decided to use this course to better evaluate the potential to deliver distance learning coursework which includes an integrated laboratory experience that can be accomplished through remote access to resources located at Texas A&M University. Several factors have recently enhanced the programs' remote access capability and the ability to deliver a more meaningful and relevant laboratory experience via a distance learning environment. Among these factors are a new IEEE 802.11b wireless local area network infrastructure that spans Fermier and Thompson Halls, the two buildings that house the EET and TET programs and laboratories. This network allows full roaming in and around both buildings, and because it is integrated into the campus network, access to the Internet is possible anywhere within the wireless coverage. The wireless network equipment was donated to the programs to support educational-based research and development activities by Cisco Systems, Inc. and was installed by students of the EET/TET Programs during the summer semester 2001 [6]. In addition to this resource, National Instruments has provided its FieldPoint technology [7] for use in the course. The FieldPoint technology is capable of being interfaced to any Ethernet network for program download and remote control. Using the Real-Time Module for LabVIEW, it is possible to download software that was developed in the LabVIEW graphical development environment and run the resulting code on an embedded processor using a real-time operating system.

The wireless networking capability together with the real-time, network-based data acquisition and control hardware and software now make it

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possible to offer a series of laboratory assignments that can be performed at the student's location, then uploaded to a platform located at Texas A&M University. Using web-based camera technology, the student and instructor can simultaneously monitor the execution of the laboratory. With these resources in place, the faculty has developed a three-semester plan to implement a distance learning laboratory for this course [8]. Currently, this effort is in its second semester and the development of the laboratory hardware is being finalized. This paper discusses the results and lessons learned to date, presents the finalized 'MP III' mobile platform, and discusses the new distance learning curriculum that will be implemented during the third and final semester.

BACKGROUND

The Computer-based Instrumentation and Control Course

The Computer-based Instrumentation and Control course is divided into three major sections. The first section provides students with a refresher for the LabVIEW graphical programming environment and focuses their work on using data acquisition (DAQ) to perform various control and interfacing laboratory assignments. This material is generally completed during the first five to six weeks of the semester. During this time, classroom activities lead the actual laboratory work. In class, the students study data acquisition/control technology, understand how the technology is implemented in a particular device, and then see how National Instruments utilizes the device and associated circuitry on its DAQ cards. Laboratory assignments normally include digital I/O, digital-to-analog conversion, analog-to-digital conversion, and time/frequency measurements. The two other major sections share the second two-thirds of the semester. In class, the students learn about signal conditioning—designing and implementing circuits that begin with a wide range of sensors and include typical conversion, instrumentation amplifiers, offset amplifiers, and filter circuits.

Combined with this educational material is a course project allowing the students to integrate

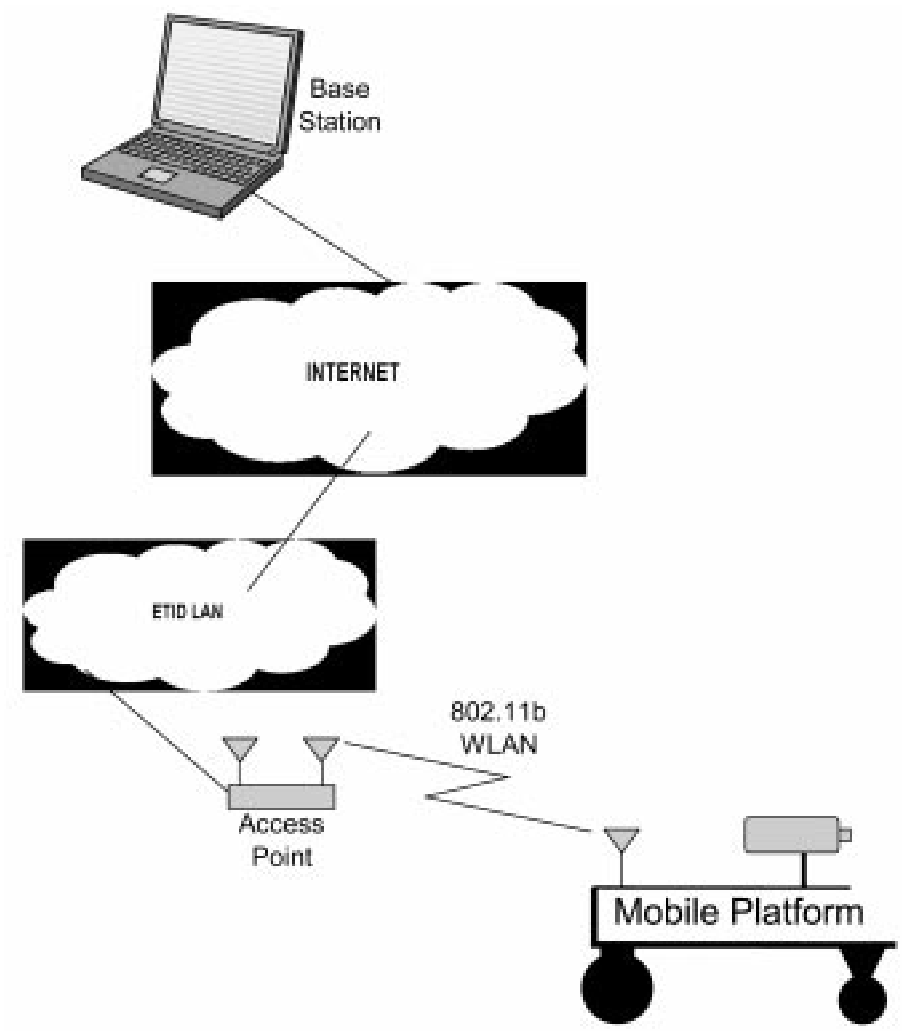

Fig. 1. Diagram of the network architecture for mobile platform. Remote users can access the platform through the Internet. By using a wireless connection in the laboratory, the platform can be completely mobile for the final project phase of the course.

the individual course objectives into a single instrumentation solution. In the past, projects have included the development of a medical titration system and a motor vibration monitoring system. While these projects were excellent 'real-world' applications, distance learning necessitates a project centered on a single common hardware platform that can be used for the entire course and that is remotely accessible. For this reason, the mobile platform was conceived. The concept was to employ a single hardware platform with onboard peripherals that could be used as a static instrumentation test bed for the first part of the course. For the final project, the platform would become mobile, thus creating a vehicle that could sense its environment and be driven remotely. It was hoped that the uniqueness of the project would create an element of excitement and enthusiasm that would also motivate the students. In addition, control of the platform's motion would add to the course rigor and encourage a higher level of understanding.

The current mobile platform implementation

Over the past two semesters, the mobile platform has been developed, tested by the students, and refined for use as the course final project. The basic concept currently relies on the use of National Instruments' FieldPoint hardware, the LabVIEW RealTime software module, and a wireless 802.11b local area network (LAN). The FieldPoint RealTime controller allows students to develop code at a remote location and then upload it via the Internet as in Fig. 1. The use of other FieldPoint data acquisition modules allows the students to experiment with computer-based data acquisition and to monitor and control the mobile platform environment. In addition, visual feedback is provided by a web-enabled camera on the platform. By using the 802.11b network in the laboratory, the platform can be completely mobile while maintaining Internet connectivity.

Development began during the Fall 2001 semester. A single platform was built and students worked in teams literally around the clock to complete their final projects. Figure 2 shows one of the teams at work testing their implementation. The initial goal was to assess the learning motivation that resulted from a comprehensive set of laboratory assignments and a team project that could be successfully performed and demonstrated over the Internet.

In addition to this major goal, other objectives included:

- the overall design of a mobile platform that was self-contained, easily reproducible and highly maintainable.
- the evaluation of a wide range of FieldPoint hardware and LabVIEW RealTime's ability to remotely upload software.
- the evaluation of the wireless 802.11b infrastructure's ability to support real-time control and full-motion video while the platform roamed from access point to access point.

Student feedback after the first semester was extremely positive concerning the new laboratories and course project. The two major negatives were problems with the drive/steering design and the lack of access to multiple common platforms. To remedy these problems, the mechanics of the platform were redesigned over the winter break and funding was requested to construct two of the second generation 'MP II' mobile platforms, each with a common suite of hardware. During the beginning of the Spring 2002 semester, students

Fig. 2. Picture of a student group testing their final project implementation. Creating this type of interactive environment is one of the major hurdles that has to be solved in a distance learning environment.

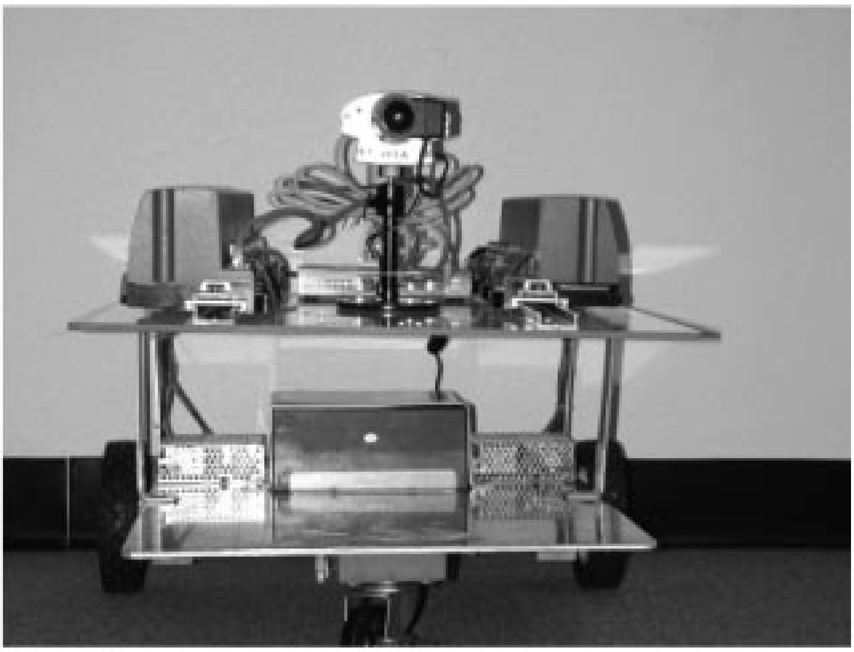

Fig. 3. Picture of the MP II mobile platform design. The second iteration solved many of the mechanical implementation problems including steering and permanent placement of the quadrature encoders needed for control of the motors.

enrolled in the course volunteered to construct two new MP II units consistent with the redesign. The MP II unit solved many of the original problems through the use of common power distribution and motor control subsystems, and a new wireless capability that will support up to four static IP addresses yet requires less power than the original implementation. The redesigned chassis also weighed less and had a larger prototyping area to accommodate the addition of new peripherals. Figure 3 shows the redesigned MP II mobile platform. This platform has now been tested extensively by students over the Spring 2002 semester.

LESSONS LEARNED

The past two semesters have conclusively demonstrated the viability of the mobile platform concept. While the MP II unit is reasonably robust and stable, many lessons have been learned that suggested a final major hardware and software redesign was needed. The following is a synopsis of problems encountered and proposed solutions:

- *Chassis weight*. Reducing the overall weight of the chassis would allow the mobile platform to operate for a longer period of time and travel faster. Several design changes were made that decreased the chassis weight without sacrificing the rigidity or maneuverability of the units.
- *Chassis and camera vibration.* In addition to reducing the weight of the platform, it was essential that the camera vibrate less. Because the camera must be mounted on the upper portion of the platform, a more rigid attachment of the Plexiglas top to the aluminum base was needed.
- *Quadrature encoders.* Quadrature encoding of the powered wheels permits the measurement of platform speed and distance traveled. In the original design of the MP I, encoding was added onto the motor shafts. However, this process did not work well and numerous problems were encountered. A similar motor was identified that had the encoding built into the motor housing which improved operation and durability of this feature.
- *Motor drivers*—homebrew versus off the shelf. After testing several different designs of motor controllers, it was decided that a controller that allowed forward and reverse direction and included breaking when switching directions was needed for satisfactory operation. The controller also needed to operate off a single voltage source. Several student groups did design and fabricate motor controller units, but an off-the-shelf unit proved to be a more robust solution that reduced the complexity of the controlling software.
- Motor supports. Major changes were made to the motor supports between the MP I and MP II units. Although the MP II motor supports proved to be much better than those on the MP I unit, the supports were bulky, weighed more than they should, and allowed the motor to turn if the screws worked loose. In one case a quadrature encoder was severely damaged when the motor turned in its mounting support. A new motor mount was needed that weighed less and would maintain motor alignment. This unit was designed by students and fabricated at a local machine shop.

- Wireless communication problems and bridge inconsistencies. One of the most significant problems encountered in the development of the mobile platform was supporting communications for up to four static IP addresses while the platform was roaming between multiple access points. Many wireless bridges could support multiple IP addresses, but would not operate in a roaming mode. Others were found to have operational inconsistencies or the firmware was still being developed and debugged. After operationally testing three different wireless workgroup bridges, a unit was chosen that provided superior operation (see next section). Cost varied significantly on these units.
- Computer control—laptop vs FieldPoint. Initially when the mobile platform project began, the authors selected a laptop as the controller because it could communicate via a wireless LAN and could control the platform using a PCMCIA data acquisition card. Subsequent discussions with National Instruments engineers resulted in the idea of using a PXI chassis, but quickly turned to FieldPoint modular hardware when factors such as low power, weight, and ease of configuration were considered.
- Camera Delay. Several IP-based cameras were tested for use on the mobile platform. Size of image, update rates, ease of use, and the ability to support multiple observers were some of the factors that were considered in choosing an acceptable unit. Having a web-based interface was also considered desirable. Testing of multiple units resulted in the selection of a camera that met the full-motion, real-time video requirements necessary for platform control over the wireless LAN. The selected unit also supported a two-way voice communications capability.
- Power supplies and power bus. Power and power distribution are critical for efficient operation of the mobile platform. In addition, it was necessary to be able to generate multiple DC voltage levels. In particular was the need to generate a voltage well above 12 V for the FieldPoint modules. Although the modules will operate from a 12 V source, attaching them directly to the battery resulted in sporadic operation. This was due to the voltage drop that occurred when both motors were energized. Most of the other electronic devices required a voltage less than 12 V. Therefore, it was decided that a power bus with three separate voltage levels was needed.
- Courseware materials not adequate for remote lab offering. If an integrated laboratory experience is to be offered to student in a distance education environment, much greater detail is needed in courseware materials. Unlike a classroom or laboratory, the student will not be able to directly ask the instructor for additional information in real-time. Using the feedback from students that have worked with the MP I and MP II units, significant improvements in course materials have been realized.

Using these hard-earned lessons, the following two sections discuss the redesign of the mobile platform and the courseware.

THE NEW 'MP III' PLATFORM

Using the performance data and information that has been collected to date, the EET/TET faculty has now designed a third generation 'MP III' platform that will allow a complete laboratory experience to be performed via remote access over the Internet. The new platform starts with a two-tiered aluminum and Lucite chassis similar to the MP II. However, the chassis was redesigned to minimize vibrations by using six cylindrical aluminum posts to support the Lucite shelf instead of the original four aluminum straps (see Fig. 3). The motor supports were also redesigned to facilitate mounting, motor change out, and to prevent motor alignment problems. The new chassis has significantly reduced the weight of the platform.

With the chassis complete, two servomotors (M455M53, Global Motors) were then attached to the vehicle. Each motor is driven separately by an off-the-shelf R/C servo-controller (PB-1860-1, Novak Electronics). The new controller is robust and also introduces students to the concept of pulse width modulation. The overall system is controlled by a distributed industrial data acquisition system. The microprocessor-based controller (FP-2010, National Instruments) allows students to develop code and then download it over the network. It also provides an RS-232 serial port for control of peripheral devices such as a GPS unit or a pan/tilt actuator for the camera. Additional FieldPoint modules provide for analog input (FP-AI-100, National Instruments), analog output (FP-AO-210, National Instruments), digital input (FP-DI-330, National Instruments), relay control (FP-RLY-420, National Instruments), pulse width modulation motor control (FP-PWM-520, National Instruments) and quadrature encoders (FP-QUAD-510, National Instruments) for wheel speed detection. This diversity in data acquisition capability provides increased flexibility for the students.

Video and audio feedback is provided by a web-enabled camera (2120, Axis) chosen for minimum video and audio delay and maximum streaming video throughput. The FieldPoint system and the video camera are wirelessly connected to the departmental 802.11b network through a network switch (FS105, Netgear) and a wired-to-wireless bridge (Aironet 350 WBG, Cisco) on board the platform. Finally, the system is powered by a 12 V, 18 Ahr lead acid battery (PC12180NB, Interstate) attached to 12 V to 5 V (SD-25A-5, Mean Well) and 12 V to 24 V (SD-25A-24, Mean Well) DC-to-DC converters. This provides 12 V for the motors, 24 V for the FieldPoint system and 5 V for the wireless bridge, camera and network switch. This final platform design can now host all of the introductory laboratory assignments as well as the final project.

In addition to the basic redesign, two additional modifications have been made. One is the addition of transducers and sensors to support basic data acquisition experiments. New hardware includes lights for use with analog output experiments, a stepper motor for use with digital I/O, and accelerometers and sonar sensors for analog input. In addition, the students will continue to learn about pulse width modulation and quadrature encoding for motor control.

A second important change is the addition of a docking station for charging. It is anticipated that students will be required to 'dock' their platforms when not in use. In this manner, the platform batteries will always be charged. It is anticipated that docking will be completed by driving forward into a pair of terminals connected to a battery charger. A light will be visible to the onboard camera that will indicate a successful connection. The complete system block diagram for the MP III is shown in Fig. 4.

During the first five weeks of the course, the platform is fixed as in Fig. 5 while the students gain experience with basic computer-based instrumentation concepts and the platform's major subsystems. Individual experiments have been designed to teach data acquisition fundamentals, the use of FieldPoint and LabVIEW RealTime, and motor control. While the students will not be able to drive the platform during these experiments, it will be able to move under external drive control. This controlled motion will allow the accelerometer and sonar sensors to provide meaningful output signals. As before, a web-enabled camera mounted on the platform will provide students with visual feedback about their experiments. Additional cameras will be fixed in the laboratory that will be used by faculty to monitor overall student activity.

Once the student teams have demonstrated the ability to develop software, upload the code to the target system, and operate the subsystems remotely, they will be authorized to take control of the platform and control its movement in a predefined area. Working in teams where members may be geographically dispersed, students will complete the laboratory experience by implementing the requirements of the course project. Although it is expected that onsite manual intervention will be needed from time to time, these system resets, etc. should be minimal. Over the summer, the final MP III system design will be produced and as many as ten new units will be constructed. These will be used in a distance learning environment during the Fall 2002 semester.

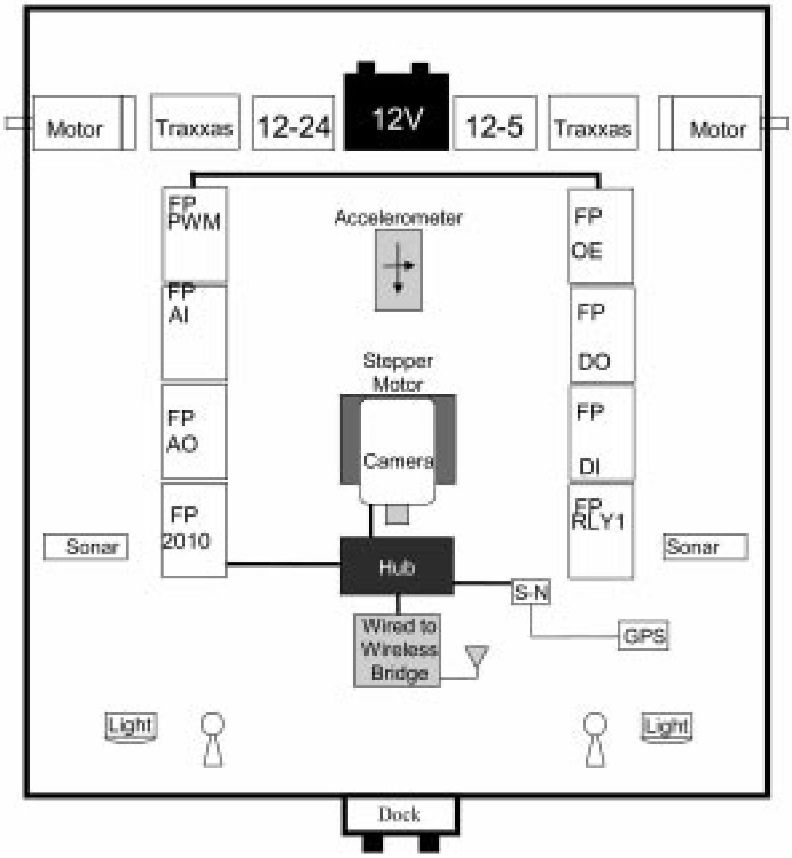

Fig. 4. Block diagram of the final MP III implementation. This final implementation adds a selection of sensors and transducers accessible by the students for experimentation.

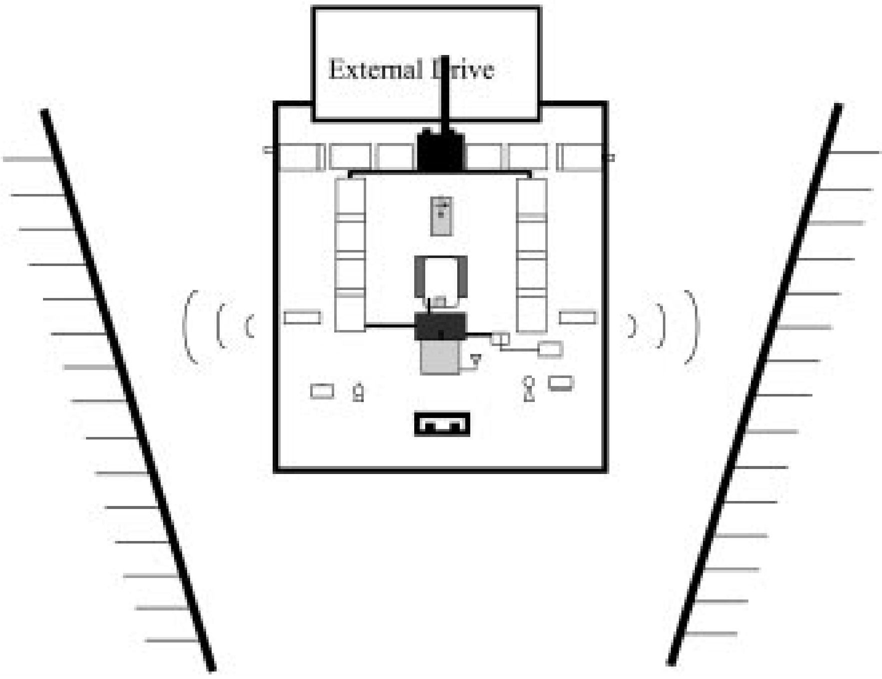

Fig. 5. Diagram of the MP III in fixed configuration. The external drive system moves the platform back and forth to create a measurable acceleration. The angled walls will create varying sonar readings as well. In this mode, the platform runs off of a power supply to avoid draining the batteries.

FORMAT FOR THE DISTANCE LEARNING EXPERIMENTS

The current course lecture material will be prepared for delivery via WebCT. While this is relatively straightforward, the delivery and evaluation of the laboratory has offered unique challenges. Unlike the traditional laboratory setting, the distance learning laboratory requires:

- Very complete laboratory assignments. Instructors often take for granted the role their presence plays in the laboratory, being able to answer student questions interactively and dynamically addressing problems with the laboratory manual.
- Experiments with web based feedback. In a traditional laboratory, the student's attention is kept through visual, audible, and tactile feedback with their experiment. Distance learning experiments need to be devised that give the student ample interactive feedback.
- Methodology for evaluating student success in the laboratory remotely. The laboratory assignments have to be designed in a manner that an instructor can remotely interact with the student.

These issues are currently being addressed through several efforts. First, over the past six months the authors have been actively working with National Instruments (NI) to prepare laboratory assignments for a variety of courses. These assignments are designed specifically to be delivered from the NI website. To do this, a specially prepared format provided by NI is being used that ensures each laboratory has the detailed, complete instructions needed for remote delivery. This format has now been adopted for the mobile platform laboratory.

Second, the EET/TET faculty has developed a set of general guidelines that aid in the design of individual laboratory assignments. Initial efforts to create laboratory experiments suffered from a lack of measured results. The new guidelines require that each laboratory has both quantitative, measurable results as well as qualitative outcomes. It is postulated that the required inclusion of measured results will engage the student and foster a higher level of interaction. In addition, each laboratory must make use of visual feedback as well as remote measurements. While it would be easy to have students upload code to the platform and then receive their results in the form of text and data (i.e., a series of voltage measurements from an accelerometer), the required use of visual feedback will promote student interest.

Finally, general guidelines have been created to maintain consistency of performance evaluation. Each laboratory assignment must require a written report that can be submitted electronically. Also, the successful completion of each assignment will be assessed through a real-time interaction with the instructor and student. The use of web-enabled cameras means that both the instructor and student can monitor the results of an experiment simultaneously. In addition, software such as Microsoft NetMeeting will be used to support dialog between student and teacher. These guidelines have been used to create the distance learning assignments in the next section. These assignments will be tested in the Fall 2002 semester.

LABORATORY ASSIGNMENTS

Laboratory 0—Laboratory Orientation

The primary objective for Laboratory 0 is to make the students comfortable with the distance learning environment. They will learn the basics of FieldPoint and LabVIEW RealTime and will download sample code to the platform. In addition, the students will investigate the WebCT environment and communicate with the faculty through an interactive web connection. Tangible experiments will include using sample code to turn on the mobile platform lights and making a visual inspection of the platform. Students will also make a quantitative measurement of the field of view of the camera using a detailed, dimensioned diagram of the laboratory facility.

Laboratory 1—Digital I/O

Once the students are familiar with the platform operation, the next laboratory will start to present the fundamentals of computer based data acquisition and control. It was decided that digital I/O was the most logical starting point due to simplicity. For this laboratory, the students will learn to control a stepper motor through digital output lines. In addition, they will monitor limit switches that indicate $\pm 180^{\circ}$ rotation and provide a zero-reference indicator. Once the students have learned to control the camera and have calibrated it, they will make measurements such as step resolution and angular position of instructor supplied targets. A discussion of drive current limitations and interface solutions will also be presented.

Laboratory 2—Analog Output

Laboratory 2 will introduce the concepts of digital-to-analog conversion and the computer based generation of DC voltages and AC waveforms. The students will use an analog output signal to control the intensity of the mobile platform lights. Instrumentation such as a DMM or an oscilloscope will be place in the field of view of the camera to provide visual feedback. The students will be required to make measurements to determine the range of voltages required by the lights.

Laboratory 3—Analog Input

One of the most important laboratory assignments deals with accepting and processing analog signals via the FieldPoint Analog Input Module. The Analog Input Laboratory assignment will require the student to acquire multiple analog signals and from two different types of sensors and integrate these data to determine specific attributes about the MP III's environment while also providing a basis for guidance and control that will be used in the course project. As can be seen in Fig. 4, the platform will include a two-axis accelerometer and two sonar sensors that will be directed to the left and right sides of the platform, respectively. When the student has downloaded his/her LabVIEW code to the FieldPoint host, the MP III Positioning Unit, depicted in Fig. 5, will be activated. The Positioning Unit will cause the MP III to move back and forth over a fixed distance. Essentially, the positioning unit will be a rod mounted to a wheel that is attached to a DC motor thus generating repetitive motion with a varying velocity (non-zero acceleration). The student will be required to determine the actual acceleration and velocity vectors as a function of time and display these vectors graphically on the remote console. The student will also be required to determine the exact distance traveled by the platform using the time-based data collected from the accelerometers. These position data will also be used in the following laboratory to calibrate the output of the FieldPoint Quadrature Encoder Module.

In addition to the acceleration data, the student will acquire analog inputs from the sonar sensors mounted on the platform. As can be seen in Fig. 5, a reflective surface that is set on an angle to the path of movement of the platform will be placed on both sides of the platform. This will allow the student to collect and process sonar data that can be used during the project to provide better guidance of the MP III especially when 'docking' the unit at the battery-recharging station. The student will determine the actual angle that the reflective surfaces make to the direction of travel of the MP III as part of this laboratory assignment. In the processing of both of these analog signal sources, the student will have to determine empirically the level of signal amplification that will be necessary to provide the best dynamic range and measurement accuracy. All of the MP III movement can be monitored by the student using the on-board camera system.

Laboratory 4—Quadrature Encoding

The FieldPoint Quadrature Encoding Module will be connected directly to the output of the optical encoder units attached to the DC motors that will power the two rear drive wheels of the MP III as shown in Fig. 3. The student will be tasked in Laboratory 4 to interface to this module to collect rotational data for both wheels. Because the two drive motors operate independently, it will be necessary to use feedback from the optical encoders to control the platform's motion—especially if the platform were to operate in an autonomous mode. Quadrature Encoder output data will be collected while the platform is being moved using the MP III Positioning System described in Laboratory 3. Using the positional data from Laboratory 3, the student will be able to calibrate the quadrature encoded data so that exact changes in position (performing a task requiring highly accurate positional changes) can be accomplished. The ability to monitor actual change in position will also allow for increased turn accuracy.

Laboratory 5—Pulse Width Modulation

In the final laboratory assignment prior to beginning the project, the student will have an opportunity to control the drive motors of the MP III. Because there is a high probability of error in the initial control processes, the MP III will actually have the drive wheels elevated so that they are not touching the ground. In this way the student can experiment with overall control through the FieldPoint pulse width modulation module while monitoring the wheel movement via output from the FieldPoint quadrature encoder module. Insuring that both wheels move in the same direction when the student is moving the platform in the forward or reverse direction as well as correct motor movement for a right and left turns will need to be verified before the student is ready to have full control of the MP III unit. Using a conversion factor the student will be able to determine the speed performance of the platform as well as predict the turning ratio of the unit. Once this laboratory assignment is successfully completed, the student is fully prepared to take on the course project in a team environment.

Final Project—Mobile Platform

The course project provides for the integration of all the instrumentation and control processes completed in the first five laboratory assignments. Using the resources of the Internet, assigned teams will design the graphical user interface and the data acquisition and control processes that will be implemented on the FieldPoint host and the remote client. A comprehensive test plan will also be required. These activities will be performed in response to a project tasking statement.

Generally, the tasking statement will include a set of mandatory functions and capabilities that must be implemented by the team. Completing the mandatory portion of the project provides a maximum project grade of 85. In addition to these mandatory capabilities, the teams will be able to choose from a list of advanced capabilities that will add to the value of their project producing a maximum project grade of 100. If the team is able to develop and demonstrate all of the mandatory and an appropriate number of the advanced capabilities, they can continue to increase their overall project grade by implementing new and enhanced features. The features can be both hardware and software oriented and can be added to the MP III or be part of the capability that resides on the remote client. Points for additional features are negotiated with the course instructor and documented in writing by the students.

To measure the degree of success in the team's implementation of the remote monitoring and control of the MP III, two major demonstrations are required. First the team must remotely control the platform along a well-defined track that requires multiple transitions between wireless access points. Total time will be the major factor in this demonstration and team lap times will be used in determining the overall winner. The second trial will be to drive the MP III through an obstacle course where some, but not all of the obstacles are known. Although time will be a factor, time penalties will be added if the MP III hits any of the obstacles. The course project will be documented by the students teams in a final project report and each team will be required to develop a web page for their activities.

FUTURE WORK AND CONCLUSIONS

Numerous additional activities still remain in order to offer the remote access laboratory experience to EET/TET students during the Fall 2002 semester. These include the overall design of the course in a WebCT environment, the continued development of the laboratory and course project materials, the design and fabrication of MP III units, systems level demonstrations and presentations for upper administration and private industry to gain support and sponsorship, and obtaining feedback and reporting of results.

One of the major tasks slated for the summer is the preparation of the overall course structure for web-based delivery using WebCT. All lecture material, handouts, and laboratory assignments will be converted to electronic format and a WebCT course structure will be designed. Also, online quizzes and exams will be developed for remote testing. Finally, over the Fall 2002 semester, course lectures will be videotaped and prepared for online delivery.

Using the experiences gained during the Spring 2002 semester, final designs for the MP III will be created, and over the summer semester, multiple MP III will be constructed. In addition, the complete complement of power subsystem, motor control, FieldPoint Module suite, sensors and actuators will be installed on each of the new units. Technical reference materials will be assembled and made available via WebCT. Final laboratory assignments and the course project statement of work will be developed. Hopefully, all of the laboratory assignments will be benchmarked using students who successfully completed the Spring 2002 semester.

In addition to these activities, the EET/TET faculty are hopeful that one or more summer undergraduate research projects can be accomplished that are directed to the overall goals of the this initiative. One such undergraduate research project would be the development of MP III monitoring and control unit using a Compaq iPAQ handheld device. This project would capitalize on the color display, sound, and wireless TCP/IP communications available on the iPAQ handheld device to develop a demonstration capability that would allow for the control of the MP III at academic conferences and at industry locations.

Beginning in the Fall 2002 semester, students enrolling in the Computer-based Instrumentation and Control course will be offered the opportunity to accomplish all laboratory assignments via distance learning. Once they are shown how to develop software and download it to the Field-Point host, all other laboratory activities will be done outside of the standard laboratory environment presently used by the EET and TET programs. Feedback from both the traditional and distance learning students will be solicited throughout the semester with improvements being implemented as quickly as possible. From the final evaluation, an overall assessment of the remotely accessed laboratory will be made and a full implementation plan will be developed.

Lessons learned from this undertaking will be shared amongst the EET and TET faculty to evaluate where other implementations might be possible or where other courses might actual use the MP III as a basis for the laboratory exercises. One such possibility would be the advanced digital design course which focuses on the design and implementation using high capacity, field-programmable devices. Finally, the success and lessons learned will be shared through technical papers and presentations made in engineering education journals and conferences.

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