Collaborative Mobile Robot Design in an Introductory Programming Course for Engineers

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A project-centered introductory computer course for freshman and sophomore engineers has been developed at the Penn State Abington College. Students form teams to collaboratively design and implement algorithms in the C language for autonomous mobile robots. The team projects have been developed to "teach" critical programming concepts. These team projects have largely replaced the traditional lecture portion of the course. Collaborative software design for mobile robots provides direct, visual feedback of algorithms and has enhanced the learning process in the computer science course.

Introduction

One of the challenges encountered in teaching an introductory computer science course for engineers is that the features of the language are revealed in a rather linear, sequential manner that results in programming exercises that are often perceived by students to be dry, or contrived. It is generally only near the conclusion of the course that students are in a position to creatively attack interesting and motivating problems and applications..

At the Penn State Abington College a section of CMPSC 201 is offered as a hands-on, collaborative, project-based course utilizing mobile robots. Students have found mobile robot programming to be highly motivating and compelling. Student teams are active in the algorithm and program design process from the start of the course, and the robot environment allows for the incorporation of interdisciplinary applications and experimentation. As this will be the only software course required for several of the engineering majors, it is an opportunity to introduce contemporary topics beyond numerical methods, such as process control, embedded control, robotics, and artificial intelligence

CMPSC 201 is an introduction to computer programming course designed for engineering majors at the freshman and sophomore levels. The traditional course introduces students to the elements of the C/C++ programming language with an emphasis on engineering applications and numerical methods. Software packages such as a spreadsheet and MATLAB are also introduced.

The innovative course comprises student teams with 3 to 4 students in each team. Team members were selected by the instructor based on data from a computer literacy survey. The range of prior computer experience was quite large, and an effort was made to combine experienced students and novices into a single team. The teams meet in a lab environment that provides ample work space and a PC with proper software and an Internet connection. Each team is provided with an identical robot platform with a variety of sensors. The group is responsible for the collaborative design of software to control the autonomous robot to perform various tasks. The course meets 2 sessions per week, and each session is 75 minutes in duration. Generally, one of the weekly meetings is dedicated to discussion of homework solutions, quizzes, tests, question and answer sessions, and short lectures. Lectures were provided on an as-needed basis, and handouts were prepared to supplement material in the required

textbook[1]. The other session was generally dedicated to collaborative robot design in the lab. Performance is evaluated on a group basis (robot tasks and team quizzes) and on an individual basis (examinations).

The motivation for this experimental offering was based on the successes in a special topics mobile robot design course offered to freshman and sophomores over the past 3 years. In this special topics course students design, construct, and program a mobile robot for entry in a national competition [2]. It was observed by the author that many of the student participants with no prior programming experience became well-versed in algorithm development and the C programming (including advanced topics such as multi-tasking). This knowledge was gained inductively through hands-on experimentation, teamwork, and exploration, without much in the way of formal instruction. Furthermore, the students in the robot design course demonstrated a great deal of enthusiasm and excitement toward the art and science of programming. It was clear that this experience could be successfully incorporated into a traditional computer science course.

Robots

Robot platforms were constructed from LEGO building materials and based on a documented design created by Fred Martin at MIT (see Figure 1). The controller chosen for the robots was the Handy Board, also developed by Fred Martin[3]. The Handy Board is a 6811-based controller package with an internal 9.6 NiCad battery for driving up to 4 motors. The board supports 7 analog (8-bit A/D) sensors (e.g. photoresistor) and 9 digital inputs (e.g. mechanical switch). The software is Interactive C (version 2.83) which supports many of the features of the C language including for/while loops, if/else, functions, pointers, and one-dimensional arrays. Additionally, there exists enhanced error-detection and an interactive mode to facilitate incremental development. Finally, a community of Handy Board users is well-established on the Internet. The Handy Board and LEGO building block approach has been used successfully in a high school outreach program, as well as a freshman design course and the robotics design course mentioned above [4].

Figure 1: Modified “LegoBug” [3]

Robot platforms for the current course were equipped with a left front and right front bump sensor, and 2 adjustable light sensors shielded by film canisters (not shown in figure 1). The IC software provides a library of high level functions that allows the students to be insulated from many hardware and electronics issues that would prove inappropriate for a software oriented course at this level.

Team Robot Projects

Each of the students in a team is assigned a role which rotates on a weekly basis. The assigned roles were those of “presenter,” “note recorder,” and “programmer.” The presenter was responsible for time-keeping and providing a written or oral summary of the team robot project; the recorder entered ideas, data and results into the team notebook; and the programmer entered the program (developed collaboratively) and debugged the software.

A total of 9 robot team projects were developed during the Fall 1997 semester. Each project consisted of a sample program and design goal. The projects were designed to be developed, implemented, and tested by a student team within a single class meeting, which is approximately 1 hour.

The majority of projects concluded in an informal mini-contest. The following is a list of selected robot tasks:

- Move robot in a square (2 feet on a side)
- Move robot in a circle (2 feet in diameter)
- Hit wall and return to start position
- Obstacle avoidance
- Robot "Convoy"
- Light seeking & avoidance
- "Robo-Sheep" (group of robots mill around in an enclosed pen)

Sample software distributed for discussion and modification by the students is provided in figure 2.

```
/*  This program instructs the robot to move forward until either
     right or left bump sensor is hit; if either sensor is hit,
     backup for 1 second, then continue forward   */
int RMOTOR = 1;  LMOTOR = 3;
int L_BUMP = 7;  R_BUMP =15
int main()
{
   while (1)                          /*   loop forever; remember 1 means TRUE in C  */
     {  motor(RMOTOR, 100);      /*  go forward    */
        motor(LMOTOR, 100);
        if (digital(L_BUMP) == 1 || digital(R_BUMP) == 1)  /* if either sensor hit, then backup for 1s. */
                                  {  motor(1,-100);
                                     motor(3,-100);
                                     sleep(1.0);
                                  }                        /* after 1 second continue going forward */
     }
   return 0;
}
```

Figure 2 Software Listing

The flexibility of the software and hardware allow the design of projects well beyond the list above. Additional sensors can be interfaced to the Handy Board that include optical shaft encoders, sonar, thermistors, and a digital compass. The Handy Board is also capable of recording data obtained from sensors, and uploading the data to a PC for analysis by software packages such as EXCEL and MATLAB.

As a final project, several teams from the Fall 1997 computer course participated in a Penn State Abington robot design competition, "Robo-Hoops," which required robots, in a head-to-head match, to pickup and shoot or dunk 4 inch diameter foam balls into a net located 12 inches above the playing surface. (The Robo-Hoops contest was designed primarily to support the freshman design course and the high school outreach program.) Other final projects included a comparison of C, MATLAB, and EXCEL tools for linear regression, a Runge-Kutta solution of a differential equation describing the suspension system of an automobile, and a line-following mobile robot.

Results

The results of the experiment were judged successful by the author. The tempo of the course and level of interest demonstrated by the students was significantly higher than in past experiences with traditional methods. The required core topics were treated with less formal lecture time. Moreover, additional topics such as robotics, real-time programming, sensors, and collaborative learning were introduced. The students have performed at least as well as former students on examination questions used in past traditional offerings of the course. With a class size of less than 20 students, it is difficult to quantify any improvement in learning at this stage based on test scores alone. Clearly, some of the expertise

gained by students in the collaborative robotics design will not measured by utilizing past examinations. Students in this course have more responsibility for participation and out-of-the-classroom reading, and it is unclear what impact this has had on performance. Quizzes on robot programming techniques yielded positive results, but are qualitative at this time. The experiment will be repeated in the near future with additional assessment.

An informal survey was distributed in the class during the last week of the course. One question asked for the student to rate the usefulness of the team robotics projects in the course. Of the 13 respondents, 3 rated the team robotics "extremely useful," 7 selected "very useful," 2 rated the robotics projects "somewhat useful," and one responded that he/she was "not sure." To the question of whether there should be more lecture time in the course, 5 responded positively, and 8 responded that they did not feel there should be more formal lecture time. The majority of students indicated that the best part of the course was the hands-on team robot design portion. It is expected that the experience during the Fall of 1997, including the student feedback, will allow for additional enhancements and improvements in the course.

Summary and Conclusions

A collaborative, hands-on approach to an introductory computer science course for freshman and sophomore engineers has been developed and implemented at the Penn State Abington College. Teams of students are collaboratively designing programs in the C language for autonomous mobile robots. Collaborative software design for mobile robots provides direct, visual feedback of algorithms. The students have reacted very positively to the innovative approach. From the instructor's viewpoint, the course has been enhanced by virtue of the heightened student interest level, team participation, and the expanded expertise of the students. The course results will serve a foundation for future enhancements in collaborative learning and robot design.

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References

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