Education Through Competition: Mobile Platform Technology

J. A. Morgan and J. R. Porter

Engineering Technology and Industrial Distribution
Texas A&M University, College Station, TX 77843

Introduction

The Electronics and Telecommunications Engineering Technology (EET/TET) Programs at Texas A&M University have developed a competition-based course project that centers on a mobile robot. The robot, named MPIII and shown in Figure 1, integrates wireless TCP/IP networking, streaming video, and data acquisition to allow students to remotely sense the environment and control the operation of the platform. The project meets several key educational objectives including applied research and design in the undergraduate environment, team interaction, technology integration, testing, and technical communications to include written, oral, and web-based documentation. The EET/TET Programs are now ready to invite other universities to join them in the continued development of these technologies and to focus on a multi-university competition that would bring students together to share experiences in an enjoyable, yet competitive environment.

Four-member teams are formed at the beginning of each semester, and each team must satisfy a set of fundamental requirements during the first half of the semester that include remote monitoring and control of the platform. Throughout the remainder of the semester, the student teams compete with one another in developing enhanced features for the MPIII Platform. Then, at the end of the semester, all teams participate in a winner-take-all competition. The

Figure 1. Red, White, and Blue MPIII Platforms.

competition has ranged from minimum time over a predetermined course with a small distance that does not have wireless coverage to totally autonomous control along a path with unknown obstacles.

The project has been developed over a series of semesters and is now ready for formal announcement as a multi-university competition between undergraduate students. The project promotes and supports a wide range of industry involvement and should provide a highly visible partnership between academia and the private sector. The project also has the potential of creating graduate and undergraduate research funding opportunities as well as stimulating entrepreneurial activities. Known as the Mobile Platform initiative within the EET/TET Programs at Texas A&M, the results of this project have been favorably received at industrial advisory and external development committee meetings and have been displayed at major industry conferences on advanced instrumentation and computer-based control. This paper documents the work to date and the presents a plan for expansion of the internal competition to include other engineering and technology programs within the ASEE membership. A complete list of parts and materials together with a pictorial fabrication log can be downloaded from our web site to allow other undergraduate student teams to construct their own MPIII. The EET/TET Programs at Texas A&M University is prepared to host the first open MPIII Grand Prix race competition during the Spring 2004 semester in College Station, Texas.

Background

Motivation

The mobile platform concept was originally developed as a tool to enable the EET/TET Programs at Texas A&M University to investigate methods for offering distance education laboratories. To accomplish this, a course (Computer-based Instrumentation and Control) was chosen as a testbed for developing remote laboratories. This course 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. A paper discussing the use of the mobile platform technology to support distance education laboratories has recently been submitted to the International Journal of Engineering Education.

Through this course, the members of the EET/TET faculty were able to assess the feasibility of delivering distance learning coursework including an integrated laboratory experience through remote access to resources located at Texas A&M University. The Programs' remote access capability and the ability to deliver a more meaningful and relevant laboratory experience via a distance learning environment had recently been enhanced by the addition of a new IEEE 802.11b wireless local area network (LAN) infrastructure with equipment donated by Cisco Systems, Inc. Installed by students of the EET/TET Programs during the summer session 2001, this network spanned the two buildings that house the EET and TET Programs and allowed full roaming in and around both buildings. Since it was integrated into the campus network, access to the Internet was possible anywhere within the wireless coverage. In addition to this resource, National Instruments had provided its FieldPoint technology 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 was possible to download software that was developed in the LabVIEW graphical development environment and to run the resulting code on an embedded processor using a real-time operating system.

In addition, the mobile platform project provides benefits to the students in several different areas. One obvious benefit that is directly related to the course is that students learn about computer instrumentation and data acquisition through an innovative and motivating approach. Also, this second-semester junior course provides students the opportunity to create project teams and to have a significant input to their project deliverables. Over the course of the final eight weeks of the semester, the student teams have an opportunity to recommend feature enhancements to the basic mobile platform control project and negotiate the level of credit that each enhancement will receive. Of significant importance is the detailed working knowledge that the project teams receive in the area of remote control and guidance and in the delivery of data and video information of wireless networks. Finally, the students are exposed to state-of-the-art instrumentation hardware and software and learn to apply their knowledge from previous courses in analog electronics, circuits and power to problems with real-world constraints.

The Mobile Platform

During a three semester time span, the mobile platform was developed, tested by the students, and refined for use as the course project. The basic concept relied on the use of the software and equipment previously discussed: National Instruments' FieldPoint hardware, the LabVIEW Real-Time software module, and a wireless 802.11b local area network (LAN). The FieldPoint Real-Time controller allowed students to develop code at a remote location and then upload it via the Internet. The use of other FieldPoint data acquisition modules allowed the students to experiment with computer-based data acquisition and to monitor and control the mobile platform environment. Through the use of the 802.11b network, the platform could be completely mobile without sacrificing internet connectivity. Additionally, visual feedback was provided by a web-enabled camera mounted on the platform.

Implementation began during the Fall 2001 semester when a single platform was built, and students worked in teams literally around the clock to complete their final projects. 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 Real-Time'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.

Beginning with the very first semester, student feedback was extremely positive concerning the new laboratories and course project. However, to remedy several student-identified mechanical and electrical problems with the technology, the mechanics of the platform were redesigned over the winter break and two second generation MPII mobile platforms, each with a common suite of hardware, were designed. At the onset of the Spring 2002 semester, students enrolled in the course volunteered to construct two new MPII units consistent with the redesign. The MPII unit solved many of the original problems through the use of common power distribution and motor control subsystems while requiring less power than the original implementation. The updated version also used a new wireless capability that supported multiple static IP addresses onboard the platform. The redesigned chassis also weighed less and had a larger prototyping area to accommodate the addition of new peripherals. This MPII platform was then tested extensively by students over the Spring 2002 semester.

Armed with new insights, the platform was redesigned a second time and four new complete platforms were built for use in the classroom. This latest version, dubbed "MPIII", involved several minor hardware revisions with the most substantial changes centered around improving aesthetics and user-friendliness.

Classroom Use

The Computer-based Instrumentation and Control course is divided into three major sections. The platform is used throughout the course to teach students the basics of computer-based instrumentation and control. During the first five to six weeks of the course, students are provided with an introduction to the FieldPoint modules which teaches them the concepts of computer data acquisition and control. During this first section, 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 FieldPoint systems. Laboratory assignments normally include digital I/O, digital-to-analog conversion, analog-to-digital conversion, and time/frequency measurements. The mobile platform with its onboard peripherals is used as a static instrumentation testbed for the first part of the course.

The two other major sections comprise 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 the individual course objectives into a single instrumentation solution. For the final project, the platform must become mobile, thus creating a vehicle that can sense its environment and be driven remotely. Student groups develop hardware for sensing platform parameters (i.e., speed, power, …)

and environmental parameters (i.e., temperature, lighting, distance to objects, …), as well as remote and onboard control software.

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.

Internal Competition

A competition where student groups test their platforms against each other is the culmination of the course. While the competition changes from semester to semester, the primary goal is to provide an environment that rigorously tests the hardware and software developed by the students. To date, end-of-semester competitions have included:

- a speed course challenge. Students race their platforms through a maze and scoring is based on time and ability to avoid walls.
- A "battle-bot" type competition. Each platform is equipped with a laser tag system. The individual groups then compete against each other in a remote laser tag match.
- An obstacle course challenge. Platforms are equipped with sensors and semi-autonomous control software. Scoring is based on time and the platform's ability to navigate around objects.

One of the disadvantages of group projects is the difficulty in ensuring that all members of a student team participate equally. It should be noted that this end-of-semester competition has in general engaged each member of every team because this tangible final goal is of great interest to each student. The competition concept has created a dramatic increase in student motivation and participation.

The MPIII Platform

Overview

The real value of the MPIII Platform is its intrinsic ability to garner and hold the interest of students. Because of its mobility, speed, size, etc., the MPIII provides a focus for undergraduate and graduate students' attention. In addition, the MPIII represents the integration and operation of multiple advanced technologies. These two factors create a educational environment that is very conducive to learning both on an individual basis and sharing knowledge through team interaction. By combining wireless communications, web-enabled camera, modular microprocessor-based data acquisition, instrumentation, power distribution, motor control, and real-time graphical software development into one integrated project, the students far exceed the understanding of each of these subjects when taught in a more isolated format. By allowing the student teams to generate ideas of their own for added features and capabilities, considerably more development effort is achieved in any given semester. Evaluation of the student features and implementation methodology can provide new and interesting challenges for the following semesters. Such features as pan and tilt mechanisms for the video camera, infrared and ultrasonic sensors for collision avoidance, and terrain mapping for improved navigation are some of the features that student teams have developed as part of their MPIII course project.

Functional Description

The MPIII Platform is a three-wheeled vehicle that is approximately 20 x 20 inches and stands 15 inches tall. The chassis' lower frame is constructed from ¼ inch aluminum and its upper frame is made from ¼ inch polycarbonate that are bolted together using ¾ inch round aluminum stock. The upper frame being made from polycarbonate allows for easy viewing of components, wiring, etc. mounted on the aluminum frame and between the two frames. The chassis was designed to withstand reasonable use while minimizing the material and construction time, cost, and maintenance. The design also allows for quick reconfiguration of the system by removing one polycarbonate frame and installing another. The polycarbonate frame can be configured with different "packages" including control and communications electronics, sensors, actuators, cameras, manipulators, etc. If need, an additional instrumentation shelve can be inserted between the two primary frame members. Finally, the design allows for the platform to be carried by a single individual when transporting the unit over large distances is required.

The MPIII Platform has been designed and constructed to operate in non-hostile environments with no intent to navigate over rough or uneven terrain. A typical setting for the MPIII would be an office building, school, prison, etc. on cement, tiled, or other reasonably smooth surfaces. The MPIII can navigate over typical door sills and is capable of maneuvering up and down ramps with less than 10 degree slants. The intent of the design is to provide a stable, yet highly maneuverable platform that can be remotely controlled over an IP-based wireless communications infrastructure such as IEEE 802.11b.

The platform can accommodate a payload of approximately 5 to 7 pounds and can maneuver under visually monitored control for over two hours on a fully charged lead-acid battery. Its top speed is approximately 4-5 mph. Power and steering are both provided by the two driven wheels. The MPIII has been designed to navigate in the confines of small hallways and uses a ball bearing type third wheel to provide an ability to make a zero tolerance turn. The design of the MPIII also allows the unit to be parked at a recharging station when not in use.

Block Diagram

The MPIII platform can be subdivided into five major blocks or subassemblies: Each of these major subsystems is graphically depicted in Figure 2.

- Chassis
- Power and Drive

- Wireless Network
- Video Monitoring
- Platform Control Hardware

Chassis

The chassis is composed of the ¼ inch aluminum lower frame, the ¼ inch polycarbonate upper frame, and the six ¾ inch aluminum struts that interconnect the upper and lower frame members. The chassis also includes the motor mounting fixtures as well as the battery mounting fixtures. Finally, the ball bearing type, non-driven front wheel is included as part of the chassis' subassembly as are the two bumper that prevent damage to walls and other objects by an MPIII .

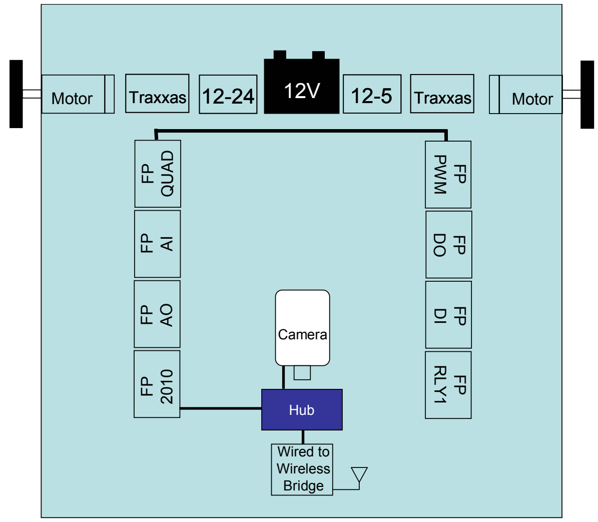

Figure 2. MPIII Block Diagram

Power and Drive Subsystem

All power for the MPIII is self contained onboard the platform. A 12 Volt lead-acid battery is used as the primary source for power. Most high current devices (e.g., motors) have been selected to operate directly from the 12 Volt source. Two DC-DC converters are also used to provide two other voltage sources. The 12 VDC to 24 VDC up-converter is used to provide power to the National Instrument FieldPoint modules. These modules can operate from 12 to 30 VDC, but the lead acid battery terminal voltage can drop below the 12 volts as it discharges or when providing large current demands such as when the platform undergoes rapid acceleration. By doubling the battery voltage, the dip in the output from the 24 VDC converter maintains the supply voltage to the Field Point modules above the 12 volt level. Many of the other subsystems require 5 VDC to operate. Thus, a 12 to 5 VDC down-converter is also incorporated into the power and drive subsystem of the MPIII.

The mounting position for the lead acid battery has been chosen to provide a low center of gravity for the MPIII while putting maximum weight over the drive wheels for increased traction. Both DC-DC converters are mounted in close proximity to the battery to reduce the length of the leads from the battery terminals to the converters. A single switch and fuse assembly is used to control the 12 volts supplied to all of the units requiring power.

The two DC motors are mounted directly to the motor mounting flanges that are then bolted to the under side of the aluminum frame. To provide speed and direction control, each motor is connected to an H-bridge that provides a pulse-width modulated (PWM) waveform of 12 volts to the motor. The polarity of the 12 volt PWM signal is changed to provide rotational control of the motor. The H-bridge also provides a breaking function when switching from forward to reverse. A six inch, solid core wheel is directly attached to the motor shaft via a ¾ to ¼ inch adapter using a set screw.

Wireless Network

The MPIII Platform has the ability to support four separate IP addresses in a mobile environment. Thus, multiple, independent communications sessions can utilize the wireless network simultaneously. The 802.11b wireless network and support for four IP addresses is provided by the Linksys wireless workgroup bridge. The Linksys 5-port 10/100 Mbps Ethernet switch provides wired connectivity on board the platform and speed matching for the intelligent devices mounted on the MPIII. These include the web-enabled camera and the National Instruments FieldPoint network module that communicate via the wireless network. The wireless workgroup bridge can operate in either infrastructure or ad hoc mode, so the platform can be controlled locally over a peer-to-peer interface or from anywhere in the world if the associated access point is connected to the internet.

Video Monitoring

The Axis 2120 web-enabled camera provides the wireless video monitoring onboard the MPIII that allows a remote control of the direction and speed of the platform using a joystick or similar device. The camera provides a video update rate of up to 30 fps from its web server. The camera's web server can provide the video to up to ten different users that have properly logged into the unit. Thus, multiple locations could monitor the progress of the platform while it is being controlled from a completely different site. An additional audio unit can be added to the camera to provide two-way audio communications via the camera's web server.

Platform Control

The MPIII Platform is controlled using the newly developed FieldPoint modules. Each module is a plug 'n play unit that snaps into a FieldPoint base unit that provides power and interconnectivity with other modules. The base units are secured to the ¼ inch polycarbonate frame using DIN rails so that the units can be easily replaced and modified. The Network module is mandatory and provides connectivity to the remote base station and overall interfacing to all of the other I/O modules that are mounted on the platform. In addition to the network module, the MPIII Platform control must include the PWM module to control the motors. To be able to accept and process the position feedback information from the motors, the Quad Encoder module is used to interface to the optical encoders mounted on the motor shafts. Other modules that are available include:

- Digital Input
- Digital Output
- Relay
- Analog Input
- Analog Output

The wide variety of I/O modules provides significant flexibility in configuring the MPIII for the specific suite of sensors and actuators that are installed on the platform. All software that executes on the MPIII platform is developed in the LabView Real-Time graphical environment and then downloaded to the network module for execution. The network module also includes watchdog timers that can be used for system recovery.

Constructing an MPIII

As shown in Figure 3, four MPIII Platforms have been constructed by undergraduate students within the Electronics Engineering Technology Program at Texas A&M University. All necessary parts lists and materials are available for other programs to download and replicate this design. In fact, a pictorial fabrication log has been created to guide the faculty/students through the construction process. The project has been so successful in the EET Program that the next step would be to have multiple academic programs become involved in a competition. If appropriate, there could be a "best of the best" showdown that could include a Grand Prix style race that is conducted at one location with the drivers actually controlling their platforms from Including narrow S curves, darkened tunnels, and long straight-aways would truly test the team's ability to monitor and control their platform. A "fair" competition could be readily created by mandating the frame size and materials, the motors, and the H-bridges that have to be used. Almost all other component selection could be left to the student teams. Student teams would be encourage to solicit sponsorship from private industry to underwrite the cost of competing. The EET Program at Texas A&M would be pleased to host the first MP Showdown in the Spring 2004 semester.

Figure 3. MPIII Construction by Student.

A Multi-University Mobile Platform Competition

The mobile platform concept is now at a point where it is ready for dissemination to other universities. With this in mind, the EET/TET faculty will be working to develop a multi-university mobile platform competition over the next two semesters. It is hoped that this competition will give other engineering and technology programs a chance to evaluate the mobile platform technology and will allow them to integrate these technologies into their curricula. In addition, it is envisioned that through the solicitation of industry involvement and support, that the mobile platform competition will create an environment that fosters new academic/industry partnerships and new opportunities for applied research.

The EET faculty is currently looking for academic partners and feedback on the interest-level of other programs in participating in this type of competition. To this end, a preliminary plan and set of guidelines have been developed as discussed below.

Who Can Participate?

Any two or four year program in either engineering or engineering technology will be eligible to participate in the competition. While it is hoped that the mobile platform project will be the result of a course project involving student teams, student organizations such as IEEE will also be welcome to compete. While not mandatory, it is recommended that participating schools have access to:

- A fabrication facility for building the mechanics of the platform
- A computer for software development
- A wireless infrastructure for platform testing

Ground Rules/ Design Constraints

In order to create a level playing field for the competition, a set of guidelines for the competition are being developed. These include design constraints on the platform itself as well as rules governing the actual competition. For example, it is envisioned that all participating groups will use the same basic platform base, motors, and batteries. This will ensure that all competing platforms have approximately the same base weight, speed capability, efficiency. All groups will also be required to use 802.11b for their remote communications medium.

While it was originally desired that each group control their platform from their home school during the competition, it has been decided that all competitors will drive their platforms from a common remote facility at Texas A&M. This will avoid differences in network connections that would have otherwise resulted.

Industry Involvement and Sponsorship

Industry sponsorship has been an important aspect in the development of the mobile platform. Many of the major systems on the platform were acquired through industry/academic partnerships as well as several of the onboard peripherals. The EET faculty is currently working with several of these companies to secure permanent support for those groups interested in participating in the mobile platform competition. In addition, all participating groups will be encouraged to seek independent sponsorship to support their efforts.

Actual Competition

The first competition will take place at the end of the Spring 2004 semester. Texas A&M in College Station would offer to serve as host. The competition would require that teams travel to the event site to participate. The competition itself would be comprised of three events including a speed trial, an obstacle course, and a power efficiency test. Platforms would be judged based on:

- Speed
- Maneuverability
- Controllability through the wireless network
- Efficiency
- Aesthetics

After the competition, several prizes solicited from industry sponsors would be awarded based on overall performance as well as specific categories such as speed and efficiency.

Conclusions

Over the past three semesters, the EET/TET Programs at Texas A&M University have developed a mobile instrumentation platform for remote teaching of instrumentation and control laboratory concepts. The platform has gone through three major revisions based on faculty and student input and has reached a point where it could be duplicated by other interested programs.

While the goal of the mobile instrumentation platform was to facilitate the remote delivery of labs, the EET/TET faculty has since found that by introducing the concept of a competition where students test the final work against one another, has resulted in a substantial increase in the level of motivation and participation.

With this in mind, the EET/TET faculty at Texas A&M University would like to create a multi-university competition between schools interested in incorporating the mobile platform concept into their curricula. The plans for constructing the base platform will be made available on the web (http;//entc359.tamu.edu/mpiii/index.html) and an annual competition which is tentatively being planned to start in the Spring of 2004 is being developed. All interested parties are encouraged to contact Dr. Joseph Morgan (morganj@entc.tamu.edu) or Dr. Jay Porter (porter@entc.tamu.edu) at Texas A&M University.

JOSEPH MORGAN
Joseph A. Morgan joined the Engineering Technology program at Texas A&M University in 1989 as the Program Coordinator for Electronics and Telecommunications Engineering Technology. His current areas of interest included radar systems, data acquisition, and control systems. He received the MS degree in industrial engineering, and the D.E. in industrial engineering from Texas A&M University.

JAY PORTER
Jay R. Porter joined the Department of Engineering Technology and Industrial Distribution at Texas A&M University in 1998 as an Assistant Professor and currently works in the areas of mixed-signal circuit testing and virtual instrumentation development. He received the BS degree in electrical engineering (1987), the MS degree in physics (1989), and the Ph.D. in electrical engineering (1993) from Texas A&M University.