Session A-T1-1

INTEGRATING NATIONAL ROBOTICS COMPETITIONS INTO MULTIDISCIPLINARY SENIOR PROJECT COURSES

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1. INTRODUCTION

The integration of multidisciplinary projects to engineering education holds many benefits for students. In addition to giving them real-world experience working with members outside of their area of expertise, this can also expose students to subjects not covered by their curriculum. It is beneficial for programs in that it satisfies many ABET outcomes, including giving students the ability to work in teams. It also allows engineering programs to have projects of a more comprehensive scope.

Finding such projects, though, is often difficult. It requires finding a project that not only incorporates the different disciplines involved, but one that also has the appropriate ratio of content for the students involved. Additional concerns involve the motivation of students on the project as well as budget issues.

The Electrical and Computer Engineering and Mechanical Engineering Departments at Valparaiso University have offered a multidisciplinary senior design course for their students for the past four years and have found that robotic competitions have been very fruitful projects for such a course. In this paper, we relate our experiences in this course with such projects, and discuss the benefits and drawbacks of such an approach.

2. BACKGROUND: MULTIDISCIPLINARY SENIOR PROJECTS

In the fall of 2001, Valparaiso University's College of Engineering merged the course of Mechanical Engineering Senior Design with the senior design course of Electrical and Computer Engineering. The resulting course consisted of a two-semester sequence of two-credit courses. The courses focused on teamwork, the design process, professional issues, as well as the fabrication of a prototype for the project. Teams typically consisted of three electrical/computer engineers and two mechanical engineers. Projects were suggested by faculty at the beginning of the year, and students listed their preferences from that list and were assigned teams by the two coordinators for the course, one from each department. Each team was advised by a faculty member from each department, and each team met weekly with these co-advisors. Weekly lectures were also given by the course faculty.

As this course sequence was offered in successive semesters, improvements were made based on experience and student feedback. Presently, there are no coordinators for the course, and each team has a primary advisor responsible for all administrative tasks for that group (e.g. grading). The team has a technical advisor from the alternate department, whose sole job is to help with any aspects of the project with which their primary advisor is unfamiliar. This was done to give students a single point-of-contact and to address diffusion of responsibility concerns that appeared in early course offerings.

The course focuses primarily on the design process. Students first meet with a "customer" for their project, who informs students of his/her needs. Students then complete a list of system requirements for the project. Teams research subjects needed for the completion of the project, and prepare an electronic prototype consisting of simulations and CAD diagrams in order to verify that their design will meet their requirements. Once the team's advisor approves this preliminary design, students may then order parts and begin building their prototype. When the prototype is completed, students must submit a test plan describing how they will test and verify each of the items in their original system requirements document. Throughout the semester, students give oral presentations on their projects.

This course sequence has been tremendously successful, increasing the design skills, teamwork skills, and multidisciplinarity of both electrical and mechanical engineers at Valparaiso University. The greatest challenge in organizing this course is in identifying appropriate design projects to be implemented by the student teams. It is actually very challenging to find projects that are of appropriate difficulty (neither too easy nor too difficult), involve both disciplines equally, and have significant design content. If possible, it is also desirable to have the projects sponsored by an external customer, which adds an extra degree of accountability to the team members and helps them to see that their project is being used to address a "real-world" problem.

One excellent way of motivating students is to have the external "customer" be a national design competition. In this way, students know that they will be given the opportunity to test their design against other, similar teams from around the country who have been given the same challenge. They also have the prospect of receiving recognition if their design is judged to be exceptional. There are many types of national design competitions, but the ones that have proven most helpful for our purposes are robotic competitions.

3. ROBOTIC COMPETITIONS

Robotic competitions have many benefits when selected as design projects for courses such as those outlined above.

- Robotics is inherently multidisciplinary, so students have a chance to work on a project that requires a variety of different areas of expertise, ranging from embedded microcontrollers and sensors to motors and mechanisms.

- The design constraints are very clearly defined, giving students a realistic experience in which the definition of a successful design has been clearly identified.
- Students are motivated by the opportunity to directly compete against the designs of other teams, both from their own class as well as from other universities.
- They are also motivated by the knowledge that they will have to demonstrate their project's success or failure in front of a large group of people.
- The very visual nature of a robotic project provides positive feedback to students as they make progress toward their ultimate goal. Every time a major milestone is met (e.g., the robot moves for the first time, the robot correctly completes the maze for the first time, etc.), the team's motivation increases even further.
- If teams participate in the same robotic competition for a number of years, teams can build on the lessons learned by previous design teams. It is rare to see non-robotic-competition teams reading previous years' final design reports, but it is common to see robotic competition teams doing so.
- The robots themselves can be used for demonstration purposes long after the competition has ended and the team members have graduated. Such demonstrations can be part of community outreach activities to promote careers in engineering, or they can be part of on-campus recruiting efforts. (Matson and DeLoach, 2002)

Valparaiso University has participated in four major robotic design competitions over the past five years, with widely varying levels of design success and student satisfaction. In the following subsections, each of these four competitions will be described, along with the experience

3.1 Trinity College Fire Fighting Robot Competition.

Trinity College in Hartford, Connecticut has hosted this international competition for each of the past twelve years. Last year, more than one hundred teams participated in this two-day competition, including one team from Valparaiso University. The teams ranged from middle school students to graduate students, with a variety of different divisions to ensure fair competition. Each team was asked to design a robot that would autonomously explore a model house approximately 8' x 8', locate a lit candle, and extinguish it. Additional bonus points could be earned for meeting challenges such as avoiding furniture and climbing stairs. (Ahlgren and Verner, 2001; Verner and Ahlgren, 2002)

One of the greatest strengths of this competition is that, as technology improvements make the challenges easier, the contest facilitators introduce new facets of the competition in order to continually keep it challenging. For example, whereas in 2004 climbing stairs was a bonus option, it is now a standard requirement for all teams. New challenges introduced this year include the use of different floor surfaces and the option to locate and tag an "infant" identified by a visible beacon. The standard floor plan of the model house for 2005 is shown in figure 1.

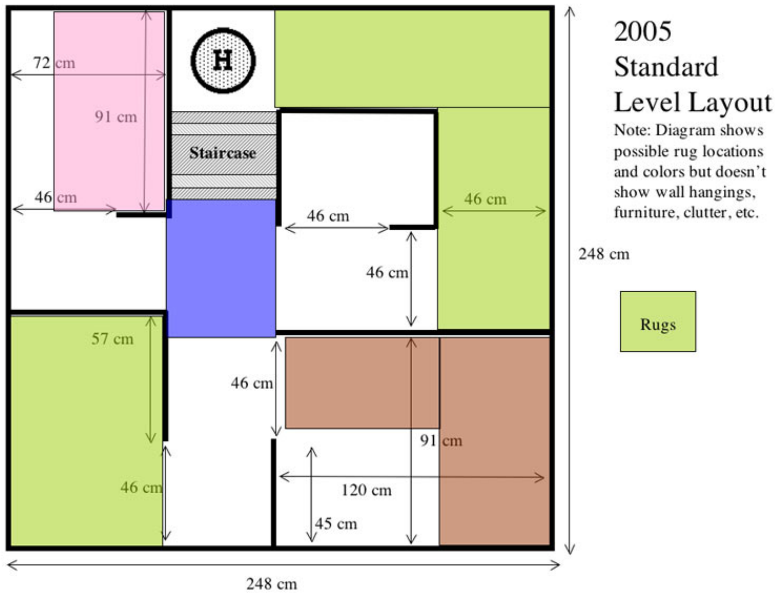

Figure 1: The standard house layout for the 2005 senior division.
(Courtesy of http://www.trincoll.edu/events/robot/)

Valparaiso University first sent a robot to this competition in 2002. The robot was designed and built by a team of students from the multidisciplinary senior design sequence, and they won first prize in the senior division. This was a very pleasant surprise, because the team had only hoped to place in the top half of teams competing. The members of the winning team are shown in figure 2, along with their robot and the model house they built for practicing with their robot.

Figure 2: The 2002 senior division winning team.

After this initial success, we were able to obtain a sponsorship from Task Force Tips, a local company that makes fire hose nozzles, to cover the cost of components and travel expenses.

With such a strong first showing and new financial backing, it appeared that future success was very likely.

However, as good as the 2002 team's robot was, their documentation was very poor. The members of the team had worked very hard to optimize their robot, but their experience and expertise were lost when all six members of the team graduated, and four of them left the country.

In 2003, two teams built robots with the intention of participating in the competition, but it was scheduled for the same weekend as the Fundamentals of Engineering exam, so no students were able to attend the competition. Students on both teams were frustrated and disappointed by this fact, and neither team did a good job in completing the design of their robot.

In 2004, it was decided to focus all of our efforts on building one robot that would have the best possible chance of success in the competition. The members of the team committed to attending the competition regardless of the date, and they worked very hard to design a high-quality robot. In spite of their best efforts, design flaws and bad luck on the day of the competition prevented them from doing as well as they had hoped. Still, they finished in the top 25% of teams, coming in tied for 14th out of 55 teams in their division. The robot designed by this team is shown in figure 3.

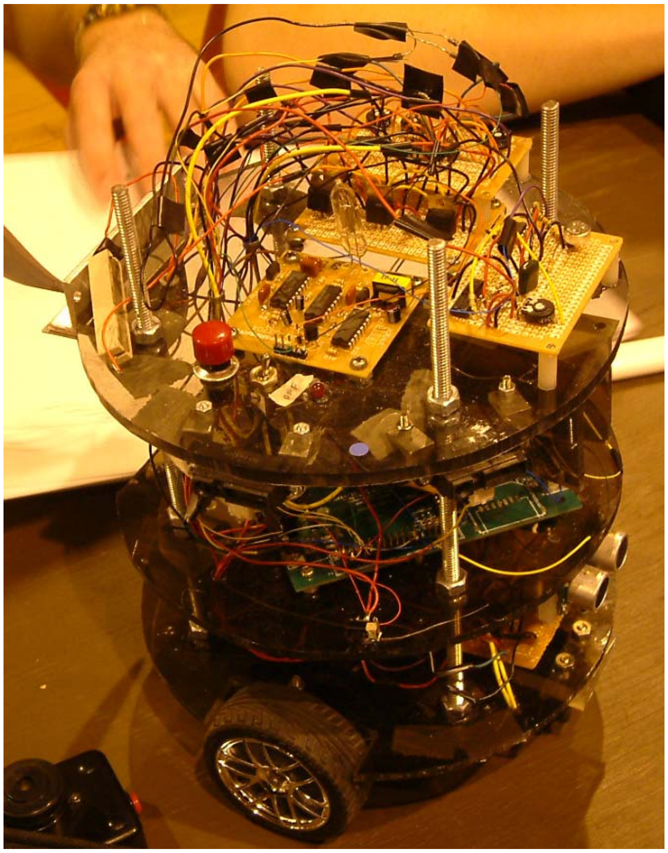

Figure 3: The 2004 Valparaiso University fire-fighting robot.

In spite of this somewhat disappointing outcome, it provided a much stronger foundation for future success than the 2002 championship had done. The members of the team (as well as their faculty advisor) learned a great deal while participating in the competition, and they were confident that if they had the opportunity to go back and change two early design decisions (the type of motor controller and the type of floor sensor), they would have placed in the top five in their division. The team wrote an excellent final report that outlined these recommendations, and reading this report was the first task of the 2005 team.

The 2005 team is working diligently to prepare for their trip to Hartford, CT in April 2005. From all indications, they will build on the lessons learned in previous years and will bring a robot that has an excellent chance of winning the competition.

3.2 AMD Jerry Sanders Creative Design Competition.

The Jerry Sanders Creative Design Competition is held each year at the University of Illinois at Urbana-Champaign and is sponsored by Advanced Micro Devices. Presently, it is in its 18th year. Generally, a newly designed course is presented each year with a unique task. This year's competition involves a course with four-inch balls placed throughout the area at different heights. Robots need collect these balls and place them in areas for points. Four robots compete simultaneously. A course layout is shown in Figure 4.

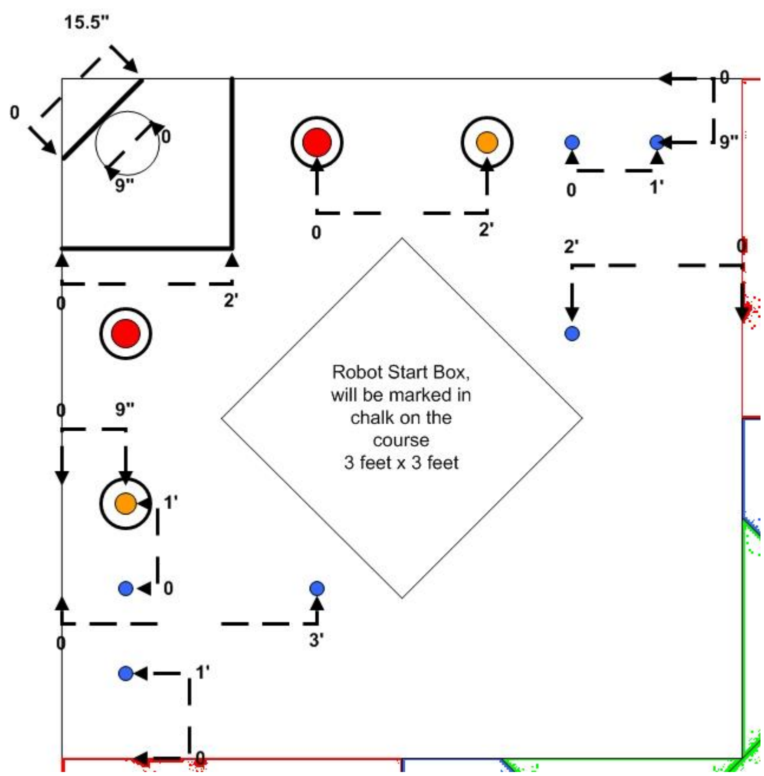

Figure 4: The 2005 competition layout

Previous years' contests included a course with Tetris-like blocks that robots had to stack, a maze with light bulbs in sockets that the robots had to remove, and a course for robots to collect helium balloons. Most robots are controlled remotely, and few are autonomous. The second day of the contest often involves the popular battle royal for robots in demolition derby style.

Valparaiso teams have participated in the contest each of the last three years. In year one, our team scored in the 50th percentile, which was a rewarding experience. Students in that year made a robot from scratch using 80/20 aluminium material, and a mechanism for collecting balloons. This robot failed in two rounds by a slipped chain, which rendered the robot unusable. The team further had considerable problems with the motor driving circuits. Still, we considered the year a success.

In the 2004 competition, the student team reused the frame from the previous year, but redesigned the drive train for the robot. The power supply system was substantially redesigned and made much more robust. Since the object of the competition had changed from the previous year, the end–effector was changed to suit the present task. This team benefited substantially from the work done in the previous semesters, and they were able to concentrate on issues of fine-tuning.

The competition this year requires a much lighter, faster robot. Because of this, the present team has redesigned the frame and drive train, producing a robot with approximately half the mass and twice the power of the previous years' robots. This has led to much more work for the team, and the end-effector for the robot is underdeveloped at the present time, due to the effort diverted to the frame and drive train itself.

3.3 IEEE Micromouse Competition.

The IEEE Micromouse competition was first announced in the late 1970s. At the time, this was an incredibly challenging competition, and it remains very challenging even today. In this competition, a small robot must navigate through a random maze of 10,000 cells in a 100x100 grid that is six inches on a side. The small size of the maze cells requires students to design a very compact robot, and the random nature of the maze requires that the robot use an advanced path-planning algorithm along with an array of dedicated sensors. The technical challenges posed by this competition make it an excellent educational experience for even the most talented of students. (Chung and Anneberg, 2003; Martin, 2001)

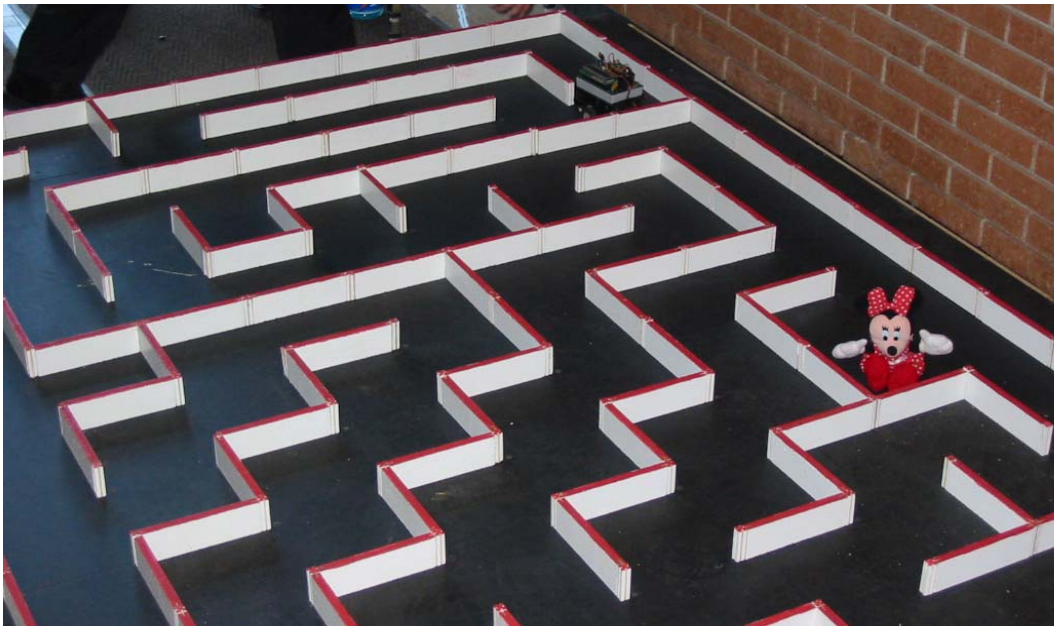

Figure 5: The MicroMouse maze.

Valparaiso University has had two senior design teams design and build robots for this competition. The first, a team of very talented electrical engineering students in 1998, succeeded in designing a robot that could occasionally solve the maze. The primary difficulty was not in decision-making about the correct path to follow, but rather in keeping track of the robot's location and orientation within the maze. This team developed an algorithm that would always successfully determine the best path to the destination, but their robot would frequently get "hung up" in the maze and lose track of where it was.

The next team to attempt this very challenging problem was a multidisciplinary team from 2003. Unfortunately, this team did not learn from the lessons of the previous team. They were also less dedicated to the problem and less capable of solving it, so their solution was not as strong as the previous team's.

The greatest drawback of this competition is that there do not appear to be any regional competitions within 500 miles of campus. There are many competition sites on both the east and west coast, but nothing near Illinois or Indiana. Valparaiso University's College of Engineering attempted to host a competition as part of their annual Design Expo in 2003, but in spite of significant publicity efforts, no other teams travelled to campus to participate in the competition.

This demonstrates a challenging paradox associated with starting up a new regional robotic competition: It is difficult to encourage teams at other universities to prepare for a robotic competition unless they are certain it will be a positive experience for their students, and it is difficult to ensure that it will be an exciting and positive event unless other schools commit to participate.

3.4. FIRST Robotics Competition.

Although not directly associated with a particular engineering course, it is also important to note that Valparaiso University's work with robotics competitions has recently extended to Wheeler High School, which is located approximately ten miles west of campus. The expertise developed by the faculty in microcontrollers, sensors, actuators, motors, power electronics, and mechanisms has been very helpful as we have co-sponsored a team of high-school and middle-school students who participate in a series of regional and national competitions each spring. Last year, more than a dozen students and faculty helped with this project, volunteering a total of more than 100 hours of service in an effort to excite talented young people about the possibility of a career in science or engineering.

Figure 6: FIRST robotics team 1000—The Cybearcats

This effort has proven very worthwhile, both for the individuals involved and for the institution. It has allowed the university to establish and maintain a very close relationship with an important local school, it has provided excellent opportunities for university students to improve their communication and teamwork skills, and it has provided excellent local publicity for the school. Most importantly, our work with this team has contributed to the development and education of more than twenty young people who may someday choose to pursue a career based on their positive experiences in this competition. (Tougaw, *et. al*., 2003)

4. LESSONS LEARNED

Overall, we have found that robotic competitions have served as excellent projects for our multidisciplinary senior design course. Key lessons include:

- Participating in a competition several years in a row holds great benefit, not only in developing expertise, but also in the reuse of components and materials.
- It is beneficial to have underclass students participate in the project along with the seniors to provide continuity for upcoming years.
- Though placing highly in contests is rewarding, instructors should gauge success by the experience students have and the amount they learn. This should be very clearly communicated to the students.
- Competitions promote the institution and provide public recognition of student work, and serve as a valuable recruiting tool.
- Documentation of work and designs is critical for providing a resource for future teams.
- Students find robotic competitions rewarding and extremely motivating
- Competitions are usually well-defined with rules and objectives, which form a good basis for students in the definition stage of their design.
- It is absolutely essential to set early deadlines for deliverables. Teams should be required to deliver their future design at least one week ahead of the contest for final testing and fine-tuning. Early completion is one of the single greatest indicators for success.
- Robotic competitions often make possible financial resources, either from donors or from the contest itself.

5. CONCLUSIONS

Interdisciplinary design is an essential part of an engineering education today. One successful way of imparting this experience to students is through multidisciplinary senior design courses. Though projects for such an experience are often hard to find, robotic competitions frequently provide appropriate material. Our experience has been that such competition-based projects are very successful and lead to many benefits. The four contests described here each offer their own advantages and disadvantages, but provide valuable lessons from their experiences. Foremost is that these competitions are motivating to students, provide good ideas for appropriate projects, and can lead to projects for several successive years.

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