Air Hockey and Tennis Balls: Playing at Computer Science Research with Robotics

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Abstract: This paper investigates issues involved in establishing an undergraduate research program in robotics. We discuss our motivation for such a program, the challenges involved with various aspects of administration and equipment, and our plans for projects for student research. One project deals with programming a robot to play air hockey and another project involves the collection of tennis balls from a tennis court using a coordinated team of robots. Preliminary results hold promise, and we are optimistic about the future of the program.

Keywords: robotics, research, computer science education

Introduction

Universities across the country are suffering from attrition in computer science. In a previous work [1] the authors point out possible reasons for high attrition rates at Southeastern. One reason for this is a lack of problem solving skills in especially the beginning computer science students [2]. Another reason may be due to lack of interest in subject matter or misguided perceptions of the computer science field in general. Students normally are interested in results that they can see or software such as games that they can play. Robotics offers a "hands-on" real world application where students can touch the equipment and see results of programming by watching a robot's actions. This usually proves much more interesting than looking at numbers on a printout. In order to attract and retain students, we need to involve them in projects that interest them such as robotics.

At the current time, we do not have a graduate program in computer science, so we focus our attention on education, research, and student involvement from an undergraduate perspective. Recent reorganization at both the college and departmental levels has paved the way for improved research opportunities for both faculty and students, and work across disciplines is encouraged. Robotics lends itself not only to applications in computer science, but also in areas such as engineering and industrial technology.

We are currently working to establish an undergraduate research program in robotics. In this paper we elaborate on some of the challenges of establishing such a program and discuss some of our ongoing projects.

Challenges

There are many challenges to be addressed in the area of student research in general. These include such things as student background and preparedness, funding, faculty involvement, and administrative support. If a lab or equipment is necessary for the research then additional funding is required, and facilities must be available to house it.

A major concern is getting students involved and keeping them interested. This can be difficult at first since many students lack the educational background necessary for research tasks in many areas of computer science. It is especially a problem with undergraduate students as many of them lack education in advanced computer science topics. Therefore, these students must learn additional concepts and be brought up to speed on the field of study before beginning any actual research. Some of this learning can be achieved while working on projects with faculty and other students. In robotics, projects can be as simple as the building and control of robots using kits. Intermediate projects might involve robotic system modification, while the design and programming of complex robotic systems applying artificial intelligence and machine learning concepts are topics for more advanced research. Because in robotics students can "see" their results in action they are encouraged and amused, staying interested in learning for longer periods of time. As the students become more versed in the terminology and the problems they encounter, they develop an interest and appreciation for research and become motivated to work on more difficult projects.

Securing adequate laboratory facilities and equipment is another challenge. In most universities space is a premium, and sometimes one has to be creative in looking for available space and finding out how to secure it. Grants will often pay for equipment, but not for facilities, so space commitment must come from the university, unless the lab is housed off campus, sponsored by local business. The university's administration must be willing to support the establishment of a lab and the funding of overhead associated with housing and maintaining it.

Although we are still seeking better lab facilities, we currently have a small room in a building on campus. We have a small amount of start up funds for faculty research, some of which have been used to purchase some basic equipment. In order to maximize the return for our money, our focus has been to purchase equipment that can be used on more than one project, such as robot construction kits. In order to reduce complexity, we are striving to find hardware that already has software drivers that have a proven track record. By doing this, we can concentrate on the robotics research and spend less time chasing down hardware/software interfacing problems. And lastly we are working to have some of our equipment compatible with existing simulations such as MicroSoft's new Robotic Studio [3].

Projects

The projects with which we are currently involved are the first in a progression of projects that will lead us towards our research goals of onboard learning for robots applied to real world tasks. Specifically we have an interest in learning as it applies to cooperative robotics, that is teams of robots that learn and share knowledge in order to more effectively accomplish a task, and in the intelligent control of jointed systems for use in walking, climbing, etc. In order to effectively use our time and resources we are pursuing a selection of projects that we think will help us in several key areas, including acquisition of experience and knowledge in the technologies and theories of our areas of interest, recruitment of students by involving them in fun projects, and the creation of the required, simulation, software and hardware infrastructures required to make research contributions.

A key factor in our strategy is to maximize student involvement. In order to do this we are relying on a strategy that taps into resources used in the nationwide FIRST and VEX robotics competitions [4] held yearly at the high school level. Our faculty members were able to make modest contributions to the local high school's maiden effort. Figure 1 shows a picture of Hammond High School's [5] robot during the construction phase. In working with them we realized that the computing equipment and mechanical hardware used in these competitions is of good quality and has a large user development group behind it. At first glance it was apparent that this equipment would be useful in our research projects because of the flexibility in its software, electrical, and mechanical arenas.

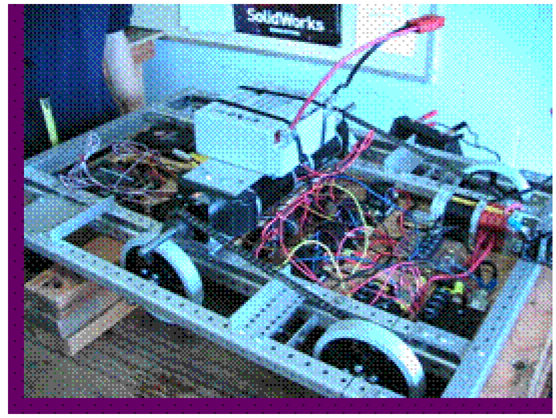

Figure 1. Hammond High School, Hammond La., participated in the FIRST robot competition held in February of 2007 as a rookie team. Here is a picture of their robot during the construction phase.

As preparation for the competition progressed, we realized that we could not help as much as was needed because we were not familiar with the processors and sensor systems used. Our current strategy was born out the realization that once we were familiar with the systems used in the competition, we could teach the students and help them with the competition. And since our projects were going to be based on some of the same equipment as that used in the competition, these same high school students could make immediate contributions once they came to the university. So we now have a commitment to help the high schools in the area, through direct mentoring and summer camps in which we will teach basic robotics using competition style equipment. In turn, we hope to attract students who can hit the ground running and help in our research endeavors at the university.

Involvement with the FIRST competition provided a fun way to gain knowledge of various robotic technologies and to interact with bright, motivated students. At the university we want to continue this trend by selecting projects that the students can have fun with while learning and helping to make contributions to ongoing research programs. We currently have two projects, both in their infancy, and both different enough to attract a wide range of students and faculty.

The first project is an air hockey table that will play against a human player. This project involves coordinating a jointed arm to hit the puck, a sensor system to track the puck, and a control system to coordinate the arm and learn how to effectively play air hockey. Other researchers [6] have also used air hockey as a learning platform. While it can be considered a real world problem, it has the benefit that the environment is relatively controlled and static. Problems associated with other jointed problems, such as balance, are avoided, making it easier to concentrate on the problem of interest, an on the fly learning system for controlling jointed mechanisms.

Initial work has concentrated on simulation of the system using a brute force learning technique in which a genetic algorithm trains a neural network to control a two-jointed arm. The system learns by playing games in which a simulated puck is bounced off a wall. It is rewarded when it the end of the arm hits the puck and when the puck hits the wall. At first it does not have the ability to control the arm in any way other than random movements, but as time passes, the system of rewards serves to encourage the generation of more and more capable arm controllers. Figure 2 shows the initial simulation software display.

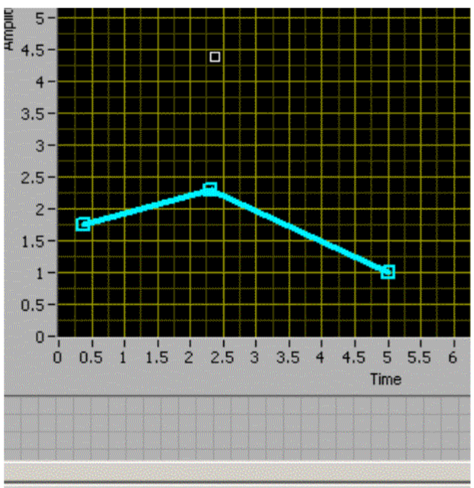

Figure 2. This figure shows a simulated 2 jointed arm, the bright line, getting ready to strike a puck, the white square above it.

The resulting neural network did an adequate job of controlling the arm, usually scoring more points than a person could by using the manual controls in the software. These results have encouraged us to move forward. Our students have continued simulation development by writing systems that have algorithmic control and also use fuzzy controls. We are getting started with the design and construction of our robotic arm to be mounted to our 7 foot air hockey table. A CMU II camera system like those used in the FIRST competitions will be used to track the puck and VEX computers and components along with fabricated components will comprise the arm. We are hoping to have the first versions ready for play for recruiting events next semester.

The second project is a cooperative robotics team that will be used to collect tennis balls on the tennis court. This project is just getting off the ground. Our straw-man plan calls for a commercially available tennis ball mower [7] (a device that a person pushes around a tennis court that collects the balls and drops them in a basket) to be automated with FIRST/VEX style computer components, motors and sensors. Figure 3 shows the Playmate brand ball mower that we intend to automate.

Figure 3. Playmate brand ball mower and tennis balls. Using FIRST and VEX components the ball mower will provide the primary platform of the automated tennis ball collection team. Note the high handle is a good mounting place for a camera.

Since the mower is good sized (about the size of a grocery cart) it will not be able to collect the balls near the fence. For this job, a commercially available hexapod robot from Lynxmotion [8] (see Figure 4) will be programmed to kick the balls away from the fence. Balls that are a long way from the majority of the balls and not near the fence will be retrieved by a small, wheeled robot. The ball mower will act as the “mother” in that it will carry the smaller robots until they need to be deployed. It will direct their tasking while their onboard systems will carry out their specific actions.

Figure 4. This figure shows a hexapod robot similar to the one that will be used to kick balls away from the fence. Hexapods are statically stable on three legs, meaning that they do not have to actively balance and they can use one or more legs to kick the tennis balls away from the fence.

Like the hockey table, the tennis court environment is excellent for research purposes. While it is not a lab environment, a tennis court has many beneficial attributes. It is contained by fences, making it much harder to lose a robot, and the surface is flat and fairly static. Additionally, the balls are all the same color, and they stand out against the mostly solid colors of the court surface.

The projects described in this section provide students and faculty alike with a wealth of opportunities to participate. They will be fun, and they will have enough notoriety to attract students, while providing the infrastructure needed for research and development of online learning algorithms, as well as other robotics research.

Conclusion

Establishing any undergraduate research program is a difficult, but rewarding task. In this paper we discussed our motivation for establishing an undergraduate research program in robotics and the challenges we have encountered along the way. We described two projects, the air hockey player and the cooperative robotics team for collecting tennis balls. These projects were designed to attract student interest, incur relatively low initial equipment cost, and scale to more difficult systems and complex research areas while providing a means for initial simple research for less advanced students, such as beginning computer science or engineering undergraduates.

Because our program is still in its infancy, it is difficult to predict the far reaching effects it will have on our computer science program, its current faculty and students, and our ability to recruit and retain good students in the future. Already, however, we are noticing an increase in student interest in research, revived faculty interest in new research areas, especially those involving collaboration of colleagues in related disciplines, and increased attention to our computer science program.

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