Introductory Computer Science with Robots

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Abstract

Starting in the fall of 2005 our department began a large-scale effort to incorporate hands-on robotics in many of our courses, including our introductory computer science sequence. This followed the establishment of a departmental robotics laboratory and the purchase of a number of different robots. Our efforts include testing a variety of projects and surveying students about their satisfaction with robots. A primary contribution is our development of an algorithmic programming environment for robotics (Robotran) and an associated robot simulator.

Introduction

Starting in the fall of 2005 our department began a large-scale effort to incorporate hands-on robotics in many of our courses, including our introductory computer science sequence. This followed the establishment of a departmental robotics laboratory and the purchase of a number of different robots, including LEGO Mindstorms RCXs, Sony AIBOs, and Evolution ER-1s. We have focused our efforts in the introductory courses on the LEGO robots. Our efforts include developing and testing projects and surveying students about their satisfaction with robots. A primary contribution is our development of an algorithmic programming environment for robotics (Robotran) and an associated robot simulator.

The first two courses in our introductory course sequence for computer science majors are a CS0 breadth-first introduction to computer science (CSC 110) and a typical CS1, namely, a first programming course in java (CSC 111). CSC 110 is taken by most incoming computer science majors as well as by a number of students in other majors seeking to fulfill a math/computing general education requirement. Most of the students in CSC 110 have, unfortunately, little interest in the field of computer science. On the other hand, as expected most of the students in the follow-on course, CSC 111, are majoring in a computing-related field, including Computer Science, Bioinformatics, Digital Media Arts, and Mathematics.

There are several reasons for introducing robotics in these two courses. One is to interest students in the field of computer science (and specifically, in artificial intelligence), with the goal of attracting new majors or minors. There is considerable evidence that robots enhance student learning and lead to overall positive experiences in the classroom (Greenwald et al. 2004). An equally important reason to have beginning students work with robots is to allow them to see the impact of programs outside the realm of the computer on which they are written.

Computing devices are ubiquitous today and robots provide examples that reinforce this, effectively showing students how they might control these sorts of devices with programs they write. Robots can also be used to help teach or reinforce a number of basic computing ideas. These range from fundamental algorithmic ideas of selection and iteration to classes and objects and the event driven paradigm.

Robots

Our introductory courses have focused exclusively on the LEGO Mindstorms platform (Klassner 2002, Lawhead et al. 2003). We developed a very stable chassis design that includes two or three motors, two for powering wheels on each side of the four-wheeled vehicle and an optional additional motor for controlling a pen used for drawing. The robots have three sensors: two bump sensors attached to the front right and left bumpers and a light sensor. The robots were built by faculty with the assistance of upper-level undergraduate student assistants.

Language and Environment

We use Lejos (http://lejos.sourceforge.net), a Java-based programming language for the Mindstorms, for all of our LEGO robot programming. This presents a challenge for CSC 110, where we emphasize basic algorithmic ideas and have conscientiously steered clear of introducing an actual programming language. Recently, CSC 110 students have learned the simple algorithmic language PALGOL (http://www-cs.canisius.edu/~meyer/PALGO/Palgo.html).

To overcome the problem of teaching students how to program without introducing the complexities of a traditional programming language we started development of a translator program (Robotran) in the fall of 2005. Robotran allows students to write programs to control the LEGO Mindstorms robots with a Python-like language rather than the more complicated Lejos. Figure 1 shows the text of an extremely simple Robotran program that can be translated into Lejos with the click of a button.

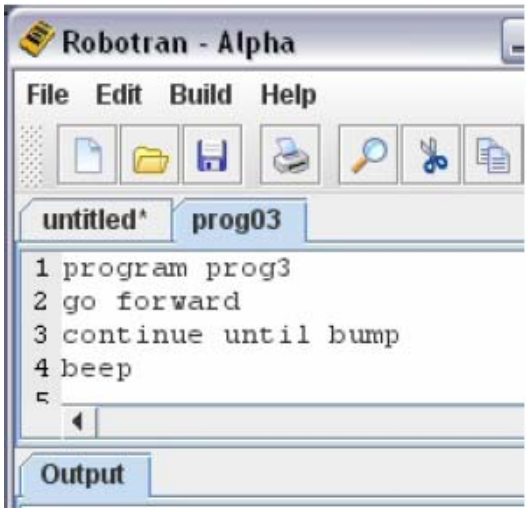

Figure 1. The Robotran Program Window

We are now developing a simulator that graphically displays the LEGO Mindstorms robot executing a Robotran program. This simulator will allow students to test their programs on-screen, possibly at home or in an open computer lab, before downloading to a real robot, which takes time and requires a supervised lab. Figure 2 shows a snapshot of the current simulator.

Robotran can be accessed on the Web (http://www-cs.canisius.edu/~rmmeyer/ROBOTRAN/home.html).

Projects

CSC 110

In CSC 110 students used the Robotran language to write programs for robots equipped with an extra motor that controlled a felt-tipped pen (pen up, pen down). Robolang serves in this case as a formalism for writing algorithms since the students are not working on robot problems in a lab setting..

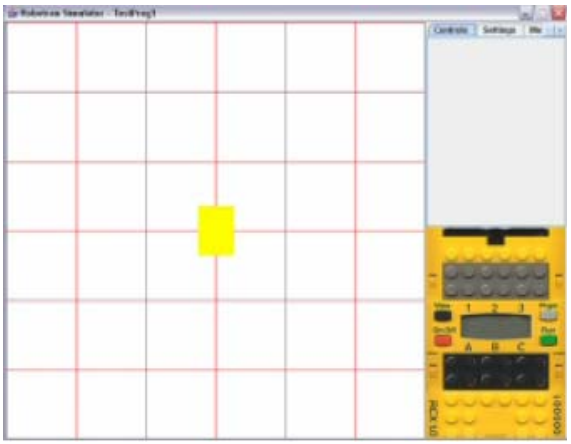

Figure 2. The Robotran/Lego Mindstorms Simulator

Students were asked to come up with algorithms for drawing a variety of letters such as upper case I, H, L, X, and P. This was done in groups of 3-4 students. Note that this activity took place in a classroom where the instructor's laptop was used to input and download programs to the robot. Future course offerings will have students at this level working in a lab on these projects.

Each group's program was run on a robot in class on a large pad of newsprint on the floor. The class sat in a circle and watched the results. Some of the groups were unable to draw their letter on the first attempt. The group was then allowed to think about what went wrong and discuss possible corrections. The class as a whole was also allowed to offer suggestions. After the class and group discussions students revised their code, which, in most cases, then worked.

Students generally liked this experience. They could see the results of their code demonstrated visibly as the robot drew on the pad of paper. They could also analyze what went wrong by watching the robot follow commands and note where commands were in error. The robots definitely generated more enthusiasm for programming than the material previously used in this course to cover programming concepts.

CSC 111

In CSC 111 students used Lejos directly for programming robots. They did this, however, in the context of the Robotran GUI to facilitate compilation of the code and downloading the compiled code to the robots.

The CSC 111 course has two lab sections of approximately 16 students each. This allows each student to work with his or her own robot, which we have come to realize has been

an important part of the success we are currently having with this new 4-week robotics course component. The robots are only available during one 50-minute closed laboratory per week, a problem that the availability of the simulator will help alleviate in the future. Students have written programs to make the robots draw a variety of shapes and patterns, to back away from detected obstacles, to follow a flashlight, and to construct a map of an area using arrays.

Results

We have collected quantitative and qualitative data from the Fall 2005 offerings of CSC 110 with a total of 56 respondants. Results can be seen in Table 1.

Question	SA	A	N	D	SD
I enjoyed working with/seeing the robots	14	45	13	4	5
The robots helped me understand algorithms better	13	46	25	11	5
The robots helped me understand programming better	16	48	23	9	4
I would like to do more with robots in the course	38	34	14	7	7
I think the robots should not be part of the class	7	5	14	39	34
The robots helped me to better understand computing	13	41	32	11	4
The robots were confusing	9	7	25	39	20
The robots were boring	5	11	14	34	36

Table 1. Survey Results CSC 110 Fall 2005 (SA=strongly agree; A= agree; N=neutral; D=disagree; SD=strongly disagree). Number of respondents = 56.

Overall, 59% of students agreed that working with robots helped them to better understand algorithms, 64% said working with robots helped them to better understand programming, and 71% said we should include more robotics material in the course.

In addition to the survey shown above, we asked students (1) did they think our plans to offer an "all-robotics" version of CSC 110 was a good idea, and (2) would they consider taking the "all-robotics" course. 82% of students said they thought offering an "all-robotics" course was a good idea, and 48% indicated they would take such a course with another 30% undecided, primarily due to uncertainty about whether the course would count towards a program requirement for their major in the same manner as CSC 110. We also solicited free text comments from students. Responses included, "seeing the visuals really helped me understand topics in Computer Science", and, "Robots are fun and make the class more interesting." Other comments convey overall student excitement and enthusiasm for the robots.

We do not yet have survey data from the CSC 11 course. However, with the addition of robotics in CSC 111 we saw an even greater appreciation for programming on the part of students this year. In the lab, all students, including both the stronger and the weaker students, wrote and downloaded robot programs with intense concentration to the point that it was hard to get them to leave when the lab time officially ended. Several students asked how to buy their own robots. These attitudes contrast with those seen in previous years.

Conclusion and Future Plans

In summary, the results from our efforts to add robotics to our curriculum have been positive. There are two issues we plan to address in the near future. First, we plan to offer a lab-based robotics course as an alternative to the CSC 110 course. At present the use of robotics in the CSC 110 takes place in the classroom where student don't directly interact with the robot software. Second, students in the programming course, CSC 111, require more hands on time with robots that we can not provide in the laboratory. For this reason we plan to continue development of our simulator to allow them to write and test programs at home.

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