Educational Robotics in Brooklyn

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Abstract

We describe a number of efforts to engage university students with robotics through *teaching* and *outreach*. Teaching runs the gamut from undergraduate introductory computer science to graduate-level artificial intelligence courses. Outreach involves collaborations between students and New York City public school classrooms. Our efforts have always involved team-based projects that culminate in demonstrations or competitions, usually based on challenges from *RoboCupJunior*. Several research projects have followed from these initiatives.

1. Introduction

For the past five years, we have been bringing LEGO robots into university classrooms to enhance courses on introductory programming and computer science (both for computer science majors and non-majors), object-oriented programming, artificial intelligence, embodied agents and multiagent systems. We have also experimented with the use of Sony AIBO robots and are currently investigating other platforms for teaching. These experiences have led to efforts involving robotics for enriching public school classrooms through our own "robotics.edu" outreach program.

Our initiatives have always involved team-based projects that culminate in demonstrations or competitions, usually based on challenges from *RoboCupJunior*. RoboCup[1], initiated in 1997, was designed to bring together robotics and artificial intelligence researchers world-wide by providing a common problem for which a solution would require both advances in many fields and a collective approach to research in those fields (Kitano *et al.* 1997). Initially, the arena was robotic soccer, played by autonomous robots in several "leagues", distinguished by differences in physical size, hardware platform and approaches to vision and software control. This was later expanded to include robotic urban search and rescue as well. In 2000, the RoboCupJunior[2] division was formed, with the goal of introducing young students (primary through high school) to RoboCup and providing them with an exciting and motivating way to learn about technology through hands-on experiences (Sklar, Eguchi, & Johnson 2002).

[1]http://www.robocup.org

[2]http://www.robocupjunior.org

RoboCupJunior (RCJ) involves three challenges: *soccer*, *rescue* and *dance*. The soccer challenge is a 2-on-2 game played on a field with a floor that is coded using a greyscale gradient, so robots will know which direction to "kick" the special electronic, infra-red-emitting soccer ball. Robots can find the ball and determine their heading using only a light sensor; a bump sensor is also useful to prevent robots from getting stuck in corners of the field. The rescue challenge involves robots taking turns exploring a multi-level "doll-house" in which light-colored floors are traversed by a black line. Robots must follow the line and locate "victims" (human-shaped figures made of green or reflective silver paper), placed strategically along the line. Teams are rewarded for accuracy and speed. The dance challenge engages one or more robots in an exciting event that encourages creativity. Robots move to music for a 2-minute performance that often involves costumes, scenery and even students dancing along.

2. Teaching

Our university teaching experiences with robotics began in Spring 2001 and have grown from one introductory robotics course for non-engineering computer science students to encompass a spectrum of courses ranging from exploring robotics for non-majors to introductory programming for majors and advanced artificial intelligence for graduate students. This section briefly describes two of these.

Exploring Robotics (for non-majors) This course covers an introduction to computer science and programming through the use of project-based educational robotics activities. Students work together in small groups on a series of multi-week creative projects, using robots to address meaningful and socially important issues, such as urban search and rescue or elder care. Along the way, students are introduced to the fundamentals of robotics (including aspects of mechanical design) and elementary programming within a graphical environment. A series of five scaffolded robotics projects build in complexity in terms of the robot solution, the task environment and the task(s) to be accomplished: (1) *Simple Go-bot:* introduces students to basic control ideas and the use of touch sensors; (2) *Dancing Go-bot:* uses event-driven motion and a light sensor; (3) *Search-and-rescue Go-bot:* combines touch and light sensors, and makes more sophisticated use of the light sensors; (4) *Home-helper Go-bot:* fourth project coping with a more complex environment and multiple tasks, just as a real robot helper in the home might assist an elderly person; and (5) *Search-and-rescue Team:* requires cooperation of all the robots in the class to achieve the goal of locating and rescuing dummy victims from a mock collapsed building.

Artificial Intelligence (for advanced majors) The metaphor of intelligent agents is a way of bringing together the many strands of work carried out under the banner of AI and presenting them to students in a convincing way. The topics in our AI syllabus include: agency, control architectures, search, knowledge representation, logic, and planning. Students engage in two robotics projects during the term, using LEGO Mindstorms and the Not Quite C (NQC) language. The first project is based on RoboCupJunior rescue, expanded to incorporate climbing and descending a ramp or detecting and avoiding obstacles, in order to make the task harder. In the second project, students are confronted with a gridworld delineated with black lines where some of the squares contain the same colored figures as in the first project. The challenge is to survey the grid, identifying the positions of the figures, and then re-position the robot (at the arrow) and move to the figures in a pre-specified order in the lowest possible time.

3. Outreach

We have established an outreach program through which undergraduate students work with in-practice teachers in New York City public school classrooms in order to introduce robotics into a number of curricular activities. Typically the undergrads are computer science majors, and they enroll in the program through an independent internship, research project or service-learning course. While many science (and other) teachers are interested in bringing robots into their classrooms, most do not have the funding to purchase the equipment, the technical expertise to program the robots, the time to learn how to program on their own, or the curricular material to intergrate robotics into their classes. Our outreach program, "robotics.edu", pairs trained undergraduate students with classroom teachers for one-semester periods. We lend limited LEGO Mindstorms sets to the school for one term, after which most schools are enthralled with the program and manage to find funds to purchase their own equipment. The undergraduates lead the class through a series of lessons that introduce students to the robots and to programming using the RoboLab (Erwin, Cyr, & Rogers 2000) graphical interface. As part of their obligation to the project, the undergraduates are each responsible for creating and implementing a new robotics lesson at the end of the series of introductory lessons. These have included lessons on gear ratios and friction. We are gradually accumulating a database of lessons and creating a web site for sharing resources[3]. Most recently, we have brought the lessons into an after-school program for inner-city girls.

[3]http://agents.sci.brooklyn.cuny.edu/robotics.edu

4. New Directions

Several research efforts have been inspired through our teaching and outreach activities. A multi-year evaluation project has been examining students' experiences with robotics, trying to identify what exactly students are learning when they engage with robots in a variety of settings. A four-year study of RoboCupJunior participants has shown that students of all ages and nationalities improve their teamwork and communication skills, in addition to their knowledge of programming and engineering (Sklar, Eguchi, & Johnson 2002; Sklar & Eguchi 2004b). Other work has examined the effect that mentoring has on the undergraduates taking part in the outreach program (Sklar & Eguchi 2004a).

Our most recent work involves development of a universal interface and simulator for educational robotics. While the use of low-cost robotics platforms in the classroom has many attractive features, there are still several shortcomings that must be overcome in order to realize the full potential of educational robotics as a practical learning environment. Particularly since time for "practice" is limited, there is a need to reduce debugging time when using robots in instructional settings. Most robotics programming interfaces are designed for university-level or late high school students and are implemented as extensions to existing languages. We have been developing an agent-oriented, behavior-based interface framework designed to address some of these shortcomings (Azhar, Goldman, & Sklar 2006). Our framework has the capability to interact with multiple agent platforms and a Flash simulator through an XML-based agent behavior language. Our longterm goal is to create a standard middle ground that can act as a "magic black box", providing a seamless transition between simulator-based debugging environments and a range of robotic platforms, including Sony AIBO and iRobot Roomba.

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