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Krisys: A Low-Cost, High-Impact Recruiting and Outreach Tool

Introduction

The United States has seen declining enrollments in engineering and technology disciplines over the past five years.[1] This trend is of growing concern to engineering professionals and is contributing to a recognized shortage of talent in the fields of science, technology, engineering, and mathematics (STEM).[2] The problem has led many funding agencies to promote STEM programs in an effort to increase the awareness and value of STEM careers among today's youth in order to boost recruiting and retention in these fields. As an example, in 2006 the United States government invested over $3B in STEM education.[3] Many new programs and tools have resulted from this renewed focus on stem education. One such example is the increasing growth of the number of programs targeted at grade school and high school students in the area of robotics.[4,5,6] Robotics programs are a particularly good way to reach children and adolescents for several reasons:

- Robotic programs are inherently hands-on and provide an opportunity for students to create something tangible that actually works. This is particularly exciting to many students because it incorporates modern technology and pushes their abilities beyond what they thought possible.
- Robotic programs are inherently multi-disciplinary. A well designed robotics program requires students to use a combination of several engineering disciplines (electrical, mechanical, …) as well as both mathematics and science in order to be successful. This is rewarding because it demonstrates to the students the "real-world" aspects of fields that are often only taught from a conceptual, non-applied standpoint.
- Robotic programs are team-oriented. The social aspects of working as a group to design, implement and compete serve to enhance the experience for most students. Not only are robotic programs fun but they help students identify the rewarding attributes of technology careers.

Two examples of robotics programs that have been extremely successful enhancing student interest in STEM fields are BEST (Boosting Engineering Science and Technology) and FIRST (For Inspiration and Recognition of Science and Technology). BEST was a program started in 1993 by two engineers at Texas Instruments and now headquartered at Auburn University.   In 2008, the program involved over 650 schools and 10,000 middle school and high school students.[7]   The FIRST program was founded in 1989 by Dean Kamen and is headquartered in Manchester, NH. Next year, the FIRST Robotics Competition (FRC) anticipates a participation of over 55,000 high school students. In addition, FIRST has other programs based on the LEGO[TM] platform targeted at grade school and middle school students.[8]

Both the BEST and the FRC programs have large teams of students (often >15) design and build a robotic platform over a period of about six weeks based on a set of specific tasks that need to be accomplished. The teams are provided with a base kit that includes a controller as well as all necessary peripherals. In the case of BEST, the controller is a VEX Robotics Control System programmed in either EasyC or ROBOTC while FRC uses a cRIO platform that is programmed

in LabVIEW, C, or JAVA. The students are responsible for the mechanical design and, to a somewhat lesser degree, the programming of the robot. The teams then compete for top honors. Both programs report success in the area of STEM recruiting. For example, FIRST reports that 55% of their alumni will major in science or engineering as opposed to 28% of a matched control group.[8] BEST reports that 58% of participants are likely to pursue STEM careers.[7] Thus, both BEST and FIRST are very good indicators of the impact that programs using robotics as a platform to develop middle school and high school students' interest in STEM careers can have.

Based on this, the Electronics and Telecom Engineering Technology (EET/TET) programs at Texas A&M University began looking at robotic programs as a recruiting and outreach tool about two years ago. However, while large-scale programs such as BEST and FIRST were initially considered, they were found not to be optimal based on EET/TET's needs. First, the EET/TET programs have limited funds for recruiting. With this said, programs such as BEST and FIRST require a substantial investment on the part of the participating schools in order to fund construction of the robot and travel to competitions. For example, FIRST requires a minimum investment of $5500 (for a single team) in order to register and receive the base kit. This cost for participation obviously limits involvement and the ability to sponsor multiple teams. As an academic program seeking recruiting impact, a second option would be to host a regional competition but this requires an initial investment that can easily exceed $20k in the case of both BEST and FIRST.

Secondly, sponsoring/mentoring either a FIRST or BEST team requires a minimum time commitment of six weeks and offers contact with about 10 to 50 students (depending on the size of the team) once a year. This limited number of students contacted each year is too low for most recruiting programs. In addition, as a sponsor one is competing for student attention with other universities and programs present at the competitions. Hosting a regional competition increases the number of students impacted but is also a highly competitive environment from a recruiting standpoint.

Finally, as with most robotics programs, both BEST and FIRST inherently place a primary engineering emphasis on the mechanical design, and to a lesser degree, the programming of the robot. While these programs are great recruiting tools for mechanical engineering and computer science, there is little to no emphasis on the electrical design (circuit design, layout, sensor interfacing, …). In both cases, canned controllers and electronics modules are used. Obviously, as an engineering technology program focused on recruiting for electronics and telecommunications, tools that are more oriented towards developing student interest and creating excitement in the area of electronics and control systems are desirable.

For these reasons, the EET/TET Programs looked at the possibility of creating their own recruiting/outreach program based on robotics. It was determined that if a new tool was going to be developed from the ground up, it should have the following traits/characteristics:

- Hands-on Project - First and foremost, the new tool should have a requirement for actually building and delivering a complete robotic system. The feeling of accomplishment that comes from actually producing a working device using technology is essential in a recruiting tool.

- Low-Cost - It was determined that since this was a recruiting tool, the EET/TET program (or their sponsors) should be responsible for associated costs. Thus, while the robotic platforms for competitions such as FIRST and BEST can easily cost in excess of $1000, this tool needed to have a per platform cost of less than $100.
- Emphasis on Electronics – As discussed previously, many robotic programs/competition place the primary emphasis on the mechanical aspects of the platform and the programming of canned control systems. The new platform needed to augment this with requirements to read and understand schematics, to work with, populate, and test printed circuit boards, to analyze and understand sensor technology and signal conditioning, and to work with microcontrollers at the chip level. In short, the focus needed to be more on the electronic control of the robot.
- Deliverable over Short Time Span – While large scale robotic competitions offer student contact over several weeks, the drawback is that this limits contact to one group of students, once a year. The target for this new program was that it could be offered, either on campus or on site, over a short time period (less than a week), multiple times throughout the year.
- Customizable based on Student Age Group – While the primary goal of this new tool was recruiting, the EET/TET program faculty also wanted to use it for outreach and STEM education. Thus, like the FIRST program, this tool should be easily customizable to accommodate its use with students groups over a broad range of ages – from grade school through high school.
- Simultaneously Deliverable to Many Small Teams of Students – To maximize the number of students impacted while ensuring that each student had an opportunity to be actively involved with the technology, the new program had a target audience that would allow up to twenty-eight students to be taught simultaneously, but allowed the students to work in small teams of four.
- Deliverable by College Students – While faculty had the capacity to manage a robotics recruiting program, actually offering it multiple times during a semester would be difficult. The new tool had to be designed so that undergraduate college students, in small teams, could deliver workshops autonomously. This not only increased the manpower available, but was considered to be rewarding for EET/TET students who wanted to be involved in outreach.
- Competitive – The new tool needed to give participants the opportunity to compete with their peers in a fun atmosphere, and afford the opportunity for them to demonstrate and experience success.
- Opportunities for Learning, Analysis and Creativity – Finally, the new tool needed to emphasize engineering through short lessons on engineering topics, opportunities to analyze and explain the technical aspects of their robots, and a chance to be creative in design and presentation.
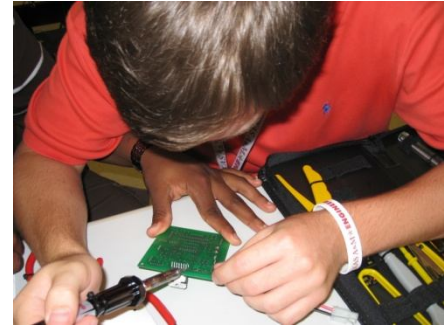
From these requirements was born what the programs now know as Krisys. The Krisys platform (see Figure XX for examples) is a low-cost, small form factor robotic platform that can be designed, implemented completely, programmed and tested in about eight hours. Supporting the physical platform is a recruiting/outreach program that can be customized by audience age group and by available contact time (four hours to several days). The program offers students opportunities to be creative in design and presentation, to learn about electronics, to compete for a variety of awards. The following sections will detail the hardware/software of the physical Krisys platform, present the salient points of offering the recruiting/outreach program, and discuss the impact, lessons learned to date and future activities.
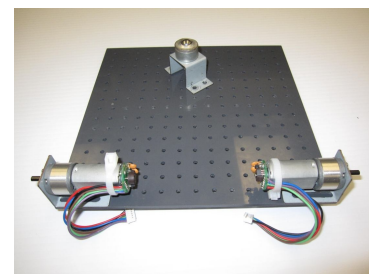
Hardware

Overview

It should be noted that the Krisys workshop typically is composed of four-student teams whose primary task is to develop a creative design for a mobile platform that can autonomously navigate a track. To this end, the team is divided into a two-student hardware group responsible for implementing the platform and a two-student software group responsible for designing algorithms and programming the microcontroller to control the platform. This section discusses the hardware aspects of the platform and the following section will discuss the software design.

From a hardware perspective, the Krisys platform is made up of several key components. These components include a Battery Krisys Inductive Sensor Board, Krisys Motor Controller Board, two motors, ball bearing, and plastic material used to design and fabricate the platform. Each of these can be innovatively integrated together to create a Krisys Robot Platform.

Mechanical

The tricycle form factor is used for the Krisys Mobile Platform that employs a differential two-wheel drive and a ball bearing. The simplicity of the design can be seen in the example of a basic platform in Figure xx. This approach has several advantages, including:

- Simple, straightforward design and construction,
- Low hardware and construction costs,
- Highly maneuverable platform,
- No servos or other more expensive mechanical parts,
- Students can chose to operate either in a tricycle manner or in a "tail-dragger" mode, and
- Software control is simplified for speed and direction.

As mentioned, the differential drive and ball bearing configuration makes the platform highly maneuverable. This is made possible by using the motors to steer the platform. If both motors

are rotating at the same speed then the platform moves forward, but by changing the speed of one wheel the platform can turn left or right. This is also beneficial for the programmer because only two PWM signals are needed to control speed and direction of the platform.

Motors

The selected motors are geared, compact, and equipped with encoders. The motors use a 19:1 gear ratio which provides excellent while allowing the students to drive at reasonable and controllable speeds. These motors are compact and include brackets for easy assembly, alignment, and mounting to the platform. The encoders, if used, provide the Krisys Mobile Platform with the ability to determine the speed of each motor and the distance traveled. This in turn allows for feedback control of platform speed and direction. The motors also perform well on readily available 7.2V RC car batteries while having the ability to be used with batteries providing up to 12V, if extra power and/or speed is desired or needed.

Platform Materials

Two types of materials (provided in 8"x8" squares) are used to support the design and construction of the mechanical platform. One material is gray PVC plastic with holes drilled on ½" centers. The other is a solid piece of clear Acrylic material. The workshop participants are generally provided one square of each type to support their innovative designs. Students then use their creativity to generate a unique and interesting design and then use power tools to cut and shape the materials for assembly into platforms of many different shapes and sizes. In most cases, the gray PVC will be used as the base of the platform to accommodate mounting of the motors, battery, etc, and the clear acrylic material will be used to realize the particular design they have created. Both materials can be cut, glued, stacked, and easily assembled using standard hardware.
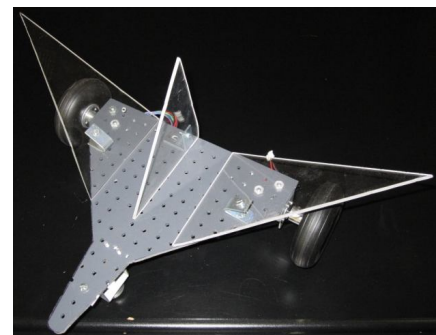
During the design/build process, students must also take into account how they will mount their motors, ball bearing, battery, and PCB. Faculty and undergraduate students involved in the Krisys workshops have been impressed in the number of unique and functional designs that have been created by the workshop teams to date.

Electronics

The key electronic components of the Krisys Mobile Platform are the

- Krisys Inductive Sensor Board,
- Krisys Motor Controller Board, and
- 7.2V battery.

The block diagram displayed in Figure XX depicts these major components and how they are interconnected.
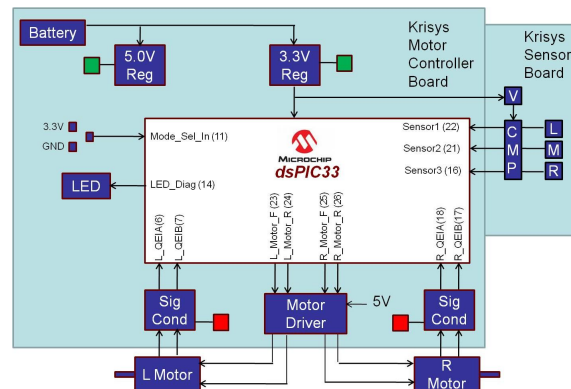
Sensors Board

The key to the Krisys platform is its ability (when programmed correctly) to follow a pre-described track. This is done by creating a track using

small gauge wire, powering the track with a sinusoidal signal generator, and using a set of inductive sensors on the platform to determine the presence of the track. While many other technologies were examined, such as optical track detection, inductive sensing was chosen based on its robustness and reliability, the "coolness factor" which excites students, and because it lent itself well to teaching and demonstration. In particular, high school students were motivated by this technology because it tied directly back to their physics courses.
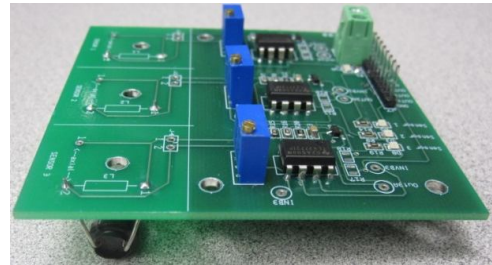
To implement the technology on their platforms, the students are provided a pre-assembled Sensor Board as shown in Figure XX. This board was designed and developed by the EET/TET undergraduate students and consists of three separate inductive sensors (L,M.R in the block diagram) and associated signal conditioning to produce three digital signals, each indicating the presence or absence of the wire track, that can be read by the embedded microcontroller. Software running on the microcontroller can use the sensor input data to determine the robot's position relative to the wire and make appropriate speed/direction corrections to follow the track.

The track, as shown in Figure XX, is created by securely taping a thin gauge wire on the floor. By taping the wire to the floor, literally any track design can be easily laid out and constructed in a matter of minutes. Any standard function generator, such as the Agilent 33120A or equivalent, can then be used to force an alternating current through the wire. The sensor board has three inductors that are used to sense the current. When one of the inductors is placed over the wire, a voltage is induced in the inductor. The output signal from the inductor is a sinusoidal wave that increases in amplitude the closer the inductor is to the wire. For signal conditioning, the signal is then rectified, filtered and compared to a reference voltage. If the signal is greater than the reference voltage then the sensor is considered to be over the wire. The Sensor Board generates a logic Low if the sensor is over the wire, and a logic High when the sensor is not over the wire. This logic definition was selected to emphasize that digital signals can be active High or Low.

The Sensor Board is normally powered from 3.3V, but can be powered by any voltage up to 7.2V. If the sensor board is powered by 3.3V then output signals from the sensors are either 3.3V or 0V. If for some reason the user wants to power the board with a source greater than 3.3V then the outputs will match the power source. This can create a problem when electrically interfacing the Sensor Board to the microcontroller so a voltage divider network was included so that the output signals could be reduced to any desired level.

Motor Controller Board

The Krisys Motor Controller Board consists of the dsPIC33 microcontroller, power conditioning, and signal conditioning for the motor encoder signals. The LM7805CT (5V) and the UA78M33 (3.3V) are both used for power conditioning and regulate voltage for different parts of the Krisys Motor Controller Board circuitry. The dsPIC33 is a microcontroller
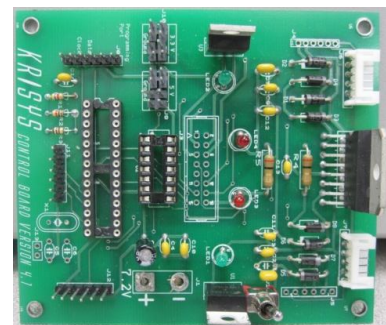
that provides the PWM signals to the L298 as well as accepting inputs from the Krisys Inductive Sensor Board. The L298 is a Dual Full-Bridge Driver which is used to amplify the PWM signals and drive the two motors independently. The SN7414N is a Hex Schmitt Trigger Inverter package that is used to condition the quadrature encoder signals provided by the motors as they turn. A picture of a Krisys Motor Controller Board assembled by workshop students can be seen in Figure XX and the schematic in Figure XX.
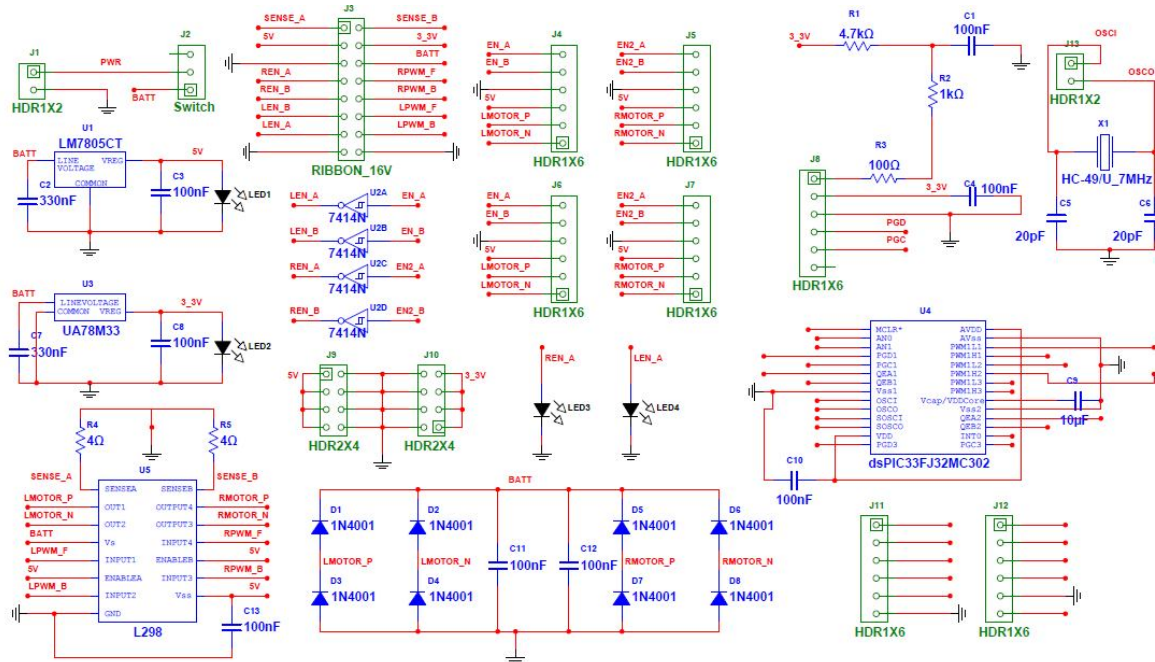
The LM298 dual H-bridge device provides the power amplification necessary to drive to DC motors using Pulse Width Modulation. The series of 1N4001 diodes are used to protect the dual H-bridge from back EMF generated by the motors and the 4-ohm resistors are used for limiting current. In addition, the L298 is designed to shut down in the event of overdrive. The motor driver circuitry has the ability to accept four different PWM inputs: 1) RPWM_F, 2) RPWM_B, 3) LPWM_F, 4) LPWM_B that are generated by the dsPIC33. Interfacing and programming headers are also provided.

Calibration and Debugging

Throughout the workshop, students gain debugging experience starting with the building and testing of the Krisys Motor Controller Board and finishing with the integration and calibration of the Krisys Inductive Sensor Board.

When building the Krisys Motor Controller board the students test two key signals: the 5V and 3.3V outputs from their regulators. Once they have completed testing the regulators, they continue building their PCB, checking each other for proper component placement, orientation and soldering of leads/pins. After they complete construction of the Krisys Motor Controller Board they will perform board-level functional testing. The students are provided a preprogrammed dsPIC33 with a generic program that operates the motors in different directions. Once the motors run correctly, the students are confident they have a properly functioning Krisys Motor Controller board

Upon completion of the robot design and fabrication, students calibrate their Krisys Inductive Sensor Board to ensure proper platform performance. The students have the ability to change the sensitivity of each of the three channels. They will have to adjust each channel based on the orientation and distance of each sensor from the floor. For example, if the platform is centered "on the line", the active low output of the sensors should be a 1 for the left sensor, a 0 for the middle sensor, and a 1 for the right sensor, or (1,0,1). If the platform is slightly to the left of center, then the sensors should output a (1,0,0) code and so on. As a team, they will check for proper motor rotation, proper direction change based on sensor input and that the selected speed profile produces optimum results for both the drag and road. A good lesson that the workshop reinforces is that those teams which take time and pay attention to detail will typically have more consistent performance and fewer race-day malfunctions.

Software

Development Environment

The development environment used to create and compile C code for the dsPIC33 is Microchip's MPLAB Integrated Development Environment (IDE). MPLAB is a free IDE offered by Microchip and is easy to install and simple to use. There are several levels in which the Krisys program is taught from a very high-level (for younger audiences without programming experience) which is heavily based on library functions to a very low-level designed for developers. The IDE is accessible to the wide range of users who develop code for the Krisys platform. MPLAB has built-in tools to use several Microchip programmers (including the PICkit 2) and libraries for every PIC microcontroller produced by Microchip. The built-in header file for the dsPIC33 used for the Krisys platform is included in the latest version of MPLAB. The libraries designed for the Krisys platform are responsible for including such files. The provided projects also are preconfigured to allow the user to begin developing as soon as the IDE and C compiler are installed. If the user chooses to create a new project, the IDE has streamlined the process making it quick and easy to get started with a fresh project.
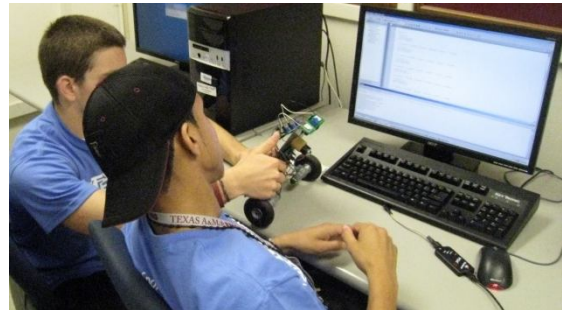
dsPIC33 Microcontroller

The chosen microcontroller for the Krisys platform is the dsPIC33FJ32MC302. This microcontroller family is designed with digital motor control in mind. The selected device has built-in pulse width modulation (PWM), quadrature encoding (QEI) ,analog-to-digital conversion (ADC), and digital input/output (DIO) modules. These modules are accessible and configurable using three Krisys library functions designed by the EET-TET development team. These are the the Pulse Width Modulation (PWM) module is used to create different motor voltages by varying the duty cycle of a digital output. The QEI, or Quadrature Encoder Interface, also referred to as FQD (Fast Quadrature Decode) is included in the low-level libraries. This function provides closed-loop control of motor movement. The Analog to Digital Converter (ADC) module is used to read analog values and convert them into a digital value which can be used in the C program.

Multi-level Software Development

The Krisys library has been designed with several skill levels in mind. There are very high-level functions to control the platform with little knowledge of C and low-level functions for those proficient in embedded programming. The Krisys library offers something for everyone, no matter the skill level or pre-existing programming knowledge.

Low-Level – The low-level functions allow for precise control over all the modules (ADC, QEI, etc.) including the modules that are not used for motor control or line following. These functions are intended to expand platform capabilities so that students can add new features. The low-level functions are primarily used by the Krisys development team and are not used by the students attending Krisys workshops.

Hybrid Mid-Level – The mid-level functions balance the power of low -level capability with the rapid development of the high-level functions. These functions allow for motor control and reading sensors. The platform is intended to autonomously follow a line based on rules given by the user. Using the mid-level functions, the user can achieve this goal and still have some flexibility to develop and integrate extra features. The mid-level functions include reading an analog voltage and controlling extra digital IO pins. These pins are broken out for more advanced users, and with the mid-level functions, students can add new functionality to the platform very quickly.

High-Level – The high-level functions are designed for younger users or those who are new to microcontrollers and embedded programming. These functions are based on the low- and mid-levels functions. There are seven functions at the user's disposal that can be used to make the platform move forward, backward, stop, and turn hard-left, hard-right, arc-left or arc-right. Within a few minutes, the platform can be programmed to perform simple tasks such as driving a square path. The obvious drawback to using these high-level functions is the extent to which they limit the student's ability to program new functionality.

Teaching Modules

The overall workshop design goal for the Krisys platform is to create an autonomous, line-following robot. Before the students are tasked to implement this capability, they complete three experiments. The experiments build upon themselves to prepare the student for the overall task. The students begin each of the experiments with an accompanying C file and are then assisted in the completion of the given task.

Blinking LED – In the world of embedded microcontroller programming exists a "Hello World" analogy known as the Blinking LED. A "Hello World" program is typically the most basic program that can be written in a perspective language. The Blinking LED program is designed to ease the user into the IDE, the microcontroller I/O, and the associated electronic circuitry.

Move Platform – The next experiment tasks the students to move the platform forward for one second, wait for one second, go in reverse for one second and wait for one second.

Sensor Detection – The third and final experiment tasks the student to move the platform forward until any of the three sensors detects the presence of the AC-powered, wire track. This experiment differs from the first two because the platform interacts with the environment. The software senses its environment and then implements rule-base control of the motion. This final

step provides the students all the skills necessary for developing embedded microcontroller software capable of having the Krisys Robot follow a track.

State Machine Considerations

The three inductive sensors can provide a total of eight possible outcomes (000_2 to 111_2). The students are encouraged to create a table with the eight different cases and the associated control outputs to be generated in terms of the two motor PWM signals that will provide responsive track following. For each case, the student determines the PWM duty cycle for each motor. For example, if the left most sensor is the only one returning true, then the platform is too far to the right. In this case the right motor duty cycle needs to be increased and/or the left motor duty cycle decreased to correct the direction of the platform. After this step, the students can begin developing their code to autonomously control the platform.

Krisys Competition

The EET/TET Programs wanted to include an element of excitement as part of their Krisys recruiting workshops. Although the designing, building, programming, and testing aspects of Krisys do support the introduction and learning of many engineering concepts, real motivation to excel is achieved through friendly competition. Therefore, the student-led Krisys development team created a four-part competition to support the elements they felt were important in their own college education. These are: 1) Design, 2) Knowledge, 3) Communications, and 4) Challenge. Each of these is briefly discussed.

Design

Innovation and design are critically important in all aspects of engineering and engineering technology. Therefore, one of the first elements of the competition focused on this. Each team is given time to present their robot to a panel of judges and explain their thought process and overall design strategy and how the design was used to enhance their standings in the competition. The EET/TET faculty members who have participated as judges for these workshops have been impressed with wide range of designs and the ability of the student teams to brief them on their process and motivations.

Knowledge

Coming up with and implementing a cool design is an important aspect of what an engineer does, but equally important is the ability to use empirical data to study and understand fundamental science/technology/engineering/math (STEM) concepts. In this element, the teams must present data they have collected and demonstrate their understanding of various mechanical/electrical aspects of their robotic platform. A portion of this element is answering a set of questions that were provided at the beginning of the workshop and the second portion is being able to "think on their feet" and answer new questions.

Communications

The workshop students must also create a web site to demonstrate their technical communication capabilities. The students are tasked to create a series of web pages to document their project and can gain points by including graphics, images, and video. The students are encouraged to use these images, videos and text to aesthetically depict their design and implementation processes. The web pages are judged on the ease of access, look and feel. and how the information is presented. As an engineer it is important to be able to communicate with fellow engineers. The

web page portion of the competition is a way to begin teaching and reinforcing this valuable skill.

Challenge

The first three elements of the competition do provide an opportunity for the workshop teams to demonstrate their level of learning and do provide motivation for increased understanding and performance during the workshop. However, the EET/TET Programs wanted to ensure that all students involved left with an unforgettable learning experience. To achieve this objective, the Krisys teams pit their robot against all other contenders in two demanding race events. These are the final two elements of the overall competition, and a team must finish strong in both races to be in contention for the coveted "workshop bragging rights" and first-place medallions. The teams are constrained in their ability to adapt the robot to the different race environments. They can make no alterations to the physical platform or the program they have downloaded to the embedded microcontroller. They can, however, flip one switch to select one of two race profiles that will be used for the different race environments. In addition, once the races have begun, no charging or changing of batteries is permitted. As the motor performance changes with battery voltage, this can be an important racing strategy. Finally, the teams are provided a "test" track so that they can fine-tune their algorithms and performance parameters, but they do not know what the final competition track will look like. So they must design for the unknown.

The first race event addresses the teams' ability to produce speed. The "drag race" is a very long and straight track that the robot must traverse. Although the race track is marked with a wire carrying an AC signal that the robot can detect, the team may choose not to use their sensor inputs to increase their speed capability. Each team is permitted up to three "heats", but do not need to run all three. The lowest time achieved in the three heats is used as the teams' best time for the drag race. To make sure that the robot has reached the end of the track, an empty plastic soda bottle is placed at the end of the track upside down. The race time is determined when the robot successfully knocks down the bottle.

In addition to being able to make their robot move as fast and straight as possible, teams must also be able to control the operation of the robot. To demonstrate this achievement, the teams participate in the final event – the "road race". Here the track contains a number of hair-pin turns and switch-backs. Although time is still the determining factor, speed is not what wins this race, control is the critical factor. Once the robot starts the road race, it cannot be touched by any of the students and will be permitted to run until it has completed the race (knocked down the coke bottle) or left the track for good. In many cases, robots have become confused on a sharp turn, have left the track entirely, entered a search pattern to regain the track signal and once found competed the race. Obviously this adds to their race time. Because the competition track is unknown to the teams, they must make good engineering estimates when setting their performance parameters that balance speed with control.

Scoring

Each event has a score for 1st, 2nd, 3rd, 4th, 5th place and so on. The scoring results for the first three elements are not provided prior to the races. Therefore, no team is aware of where they stand in the overall competition. The teams do know what the values are for each element as a function of placement so they can try to estimate their standing prior to beginning the races. The times that each team records on their drag and road race heats are announced, but they are only

recorded by the race judge. At the end of the road race heats, the final tallies are made, winners announced, and prizes awarded.

Delivery Methods

Several different venues have been used to facilitate workshops and other events using the Krisys platform. The mechanical, hardware and software development support required for completing all aspects of the Krisys workshop lend themselves best to offering workshops on the Texas A&M campus using EET/TET laboratory resources. These include, but are not limited to the following

- Mechanical Design/Fabrication – drills, saws, sanders, printers, hand tools;
- PCB Fabrication – soldering stations, test equipment, electronic parts, hand tools;
- Software Development – computers, compliers, programmers, debuggers; and
- Miscellaneous – web development and storage, testing and tuning area, race course.

Delivering a Krisys workshop within the EET/TET Program area allows for ready access to spare parts, advanced test equipment, computer servers, etc. Using these resources also reduces the need for coordination and associated impact on other activities/organizations. Having high school students spend time within the EET/TET Program area and laboratories provides a lasting impression of the resources and educational opportunities awaiting them in their college education.

Krisys workshops have also been offered in situ at local schools. A workshop was conducted at a junior high school as a STEM elective in one of the technical courses. Support for this course was more difficult than conducting the workshop within the EET/TET facilities at Texas A&M, but did not become a major roadblock to success. The period of time the teams had to design, build, program, test, and compete was extended to accommodate both the timely access to all development resources, and to ensure that all students had the opportunity to fully participate. Krisys platform demonstrations have also been included in a number of outreach events at off-campus locations such as elementary schools. Younger children enjoy learning about the robots and have the opportunity to actually control one of the wireless tele-operated versions of the Krisys platform.

Outreach and Recruiting Impact

As with most engineering technology programs, the EET/TET Programs have long suffered from lack of name recognition and differentiation from other more typical engineering disciplines. Other outreach/recruiting processes have been tried with limited success. For example, working with high-school counselors, using program pamphlets, developing web pages, etc have not produced the desired results in terms of attracting high-quality student interest. At best, these modes of communications have fallen short of expectations.

The Krisys Robot Platform, however, has produced a much more viable way to introduce high school students to the opportunities that exist in pursuing an undergraduate degree in engineering technology. In addition, Krisys workshops create an enjoyable and motivational experience for the high school students and provide an opportunity for the EET/TET Programs to reach out to women and minority students. In fact, the success of these workshops has led the programs to expand recruiting activities to junior high school students and to other on- and off-campus recruiting events. These activities include: 1) Women Exploring Engineering, 2) Exploring

Engineering, 3) Student Transfer to Engineering Workshop, 4) Youth Adventure Program, 5) other events and workshops.

Each summer, the Look College of Engineering offers a series of engineering workshops as part of student outreach and recruitment. The college conducts two different high school recruitment sessions and one session for junior college transfer students. During each of these sessions, three different workshops are available for student to attend. For the last two summers, the Krisys Robot Workshop has been offered as one of workshop options. Each workshop includes 20 students that form five teams of four students.

The first of the three workshops is the Women Exploring Engineering (WEE). This workshop is open to all female high school students from across the US who are considering Texas A&M and the Look College of Engineering as their choice for college education. A number of high schools in Texas have also been selected to participate in the Exploring Engineering Workshops (E-12) based on school demographics, TEA performance ratings, average SAT scores of seniors, and the number of students attending Texas A&M from that school. Students participating in these workshops must be currently enrolled at one of the designated E-12 high schools. The third workshop – Students Transferring to Engineering Workshop (STEW) offered by the Look College of Engineering is for students who are considering transfer to one of the engineering/engineering technology programs at Texas A&M University. These students are generally from junior/community colleges within Texas and have completed the necessary math/physics/chemistry in preparation to move forward with a four-year undergraduate degree. All of the College of Engineering workshops are included as a major element in the students' four-day on-campus experience and introduction to college life.

In addition to the sessions offered by the Look College, the College of Education at Texas A&M also offers a series of summer workshops for students considering Texas A&M for their education. The Youth Adventure Program (YAP) experiences include an educational workshop as a focal point for the student participants. Unlike the College of Engineering workshops, the YAP workshops are offered by a wide range of technical and non-technical programs across the entire university.

Based on the very positive feedback the EET/TET programs have received from the high school/junior college students and the individuals that organize and host these on-campus opportunities, EET/TET have tested the Krisys approach to outreach and engagement in other venues. These included offering a short course for junior high students. The students participated in the short course as part of a math/science/technology block one period each day for three weeks (approximately 15 hours total). Finally, EET/TET have used the Krisys Robot platform to expand its involvement in recruiting events such as Aggieland Saturday, Discover Engineering, and Science Night. Aggieland Saturday and Discover Engineering are two events hosted on the Texas A&M campus to provide visibility for the university during the spring and fall semesters, respectively. The Krisys Robot booth generates a significant amount of interest in engineering, particularly for the hands-on approach provided within the engineering technology programs. The Science Night event is offered at one of the local elementary schools, but is open to students across the entire College Station school district. As with the other two events, students are drawn to 'things that move" and become more interested in considering educational programs at the college-level that allow for combining mechanical, electronic, and computer science disciplines.

Student Involvement

From the outset of the EET/TET Krisys Robot Platform initiative, undergraduate college students have played a significant role in the overall development and delivery of the workshops and other recruiting/outreach events. This experience has been a win-win proposition. The undergraduates get leadership and decision-making experience, and the workshop students get more opportunity to interact with real college students who are doing what they hope to do one day soon. The undergraduate student team ranged from two to four students and participated as both designers/developers and instructors.

As developers, one group of undergraduate students researched and selected all the mechanical components for the robot. In addition, they created the microcontroller-based control schematics and laid out the PCBs. The students were responsible for selecting/purchasing all the parts and assembling/testing of the initial mechanical/electronic subsystems. In parallel with these efforts, a second group of undergraduate students developed the overall sensor-based control algorithms and implemented them in the C programming language. Once the hardware/software was ready, the student developers prepared documentation and teaching materials necessary for the workshops.

The hardware instructors had overall responsibility for all aspects of the physical design and fabrication of the robot platform itself. In addition to the mechanical aspects of the robot, the hardware instructors were also responsible for the electronic fabrication, interfacing, debugging, and testing. This included the teaching of good assembly and soldering practices for the through-hole components that make up the Krisys Motor Controller Board. Finally, the hardware instructor had to be able to quickly diagnose problems and issues with robots that did not perform at an acceptable level and develop a corrective action for the students to follow.

The software Instructors were responsible for teaching basic programming and aiding the students in completing the experiments and final task: the competition. The students spent approximately two hours in an interactive presentation learning basic programming concepts. The goal of the presentation was to start a conversation with the students so they could begin to ask insightful questions. Near the end of the presentation, the instructors presented the three experiments. As each experiment was revealed, the workshop students began programming.

Publicity

The Krisys Robot Platform, the associated workshops, and special events have received very favorable publicity thus far. Several articles in newsletters have been generated and the Krisys Robots continue to be invited to participate in number of outreach/recruiting events. The local newspaper has also carried pictures and a story about the workshop and competition that has generated interest in the local area. One of best articles that has been published about the ability of the Krisys Robot to solicit interest in younger students appeared in a recent issue of the Texas A&M Engineering NEWS[9] about the first Discover Engineering Day at Texas A&M University. In addition to getting a very positive reception by a number of visitors to the Krisys Robot booth, the development team took away the need to expand its workshops to younger students in the future. With the new grant support recently received from the private sector, more publicity will be generated about Krisys so that more students can attend these summer workshops.

Lessons Learned

Although still a new initiative to the EET/TET Programs, the development of the Krisys Robot and the associated workshops and outreach events have provided a number of learning experiences. First and foremost of these is that it takes a committed group of individuals to make something this successful and sustainable. Within the EET/TET Programs, there are a minimum of three faculty members who have agreed to volunteer a significant effort and resources to this initiative. Bringing their own funding resources as well as developing other sources of financial support is critical to kicking off such a project. In addition to supporting the costs of hardware and software development, funding for a minimum of three part-time undergraduate student workers is necessary for continuity of efforts in the preparation and delivery of the Krisys workshops.

Significant effort is necessary to develop the fundamental building blocks for the mechanical, electronic and software toolkits necessary to create an educational, motivational and rewarding experience. All of these resources should provide each team with the tools to be successful while allowing for and promoting innovation, design, and engineering skills. Having a modular approach to the initiative has also allowed for tailoring of workshops/events to the needs of the sponsor as well as the skills of the audience. Being able to reuse many of the basic materials has allowed the programs to reduce and manage overall costs associated with the initiative.

Another lesson that has been realized is the ability to include a number of associated STEM learning experiences in the context of design, fabrication, testing of the Krisys Robot. Principle of math and physics are easily incorporated into the workshops and statistics is also been integrated into the testing aspects of the workshops. For example, if only a few hours are available for the workshop, students can be taught how to change several of the performance variables of the Krisys Robot. The students will then collect and reduce data to a graphical format that they will need to use in determining the platform configuration best able to meet task constraints given by the workshop instructor.

The final lesson learned to date is that even though Krisys is a very cost-effective alternative to other robot competitions, it is still too expensive for the programs to provide these to everyone that would like to have one. Another "basic" kit needs to be developed that allows one or two students to build and program the unit which "really works." A tentative solution to this need is discussed in the following section.

Future Plans

With the success the EET/TET Programs have had with the Krisys Robot in generating both a better understanding and differentiation of EET/TET from electrical engineering and computer science, the programs are looking at ways to expand this competition project-based approach to recruiting and outreach on a long-term basis. One of the first things that needed to be accomplished was to secure private support through grant funding from the private sector. This task was recently kicked off and has already produced one multi-year grant. The company reviewed the concept of Krisys and saw it as a way to recruit more women and minorities into the EET/TET Programs thus meeting a major corporate objective. With this and hopefully other private support, the EET/TET Programs have set up a series of short-term goals. These are

- Expanding the number of workshops and events to include 2-year junior/community college offerings
- Making Krisys Kits available to workshop students to support a course project at their school

- Host an open competition during Aggieland Saturaday 2012
- Develop web-based educational materials
- To add a new E-Clock embedded microcontroller-based kit

By expanding the Krisys workshop/competition to two-year schools, the programs seek to identify young men and women who will complete the requisite math, physics and chemistry required for direct transfer to the Look College of Engineering. Informal discussions with instructors at a local community college have generated real interest in including a Krisys workshop as part of a Calculus or Physic course. The current plan calls for a first-pass at this interaction during the Spring 2011 semester. Winners of the competition would be offered scholarships to transfer to the EET/TET Programs at Texas A&M University.

Currently, summer workshop students design and build a Krisys Robot, but after the competition the unit is disassembled and the major parts and pieces are reused to support the next workshop. In many cases, the students want to continue working on and improving their designs, control algorithms, software implementation, etc. With on-going private support of the Krisys initiative, the programs will be able to provide Krisys Kits to workshop students who would like to use the robot in one of their high school courses, projects, or potentially to form a competition team at their high school and return to A&M during Aggieland Saturday or Engineering Day. In this way, the programs will leverage the excitement and interest in electronics and telecommunications to more students. Supporting this goal with web-based teaching materials and seminars will promote further enhancement of the outreach objective.

Although relatively low cost when compared to other robot platforms and competitions, the Krisys platform is still not inexpensive and therefore cannot be used as a mass "take-away" outreach tool. The EET/TET Programs are now working on a much lower cost embedded microcontroller-based kit to meet this demand. Code name "E-Clock", the project has just been started and will develop a small PCB that can be assembled by much younger students, but it will have the processing power to allow significant expansion. The E-Clock approach allows the EET/TET Programs to provide a "starter kit" as a giveaway item at various recruiting events and school visits and then continue to interact with the student through web-based developers club. Increased name recognition is one of the primary goals of this effort. The opportunity to have the electronics and telecommunications engineering technology name seen by many more college-bound students should have a very positive impact on improving the recruiting success of new freshman students.

Summary

The Krisys Robot Platform has met or exceeded the expectation of the EET/TET Programs faculty members in developing a successful and sustainable methodology for recruitment and outreach. As more resources and learning experiences are realized, the scope of the initiative will continue to expand. Having better name recognition among high-school students and having them gain a better appreciation for and ability to differentiate between the Engineering Technology curricula and other more typical electrical engineering and computer science programs is of value to the ability to attract high caliber freshman into technology programs. Expansion to include more availability and variety of workshops and online support for younger students to get started will pay significant dividends in terms of increased enrollment of motivated and capable students. This initiative is also providing a challenging and rewarding

learning experience for undergraduate students involved with the development and delivery of these workshops.

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