Finding the "Right" Robot Competition: Targeting Non-Engineering Undergraduates

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Abstract

Robot competitions run the gamut from research-oriented challenges to K-12 contest aimed at basic problem-solving. For students and faculty at small liberal-arts colleges with limited resources, finding the right level of competition can be a difficult proposition. At Macalester College we have hosted a series of robot competitions, inviting nearby liberal-arts colleges to participate. Our goals were to engage students with robots and artificial intelligence, to raise the profile of AI on campus, and to create ties among the different colleges. The contests succeeded in forging ties among the faculty who participated, and succeeded as an extracurricular to interest students in Computer Science. They failed, however, in teaching students much about AI and robotics techniques, and in engaging students with the sponsoring faculty members. I propose a model of local-area competitions that focus on AI and robotics concepts, rather than physical robot design, and that are respectful of the limited time and resources faculty and students have to contribute.

Introduction

Robot competitions have proliferated over the past ten years. The target audience for each competition varies, as do the goals underlying the competition. Some competitions are suited only to teams of researchers, others are aimed at children. Those in between, as often as not, involve interesting engineering, but not so interesting control systems. Finding the right model for a competition to suit our own particular goals, and the time and resource constraints we work under, can be a challenge.

Undergraduates at liberal arts institutions, with interests more on the software side than engineering, may not be well served by many existing competitions. Either the competition requires little AI or robotics knowledge, or engineering the robot takes precedence over constructing the control system.

The Math/CS Department at Macalester College has hosted a small "Robot Day" competition three times in the past six years. The participants were non-engineering undergraduates, working on the robots as a volunteer, extracurricular activity. While the competition succeeded as a fun extra-curricular event, it failed to engage students enough with AI or robotics, as the competition tasks required only simple "direct control" systems.

Macalester College is a small, undergraduate-only, liberal-arts college. The college has a total of 1900 students, and graduated between fifteen and thirty Computer Science majors per year during the period from 2001 to 2006. The Math/CS Department houses a Robotics Laboratory, used by Computer Science and Cognitive and Neuroscience Studies students for courses and independent studies, as well as serving my research needs. The lab includes two aging Pioneer robots, and 8-10 Handyboard and RCX controllers, plus countless Lego parts. Other colleges participating in Macalester's competition were similar in size and composition, and had access to Lego robots only.

My experience organizing Macalester's competitions in the past leads me to believe that more thought must be given to a competitions goals and target audience, to make student experiences more effective. We need to ask who should participate in a given competition, and why? What skills must a team have, and what skills might we want a team to acquire through its participation in a contest?

Once we know the answers to those questions, other issues arise. How can we design competitions that permit different schools to participate, given that they may have limited robot equipment, and given the heterogeneous collection of robots that are likely to be available. How much time and resources are reasonable to expect, particularly of teams of undergraduates and their busy faculty sponsors.

I would like to suggest the creation of a repository of robot competition models and tasks to serve the AI and robotics communities. Designing a competition from scratch can be a daunting and disheartening process: it would be more effective to learn from one another about the "best practices" for a particular target group and set of goals.

Why have robot competitions?

It would do a disservice to the many wonderful and different competitions that exist to presume that they all have the same, or even similar, goals. The goals are as varied as the venues.

Those of us who are robotics researchers need competitions to push the field. Competitions provide standard tasks and a level playing field where we can put our different ideas into practice and be judged on how they play out on "neutral

ground." We are pushed outside our own comfortable lab environments and, therefore, are given true picture of how our systems perform.

Robotics and AI educators have different goals, and require competitions accessible to our level of student. We use competitions to engage and inspire students to move beyond classroom assignments. We want to encourage student interest in AI or robotics, to extend their knowledge of those subfields, and perhaps to give them an entry point into "real" research. For younger students, the goals are less related to AI or robotics techniques: to encourage interest in technical fields, including computer science and engineering. We want younger students to practice problem-solving skills, and learn a little bit about programming.

No one model of competition can possibly suit this range of goals. When designing a competition, or selecting one to participate in, we we must ask ourselves what our goals are, and when does the competition forward those goals?

Existing models of robot competitions

I surveyed an on-line list of robot-related competitions maintained as a FAQ (Rainwater 2006), to discover the range of competitions that are available. To make things manageable, I restricted my survey to competitions within the United States, and only examined competitions for *autonomous* robots, eliminating those that were for remote-control devices only. I discovered that most competitions fell into four categories, spanning a wide range of target audiences and task complexity.

At one end of the spectrum are national or international competitions whose goal is to push the field of robotics forward (RoboCup 2006; AUVSI 2006). Such competitions require intensive, full-time work by participants, who are typically researchers in private industry or teams of faculty and graduates students from research universities.

There are a number of great competitions aimed at university students, with sophisticated challenges (UI 2006; UC-Davis 2006). Many of them, however, target engineering almost to the exclusion of anything else. They require much less sophistication on the AI side than on the physical construction of the robot.

At the other end of the spectrum, there are many robot competitions aimed at K-12 students, local and national (Botball 2006; SME 2006). These competitions emphasize problem-solving skills in construction and programming, but typically require very little AI or robotics techniques. Similar competitions, at a slightly higher level of performance, target robotics hobbyists (ChiBots 2006; PAReX 2006)

There are relatively few competitions that are suitable for non-engineering undergraduates, and yet incorporate enough complexity to require undergraduates to master sophisticated robotics or AI techniques. Examples I found include the Penn State Abington contests (Avanzato 2006) and a few competitions tied to specific courses. Macalester's "Robot Day" competition was aimed at exactly that population and that goal, and met with only some success.

Figure 1: Macalester College robot from "Robot Day 2002"

Macalester's contest

In Spring 2001, Macalester's Math/CS Department decided to hold a robot competition, "Robot Day", and to invite participants from a number of small liberal-arts colleges in the region (all within two hours driving distance). The contest was repeated in 2002, and revived again in Spring 2006, although other schools did not participate in the third installment. I organized the competition, and advised the Macalester teams.

In creating the competition, we had social, educational, and self-serving goals. We hoped to provide an new kind of extra-curricular activity that might appeal to a different population of students. We wanted to strengthen ties among faculty and students from nearby schools. We wanted to raise awareness about AI and robotics at our schools, and to expose students to AI and robotics topics. This is particularly important at a school where only one course addresses AI and robotics, and that course occurs every other year. The self-serving goals were mine: I hoped to create a community of students with experience with robots, who could mature to work with me on my own research when they were juniors and seniors.

Each year, I posted the contest problem one to two months prior to the competition day, and registered teams of students, two or three students per team. My robotics laboratory, which contains a suite of Lego parts and Handyboard controllers, provided the equipment for Macalester teams. Other participating schools had limited numbers of Lego robots, but nothing else.

On the contest day, all teams gathered in a public space near the Math/CS Department and exhibited their robots. Typically, 4 to 6 teams, from 3 or 4 schools participated. The competitive aspects were kept low-key, with bragging rights and a round of applause going to the winners. Demonstrations of other robot projects were a part of the first two competitions, as well.

The first contest's task was route planning and navigation in a grid environment, with and without obstacles. The second contest focused on clearing ping-pong balls from a grid world, and the most recent contest was a "time trial" traveling an irregular circuit course. Figures 1 and 2 show two robots from the 2002 contest.

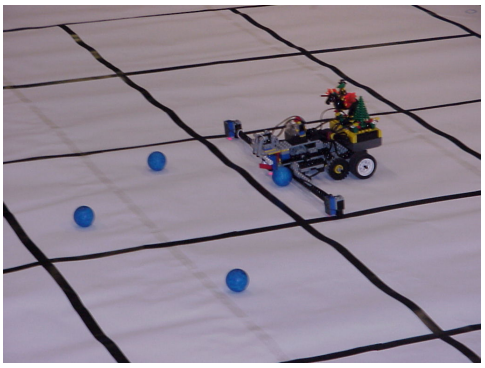

Figure 2: Carleton College robot from "Robot Day 2002"

Limitations of time and resources

Because of the size and nature of the participating colleges, students typically worked on the robot competition task purely as an extra-curricular activity: not for credit nor as part of a class. Working with the students then became a voluntary task for faculty advisers, as well. This limited the complexity of the task: we couldn't expect participants to sink hours each week into the project. It also meant that, in practice, students worked independently of their faculty adviser, on weekends and in the evenings. Students had too little incentive to seek me out, and therefore got little guidance from me. They viewed the contest as something they should do on their own, and felt consulting me was inappropriate.

We chose to limit the contest to Lego-based robots, because those were the only robots that all participating schools had access to. We hoped by limiting the kind of robot we would ensure a level playing field, but in that we were disappointed. At the same time, Lego robots using RCX or Handyboard controllers, untethered from a base computer, have extremely limited computing and battery power. I found it difficult to design contest tasks that were achievable and at the same time required any sophisticated techniques.

Managing variable robot platforms

Despite our best efforts to restrict the robots to equivalent types, and to choose tasks suitable to a range of approaches, it was difficult to judge "fairly" between different teams' robots. Teams had access to different equipment at different colleges: some used RCX bricks with robust reflectance sensors, some used Handyboards with simple touch and photoresistor sensors, some had sonar sensors. At the same time, Macalester students had access to the contest environment ahead of time, as it used materials stored in the robotics lab.

As a team adviser, I felt that the ability of teams to construct many different kinds of robots out of Lego parts was a mixed blessing that tended toward disastrous more often than not. Some teams constructed elaborate, complex robots and failed to program them sufficiently. As a judge, I could say "too bad," but as an adviser, I felt the students had missed the goals I wanted them to reach.

Macalester's outcomes

The contest was successful in attracting students not interested in other extra-curricular activities. It did attract attention on campus, raising the profile of the program. The faculty involved got to know each other, and built connections that have remained over the intervening years. Each team at least partially succeeded in addressing the tasks, and many had innovative designs that succeeded thoroughly.

Nevertheless, I was left unsatisfied by what I observed. As I noted above, it was very difficult to compare the robots and their performance during the competition, diminishing the competitive aspects of the event. Robots were too different, and responded too differently to the contest environment.

The biggest issue with Macalester's competitions, though, was the lack of AI and robotics knowledge used by the teams. The constraints of the contest structure meant tasks were relatively simple. Teams needed only basic programming skills in order to create successful robots In one case, not even programming skills were used: a team at the third competition entered a completely mechanical robot that outperformed every other entry. Macalester's competitions failed to engage students with AI or robotics topics: they simply weren't necessary to solve the contest tasks.

I plan on holding more "Robot Day" competitions in the future. I am, however, undertaking a complete re-design of the contest from the inside out. The future competition will begin to move away from Lego-based robots, to allow any standard robot platform or suite of sensors. I must find tasks of greater complexity so that students must learn something about AI or robotics to build a successful robot. In order for more difficult tasks to be feasible, I need to encourage faculty and students to commit more time to the competition. Both students and faculty need some compensation for time and effort: the work must be integrated into a course, an independent study for credit, or a student/faculty research collaboration.

A repository of contest ideas

Most existing robot competitions are not suitable for engaging non-engineering undergraduates with AI and robotics ideas. Major competitions are often aimed at research teams, making it difficult for undergraduate teams to compete without an unreasonable time commitment. Many student-oriented competitions focus on engineering, rather than software systems. And too many competitions target simple programming skills rather than understanding of robotics techniques.

The burden of designing creative and interesting tasks would be best shared by a community, rather than requiring each competition organizer to reinvent the wheel. There are good ideas out there, but the burden of tracking them down is currently too high. I propose a centralized repository of robot competition tasks, including what kinds of robots it is suited for, and what particular robotics concepts are needed to solve it. We must also develop tasks that can be adjusted for multiple robot platforms: robotics has never been homogeneous, and the future looks more heterogeneous than the past.

Conclusions

Robot competitions vary in their target audience and the complexity of knowledge required to solve the competition tasks. Competition goals range from pushing the cutting edge of research to encouraging children to like engineering and science. Before hosting or participating in a competition, we need to be sure that our goals line up with the competition task and time-line.

There are terrific competitions designed for research teams. There are many great competitions focused on engineering of robots, more than sophisticated programming of them. And there are many competitions aimed at children or hobbyists that, again, emphasize simplistic control programs. There are relatively fewer competitions suitable for non-engineering undergraduates, if we intend for the competition to introduce such students to AI or robotics techniques.

Macalester has hosted a "Robot Day" competition several times. Through those competitions, it became clear that moving beyond competition tasks that rely on simplistic control systems is not easy to do. Simple robots lend themselves to simple tasks, and more difficult tasks require a greater time commitment on the part of both faculty and students.

The AI and Robotics communities could support undergraduate participation in competitions by constructing a repository of "Good Ideas" for robot competition tasks, and by building a network of faculty at undergraduate institutions who can work together to develop better models for undergraduate competitions.

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