Robotics Competition: Providing Structure, Flexibility, and an Extensive Learning Experience

Joseph Grimes and John Seng
California Polytechnic State University, San Luis Obispo, jgrimes@calpoly.edu, jseng@calpoly.edu

Abstract - **This paper presents the design and implementation of the annual robotics competition at Cal Poly State University, San Luis Obispo. Described are the infrastructure used to run the competition, the educational outcomes, and student responsibilities that make this competition an excellent opportunity for broad-based student educational growth. This annual robot competition provides a forum for students to receive educational credit while working on a multi-faceted project that provides an experience that is close to what they would encounter in their future professional career, and to compete for prizes. With faculty advisor supervision, the students have full responsibility for defining the competition rules, designing and constructing the competition course, developing partnerships with industry, and carrying out the competition. Each year the students define a new set of rules for the competition that results in the development of new robots. The key student learning possibilities that will be presented in the paper include:**
a) team-based learning; b) interdisciplinary experience that includes mechanical engineering and computer engineering; c) life-long learning skills; d) communication skills; e) leadership skills. Also this paper will address the key responsibilities of the faculty that are necessary for this student learning experience to be successful.

Index Terms – Robot contest, Learning Outcomes, RoboRodentia, Capstone, Team.

INTRODUCTION

The California Polytechnic State University, San Luis Obispo (Cal Poly) mission statement is partially stated as follows: "Cal Poly fosters teaching, scholarship, and service in a learn-by-doing environment where students and faculty are partners in discovery." In the engineering curriculum, students are heavily engaged in project-based learning and are encouraged to explore and be innovative. The curriculum causes the students to be involved in disciplinary problem solving and critical thinking, as well as direct engagement in their fields of activity. Lifelong learning for them results from self-directed learning such as monitoring professional learning needs, searching out learning resources, and planning their individual learning program. The robot contest discussed in this document is an exemplary opportunity for students to achieve learning outcomes that are generally stated above and the specific university-wide learning objectives of: a) thinking critically and creatively; b) communicating effectively; c) demonstrating expertise in a scholarly discipline and understanding that discipline in relation to the larger world of the arts, sciences, and technology; d) working productively as individuals and in groups; e) using their knowledge and skills to make a positive contribution to society; f) making reasoned decisions based on an understanding of ethics, a respect for diversity, and an awareness of issues relating to sustainability; and g) engaging in lifelong learning. The robot contest learning opportunities have been diverse and the learning has had great depth.

HISTORY

The robot competition at Cal Poly has a rich history of approximately twenty years. It has been called RoboRodentia for the past thirteen years.

RoboRodentia began with students' interest in showcasing their educational experience during the Cal Poly Open House held each year. It has always focused on volunteer students being responsible for and participating in the event under the guidance of faculty members, one of whom has been an advisor for this competition since its beginning. The event was informal in its initial phase with complexity growing as the years passed. It currently requires involvement of the students during the entire academic year.

Student learning is the primary focus of all aspects of the event with competition rule changes now occurring yearly in order to give the students the experience of defining a competition and to give participants the experience of designing a robot from its inception. The competitions of the first few years were more of a demonstration of the ability of students as opposed to a true competition.

Though exciting, the very first event was marred by a last minute decision to move the event outside into a full-sun area. The sun created problems with the tracking sensors and the heat caused some of the components of some of the robots to fail. However, even decisions like this have provided excellent learning experiences.

It was decided at the beginning to make the competition locally defined by Cal Poly and not a part of national competition so that the students could gain experience from defining the rules for the event and have the robot contest experience be a good capstone experience in the Cal Poly curriculum. As the event has become more complex, it has become a near necessity for successful robot development to be a team effort of students with mechanical engineering and computer engineer/scientist skills. A couple of years ago, a faculty-developed board was made available to all student teams to provide a balanced starting point. During the history of the competition, students from other national and international universities have participated in RoboRodentia. It has grown from an audience of a few to one of nearly 2000 spectators.

LEARNING OUTCOMES

Achieving excellent student learning outcomes has been the driver behind how the robot contests are planned, defined, and implemented. The learning outcomes fall under one of three major categories: a) participating in the process of developing an engineering product; b) defining the rules for the robot competition; and c) planning and executing the event. Any student may choose to participate in part or all of the learning opportunities.

FIGURE 1
STUDENT TEAM PREPARING FOR COMPETITION

The first and most important learning outcome is to give students an opportunity to participate in a capstone experience. They are not required to be currently enrolled in a course although they may receive senior project or independent study course credit for their efforts. This experience allows them to work on a team to aid in learning how to carry out the stages of the life cycle of an engineering product that must meet a defined set of specifications: a) perform an analysis of the specifications; b) design the robot to meet the specifications; c) build the robot according to the design; d) test the robot to see if it meets the specification; and e) maintain the robot and enhance its capability within contest and budgetary constraints. As with any project, if a problem arises at any of the stages (for most this would happen) students gain experience in iterating back through the appropriate stages of the robot life cycle. Playing the role of coach, the faculty provides workshops and advice as appropriate. Figure 1 shows a team with good team skills participating in the contest [1].

Students who participate in robot competitions have an interdisciplinary experience developing a robot that requires computation, electrical, and mechanical skills. This is one of the reasons for the success and popularity of robotics competitions at many universities [2,3,4]. Students have an opportunity to work on a team and develop teamwork skills and/or work with students from other disciplines. During the competition, students: a) get the experience of honing oral communication skills by describing their robot development experience and why they decided to use their particular design; b) have an opportunity to complete under pressure and make unanticipated adjustments to fix an unanticipated problem; and c) compete while watched by a large audience.

Defining the rules for the competition probably provides the second most valuable learning experience. This involves a faculty guided team of students developing a set of rules for competition that are challenging but achievable, that will not tolerate gaming the system or destruction of opponent's robots, and that will require the robot creators to use much of the knowledge that they have gained through courses that they have taken. During the rules development exercise, students achieve the ability to: a) develop knowledge of the limitations of the robots; b) weigh the tradeoffs between different choices; c) negotiate with others; d) work in a team to define a set of specifications.

Event planning and implementation is the third valuable learning experience that is performed by a team of students. Again with faculty supervision, the students are responsible for finding industry sponsors to fund the event. They must advertise the event, prepare directional traffic and foot signage for the day of the event, and design shirts. They also are responsible for facility reservation, audiovisual equipment, food for participants, announcing the event, setup of the competition course, acquiring and setting up tables for competitors to use, acquiring any other necessary event items, and monitoring the facility after it is made available to the participants. These activities give them the opportunity to develop some management skills that they may find valuable after they graduate.

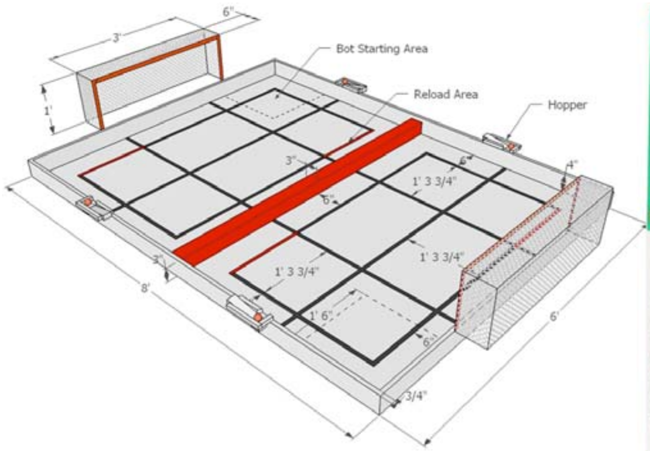

FIGURE 2
2008 ROBORODENTIA COMPETITION COURSE

FIGURE 3
POLYBOT BOARD

CONTEST COURSE AND RULES

The following general description of the unique rules for this year's contest provides the general guidelines that the contestants must follow in designing and implementing their robots. The diagram in Figure 2 defines the layout of the competition course. The goal for this year's contest participants is to collect as many standard ping pong balls from the hopper on the left and right sides of their side of the course and launch them into the goal located on the opponent's side of the course. Two robots compete in a given match.

At the start of each match, Robots must fit within a cube of 12" on each side and must be fully autonomous.

The contest is typically announced in October and the actual contest is held in late April. In order to achieve greatest success, this year's contest requires line-following capability, a reliable ball shooting mechanism, and a ball loading mechanism. The contest definition allows competitors to be creative while providing for fair competition and score keeping. In this year's contest, the lines on the ground are placed so that they provide a reference point as to where the hoppers are located.

POLYBOT BOARD AND VALUE TO LEARNING

The PolyBot board [5] in Figure 3 is a robotics controller board that was specifically designed by students and a Cal Poly faculty member for use in the RoboRodentia competition. It is inspired by the popular Handy Board [6] robot controller board that is based on the Motorola HC11. The goal for the PolyBot board design was to achieve a similar level of ease of use while adding additional functionality specific to RoboRodentia.

The PolyBot board features the following specifications: a) several input ports (digital and analog); b) eight hobby servo outputs; and c) a backlight LCD port. Digital and analog input pins provide a means for the students to connect various sensors of the robot to the board. The digital pins are used for mechanical switches and break-beam light sensors. Analog input pins are used when connecting infrared photoreflectance sensors to detect light or dark surface. Also, potentiometers are sometimes connected to the analog input pins.

The drive motors for robots that enter RoboRodentia are typically based on small DC motors and/or hobby servos modified for continuous rotation. This made it necessary to provide PolyBot support for both types of motors. In addition to the drive motors, hobby servos are the primary means of actuating any type of articulating robot arm, grabber, or scoop.

Students are provided a C library to read the various inputs, control the servos, and manage the LCD display. The software for the PolyBot board is written in C and compiled using GCC. For the PolyBot microcontroller, there is a C library that is actively being further developed and well supported.

At the outset of designing the controller board, we believed that providing a standard board design on campus would improve the students' designs as it would provide a controller starting point familiar to them. Before the PolyBot board was provided, students typically selected a controller board based on the programming language it supported (typically assembly or C) and the features that the controller provided. The boards that students used were all microcontroller-based boards representing various popular instruction sets.

Over a typical 6 month design cycle for a robot, a student group may spend a considerable amount of time becoming familiar with a robotics controller and it was our belief that greater learning would be achieved by spending time on other robot design and implementation considerations. In the past, without the current Cal Poly support for their selected controller, the students' progress was sometimes slowed and has led to robots that were less sophisticated in their software and not as reliable.

One design decision with the PolyBot board that has both positive and negative educational ramifications is the provided software library. The software library provides servo control functions, motor control functions, and various other methods that abstract away some of the inner working of the microcontroller. The educational benefit of providing the library is that the students can focus on higher-level algorithms without having to program some of the lower 'device-level' functionality into their robot. This results in robots that are more robust and have better intelligence algorithms. At the same time, providing students with a pre-built library keeps them from having to implement the lower-level functionality, which could be a good educational experience for an undergraduate engineering student.

For the competition, we do not require that students use a particular controller board, but we have found that most opt to use the PolyBot board. We have found that developing this board has led to the development of a student community and support for the board. Several students are familiar with using the controller and they provide technical support for the younger students who are just learning about robotics. Student teams have been more successful in designing and implementing robots with the supplied PolyBot board.

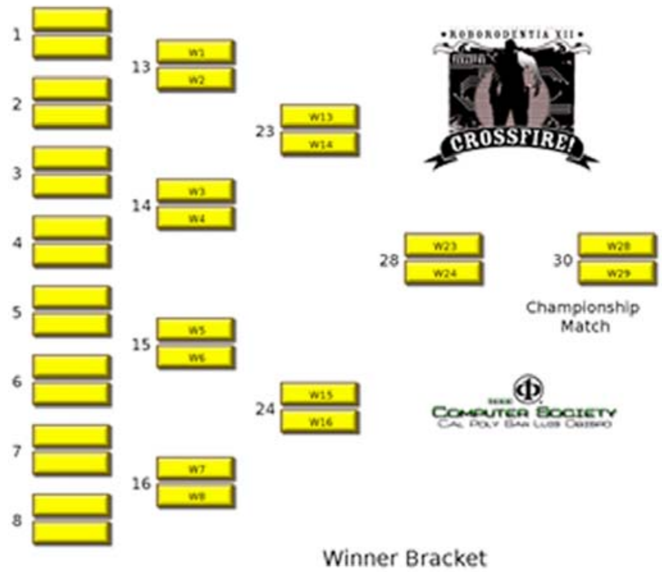

FIGURE 4
SCREENSHOT OF CONTEST TOURNAMENT SOFTWARE INTERFACE

SCOREKEEPING HARDWARE AND SOFTWARE

In order to manage the competition, we developed custom hardware and software for the double-elimination, head-to-head style tournament. These consist of a software GUI application and hardware scorekeeping devices. The tournament software runs under Windows and is written in PyGTK [7]. This toolkit provides Python bindings for the GTK toolkit. Because the application is written in Python in combination with a graphical toolkit, it allows us to easily modify the application when necessary and create a visually pleasing interface for the audience. The hardware scorekeeping devices are used to maintain the score during a particular match. Maintaining a real time score is important in engaging the contest audience. The scorekeeping devices consist of a handheld 2.4 GHz wireless module mated with a microcontroller. Figure 4 is a screenshot of the scorekeeping software.

These tools were developed by a faculty member and student contest organizers. The software was developed as an extracurricular project. The wireless hardware was developed as part of an embedded systems class project. The development of these management tools provided students with experience of creating a hardware system and the maintenance of the software.

FUTURE DIRECTIONS FOR THE COMPETITION

Although this robotics competition can be improved in a number of ways, we see 2 primary areas that can be further developed. One of the areas where we would like to focus our attention is the area of freshmen involvement. We believe that finding ways to incorporate freshmen level students into such a competition can greatly enhance their engineering experience and develop them into leaders.

Robotics competitions provide an excellent ‘hook’ to attract and retain students in the field of engineering whether it is mechanical, electrical, or computer science. We have been continually encouraging teams to recruit freshmen students to be team members, and currently we are looking into assembling teams consisting solely of freshmen students and providing additional mentoring for these teams. Having a team of freshmen students will provide them with a challenge and at the same time inspire other contestants as well.

Another area that will be developed is the area of sponsorship. Our competition is funded by a single corporate sponsor along with additional university funding. It would improve the competition to obtain sponsorship from several industrial sources. In addition to the increased visibility and funding that comes with broad corporate sponsorship, it would provide an opportunity for companies to interact with students who are passionate about their engineering experience through this competition. Contest participants currently have to fund their own robot designs, which does impose budgetary constraints on the participants. While budgetary constrains do reflect what students would face in industry, with greater corporate sponsorship, the competition organizers may be able to provide some initial funding for contestants. This may increase participation as a whole and at the same time allow students to pursue more complex designs.

CONCLUSION

The robotics competition at Cal Poly State University, San Luis Obispo involves groups of Cal Poly engineering students or outside teams who build an autonomous mobile robot for the contest. The rules and layout for a competition provide a challenge but allow for creativity in the design. In addition, some of the technical infrastructure was created in order to streamline various aspects of the contest. The PolyBot board is a controller that was developed in order to provide the contestants with a basic microcontroller platform. In order to display the contest bracket and manage scoring, a hardware/software system was developed. The development of both of these systems involved faculty and student engineering work.

It is important that students be involved in every aspect of the contest. The competition is run by a group of students who manage the development of the competition, organization of event logistics, and acquisition of necessary resources.

Another important aspect is that contestants are challenged with different engineering problems which are multi-disciplinary. Building autonomous mobile robots requires solving problems in the areas of computer, electrical, and mechanical engineering. In addition, the students are often faced with budgetary constraints.

The educational aspects of this robotics competition are diverse and the learning outcomes go far beyond the contest itself. The contest teaches the students involved to think critically and creatively, and it promotes a level of initiative that is beyond a typical classroom experience. The involved students in the contest extend their knowledge of one or more disciplines, advance their ability to work across disciplines, develop team participation skills, learn how to apply their knowledge, and develop management and planning skills that they find valuable after they graduate. Most students heavily involved in RoboRodentia take the most desirous professional positions that are available or go into excellent graduate programs.

REFERENCES

[1] Michaelsen, L, K, Knight, A, B, Fink, L, D, “*Team-Based Learning: A Transformative Use of Small Groups in College Teaching*”, 2004.

[2] Almeida, L., Fonseca, P., Azevedo, J., “The Micro-Rato Contest: A Popular Approach to Improve Self-Study in Electronics an d Computer Science”, *International Conference on Systems, Man, and Cybernetics*, October 2000

[3] Trinity College Fire Fighting Contest, Retrieved March 21, 2008, http://www.trincoll.edu/events/robot/

[4] RoboGames Robotics Competitions, Retrieved March 21, 2008, http://www.robogames.net

[5] Seng, J., S., “PolyBot Board: A Controller for Robotics Applications and Education”, *2006 International Conference on Frontiers in Education: Computer Science and Computer Engineering*, June 2006

[6] Martin, F., The Handy Board Technical Reference, http://www.handyboard.com/techdocs/hbmanual.pdf, November 2000

[7] GTK+ for Python, Retrieved March 21, 2008, http://www.gtk.org

AUTHOR INFORMATION

Joe Grimes, Director of Faculty Professional Development and Professor of Computer Science, California Polytechnic State University, San Luis Obispo, jgrimes@calpoly.edu

John Seng, Assistant Professor of Computer Science, California Polytechnic State University, San Luis Obispo, jseng@calpoly.edu