Transplanting a Robotic Hockey Competition between Universities

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Competitions have been used for engineering design education for several decades in the United States, and starting in the early 1990s, competitions ranging from FIRST and Robocup to DARPAs "Grand Challenge" generated interest in robotics in specific, and engineering in general. This paper discusses advantages and disadvantages to utilizing existing competitions to generate design projects for capstone courses, as well as tradeoffs between participation in existing competitions and creating a new one for the design course. Finally, our experience is presented at adapting a local competition from the mechatronics lab of the University of Pennsylvania for use in an engineering science program at Trinity University in San Antonio.

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Introduction

Engineering educators are constantly looking for authentic, motivating, and relevant design challenges for their students. Jakubowski [1] identifies project selection as one of the most challenging aspects of a capstone design course.

Harrisberg et al. [1] categorize experiential learning activities into "simulations" and "authentic experiences", highlighting the advantages of each. In particular, faculty can control the scope and scale of a "simulated" project, and ensure that the relevant learning outcomes [2] are addressed. The open-ended nature of "authentic design experiences" provides students with a valuable learning experience that more closely resembles the practice of engineering.

Clearly, there are advantages to having either "simulated" and "authentic" experiences in the portfolio of a capstone program, or to having a mix of experiences [4]. Faculty often consider that capstone design projects from industrial sponsors or scenarios to be very open-ended and address more real-world scenarios than more constrained projects. Competitions may proved a more authentic, less "simulated" experience while still providing structure to the experience for the students.

Competitions as Design Projects

Design projects vary widely between programs, departments, and universities. One of the many differences that can be drawn between projects is the degree of control the instructor maintains [3] over the project. One advantage of "simulations, case studies, and contrived situations" [1] is that the instructor can optimize the situation and tune the learning outcomes associated with a given course/project. In addition, the instructor can ensure that projects have possible solutions of an appropriate level of difficulty and scale suitable for the relevant students.

More industrial projects, having a real need and client, provide design teams with a more authentic experience, but the instructor loses some degree of control over project makeup and scale [4], or project selection becomes a very challenging process.

Competitions offer an intriguing middle-ground, providing open-ended challenging problems for students [5] [6] while automatically limiting the scope and focus of the potential solutions.

National design competitions have a long history in engineering education. The Illuminating Engineering Society, in cooperation with the Royal Institute of British Architects and the Institution of Electrical Engineers, offered a £75 prize for designing the layout, lighting, decoration, and furnishings for a dining room and cocktail bar in a city hotel in 1954 [7]. IEEE proposed the Micro-mouse robot competition in 1977 [8]. Competitions allow students across the country to work on a similar project. This has a motivating effect on the students [9], and allows them to interact with students from other universities.

The motivating effect of competition has caused a proliferation of these competitions, ranging from K-12 projects intended to motivate students to stay in school and study science and engineering in the first place, such as FIRST (For Inspiration and Recognition of Science and Technology) [10], to competitions intended to help provide authentic learning experiences for undergraduates [5] [6], to graduate level competitions intended to drive research forward in a research field, such as the AAAI Robot Competition [11], Robocup [12] [13], and the DARPA Grand Challenges [14].

It is worth noting that "Industrial" and "Competition" are not mutually exclusive, as evidenced by the growing sponsorship of competitions by companies, and even companies creating their own competitions [16][17]. While the types of capstone design projects undertaken for an industry-academic collaboration will be different from those undertaken for an industry-sponsored student competition, companies clearly appreciate the motivation, problem-solving skill development, and design experiences brought by these competitions.

There are several difficulties with incorporating participation in these competitions as a design project for a credit-bearing course, however. If a design course has many teams working on the same project, the sheer numbers of teams could overwhelm the competition organizers. The timing of the competition could make tight integration with course deliverables difficult. The expenses associated with travel and entry into competitions also adds a burden to either the sponsoring department or the design team (in terms of monetary contributions and/or fundraising efforts).

One reaction to these challenges is to design a local competition that has many of the attributes of a broader competition, but has rules, timetables, and deliverables customized to the local program. One such local competition is the "Robockey" robot hockey competition held in 2008, 2009 and 2011 for MEAM 410/510 (Mechatronics Course) at the University of Pennsylvania [15] [16].

Robockey at University of Pennsylvania

The department of mechanical engineering and applied mechanics at the University of Pennsylvania coordinates a Mechatronics Design lab, which includes facilities for laser cutting, 3-d printing, and machining of parts. The lab supports various mechatronics and design projects, including custom-designed microcontroller [17], and has an impressive portfolio of competitions.

One such competition is part of the senior/graduate level course MEAM 410/510 Design of Mechatronic Systems. Robockey, or Robot Hockey, is played by a team of 1-3 robots sporting identifying glyphs[18], tracked by an overhead camera. The puck has infrared light emitting diodes (LEDs) that can be seen by the robots. Henceforth, this version of Robockey will be referred to as Robockey @ UPenn.

Trinity University & Engineering

Trinity University is a small private liberal arts and sciences University in San Antonio Texas. The Engineering Science Department at Trinity University is an unusual one. We offer a broad-based curriculum with a grounding in the "fundamentals" of electrical, mechanical, and chemical engineering, along with some specialization through disciplinary electives. Students earn a B.S. in Engineering Science, and customize their program with help from their academic advisor. More detailed information on the program is given in a paper by Uddin [19].

The Senior Design Course has been a mainstay of the engineering educational experience at Trinity for many years, and has been in its present form since approximately 1985. There is one course administrator, who coordinates the efforts of all the group advisors, sets course policy, gives guidance to the students on expectations, procedures, and policy, and provides any new course content either directly or via guests from the faculty and industry. Each faculty advisor works with a group of four to five students, providing technical advice, day-to-day project management, progress feedback, etc. The group advisor has the majority of the grading responsibility for the course.

One of five senior design projects for the 2011-2012 year is to adapt the Robockey competition for use at Trinity, starting with the Spring 2012 offering of the mechatronics course. The senior design course, like the department, is very interdisciplinary - the other projects are an airborne photography platform, an improved humane cat trap for feral cats, a solar-powered hot water heater for low-income home, and a microwave-based chemical characterization device.

Mechatronics at Trinity

The Engineering Science program at Trinity builds on the fundamentals of mathematics, science, electrical, chemical, and mechanical engineering. Students in their first two years undertake required cornerstone courses in engineering design, mathematics, physics, chemistry, statics, dynamics, mass/energy balances, and electric circuits. In their next two years, they continue deepening their engineering knowledge with more engineering design, thermodynamics, control systems, fluid mechanics, heat transfer, materials, and some electives in mechanical, chemical, and/or electrical engineering.

One of these electives is ENGR 4367, Mechatronics. This course is split into roughly three parts. The first third is a survey of supporting theory – some review, some new to Trinity students – including circuits/electronics, control architectures, digital electronics, data acquisition & sampling, and microcontrollers. The second module extends students' understanding of feedback control and applies it to modern and digital controllers (state space, digital control). The third part of the course, interspersed chronologically throughout the semester, involves labs on each topic, culminating in a course project that integrates one part from each supporting module. This project is heavily inspired by David Alciatore's MECH307 Mechatronics course at Colorado State [20].

This very interdisciplinary course takes advantage of Trinity students' broad background in mathematics and several fields of engineering, and applies it to an inherently interdisciplinary topic.

Robockey @ Trinity

In order to adapt the Robockey @ UPenn competition for use at Trinity, the design team needs to develop the infrastructure, adapt the rules, and field a team for the inaugural competition.

Infrastructure

The infrastructure for the robockey competition includes a rink, an overhead camera, glyph tracking software, game control software, a puck, and a house-bot (an opponent for the inaugural team to compete against).

The rink is well-described by Feine [15], and was easily constructed from a 4'x8' sheet of plywood, a 4'x8' sheet of melamine, and Plexiglas.

The overhead tracking camera was a greyscale USB2.0 camera from Mightex Systems (BCE-BG04-U) [21] that Trinity had purchased for a previous design project. A wide-angle lens suitable for imaging the entire field was specified and purchased.

The glyph tracking software used at the University of Pennsylvania [22] is not freely available for current distributions of Linux or Windows, but a similar project, Glyph Recognition [18], a part of the A.Forge open-source project [23] was located and adapted for use in the project.

The decision was made to utilize the M2 custom microcontroller board, based on the ATmega32U4 processor developed and used at the University of Pennsylvania, for both the game control software and the student robots.

The game control software consists of a single M2 communicating with the computer doing the overhead robot tracking. A Nordic wireless module known to work with the M2 was chosen to communicate with wireless modules on the robots.

The IR-emitting puck is well described by Feine [15], but both the electrical and mechanical designs needed to be replicated and manufactured locally. The Trinity puck is powered by a 9V battery and carries 12 LTE-4206 infrared light emitting diodes (LEDs), instead of the 8 specified. Local testing revealed significant "dead spots" around the puck with 8 LEDs on a prototype.

The overhead florescent lights at Trinity also contain a significant amount of energy in the 940 nm range, interfering with the student robots. Alternative lighting sources are under consideration.

Finally, since a single team is fielding a robot team for the inaugural competition, a team of "house-bots" [24] will need to be developed and fielded.

The investment in time and money in transplanting a local competition should be considered when considering utilizing one as a design project. An established competition will often specify components and designs for infrastructure [25] that make replication easier.

Rules

The rules developed for Robockey @ UPenn were analyzed and may need to be adapted for use at Trinity. Certainly, the number of teams competing (26 teams in 2011, 14 teams in 2009, 8 teams in 2008) may allow the use of simpler rules at Trinity. There are 16 students in ENGR-4367 in Spring 2012, so the tournament structure may be simpler.

The size constraint on the robots may also need to be relaxed, since the UPenn students rely heavily on laser-cut acrylic as mechanical building material, and Trinity students will need to hand-machine all parts.

As the design team adapting the project is working to support the Spring 2012 mechatronics class, further rules changes are under consideration. Adapting the rules of a local competition to better suit another locale is one advantage of using a custom competition over entering a regional, national, or international competition.

Inaugural Team

The design team also needs to design and construct a team of robot hockey players. This task is very similar to that of the UPenn students, except without the lab infrastructure, experience, and teaching assistants available at the University of Pennsylvania.

As of December, the team has a single prototype robot constructed and has ordered parts for a complete team.

Conclusions

Games and competitions offer an intriguing source of design projects. They occupy a middle ground between simulations and case studies on the one hand and industrial client-centered projects on the other.

Participation in an existing regional, national, or international competition is an attractive option as a design project, offering students a well-developed set of guidelines and project constraints. However, integration of these competitions into a design course creates different challenges, including funding, logistics, and duplication of effort.

Adaptation of an existing competition overcomes some of these challenges – travel and other logistical issues are greatly reduced, for example, and constraints that affect local students can be changed. However, the costs in time and effort of developing the local infrastructure should be considered, as well as the temptation of students to modify the contest rules to match their first prototype.

Robockey @ Trinity is a work in progress, but the process of analyzing, adapting, and implementing a robot hockey competition is shaping up to be an excellent learning experience for the design team.

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