Fire-Fighting Robots To The Rescue

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Abstract
A project-based mobile robotics course has been designed for freshman and sophomore honors engineering students at the Penn State Abington campus. The unique feature of the course is the focus on designing an autonomous mobile robot to be entered in a national fire-fighting robot competition at the conclusion of the course. Teams of engineering students have each designed, tested, and debugged a mobile, microcontroller-based robot capable of navigating a maze, locating a candle, and extinguishing the candle. Topics such as gear mechanisms, motor control, sensors, and control software have been integrated into the project-driven experience. The success of this strategy suggests further experimentation in hands-on, context-driven course delivery.

Introduction

The Penn State Abington campus has been experimenting with non-traditional learning strategies for freshman and sophomore level engineering and engineering technology courses based on the design and implementation of mobile robots. The goal is to improve the effectiveness of the instructional process by shifting from lecture-based delivery to hands-on, project-based delivery. In the Fall of 1995, a robotics-based course in microprocessors was developed and implemented for the engineering technology curriculum[1]. An engineering design component to a freshman engineering design and graphics course was developed and implemented successfully over the past two years. The robotics competition, called "Robo-Hoops" is a Nerf basketball robot competition and is detailed in [1]. Recently, a collaboration between computer engineering students and geoscience students has resulted in the design of "Geo-Bots," autonomous mobile robots capable of terrain navigation and data collection. A Saturday workshop in robot design is also offered to Philadelphia area high school students.

The focus of this paper is to describe a special topics course in robotics for freshman and sophomore level honors engineering students. The unique feature of the course is the focus on designing an autonomous mobile robot to be entered in a national fire-fighting robot competition at the conclusion of the course. Teams of engineering students (many with no prior experience in electronics and programming) have each designed, tested, and debugged a mobile, microcontroller-based LEGO robot capable of navigating a maze, locating a candle, and extinguishing the candle. The approach has been inspired by the work of Fred Martin of the MIT Media Lab and the MIT 6270 course.

Topics such as gear mechanisms, motor control, sensors, control software, and artificial intelligence have been integrated into the project-driven experience. Design projects of this nature have generally been the hallmark of senior design and capstone courses. This investigation explores the use of the design project thread in the freshman and sophomore level

courses. The student interest and motivation level has been strong, and the success suggests further experimentation and application of hands-on, collaborative, context-driven course strategies.

The Competition

The rules and regulations defining the Trinity College (Hartford, Connecticut) annual fire-fighting home robot national competition are distributed to the students on the first day of the course. This contest establishes the focus and context for the entire course. The objective of the contest is to design an autonomous robot capable of navigating a maze and locating and extinguishing a randomly placed candle in the least amount of time. The competition maze is an 8' by 8' area divided into 4 rooms. The walls of the maze are 13" high and the hallways and entrances to the rooms are 18" wide. The robot is limited in size to a maximum 12.25" by 12.25" by 12.25" volume. The candle flame is at a height of 6-8 inches. There is no minimum robot size requirement, and no robot weight limit. A floor plan for the maze is provided in Figure 1.

The candle flame may be extinguished in a variety of ways including foam, water, air, CO2, baking soda, etc. There exist options that result in bonuses (time reduction) such as the placement of obstacles within the rooms, robot activation upon sensing an audible tone, returning to start position following flame extinguishing, and untethered operation of the robot. Penalties result when the robot touches the walls of the maze, or if the robot makes contact with the candle. Details concerning the regulations of the competition can be obtained on the Internet [2].

The competition is held in April (which conveniently corresponds to the end of the semester) and draws participation from diverse locations within the US and Canada. Over 40 robots participated in 1996. The contest is challenging – roughly 25% of the entries are successful in extinguishing the candle in 2 of 3 trials.

The Course

Course topics include gear assemblies, locomotion strategies, DC motor operation and speed control, microcontroller architecture, digital and analog sensor interfacing, C programming techniques, open-loop and closed-loop control strategies, and artificial intelligence concepts. The students are also introduced to LEGO building and prototyping strategies[3], and commercial applications of mobile robots. Specific details and mini-lectures are provided on an as-needed basis. Mini-competitions and milestones are established to insure suitable progress. Teamwork, project management, and documentation are important issues in this course format. Frequent consultation between teams and instructor are characteristic. In the 2-credit version of this course, no textbook was required, but supplemental materials were utilized. Some materials originated from the MIT Internet repository and others were generated by the instructor. Jones and Flynn [4] also served as an important reference. Individual performance was evaluated by exam and instructor observations. Individual grades were determined by team assignments, individual exams, peer reviews, instructor evaluations, and robot performance in mini-competitions and the Trinity competition.

The Robots

Each team of 3 students was provided with an assortment of LEGO building blocks, DC motors, IR sensors, shaft encoders, photoresistors, servo motor, and a MIT 6270 controller board or Handy Board[5]. "Interactive C" is the software that operates the controller boards and is capable of floating point operations, interactive programming, and multitasking. The 6270 Controller and the Handy Board are both Motorola 6811 microcontroller designs. The Handy Board features 8 digital inputs, 8 analog inputs, 4 PWM motor outputs, and control of 2 servo motors.

The majority of teams in the 1996 course designed robots with "dead-reckoning" navigational capabilities, and sported powerful electric fans that were capable of extinguishing the candle at a distance of 3-4 feet. An inexpensive IR photoresistor shielded by a black film canister provided candle flame detection. Figure 2 and Figure 3 provide pictures of robots designed by student teams for the competition. The robot in Figure 2 utilized a servo motor for steering and the robot in Figure 3 used a chain "tank" drive system. In each case, an IR sensor and fan assembly were mounted on a rotating turret. Both robots employed shaft encoders and dead-reckoning algorithms. While the dead-reckoning algorithms displayed some weaknesses, both robots were able to place in the top ten positions in the contest.

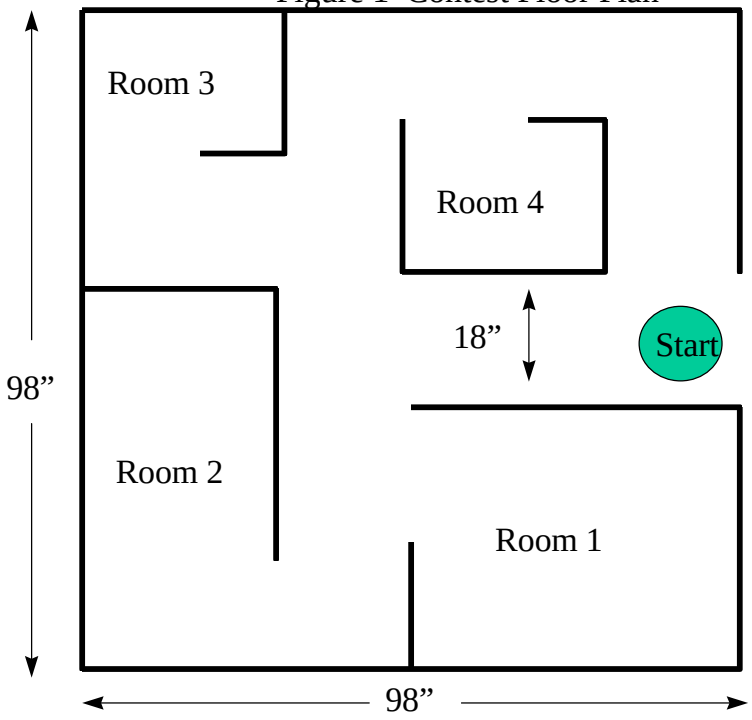
Results and Conclusions

The results of the course were highly positive. The participation in the competition was highlighted as especially significant for the students. The hands-on, multidisciplinary nature of the mobile robotics was also found to be generally attractive to the students. The contest provided the necessary focus to balance the unstructured nature of the course delivery. For the most part, the students exceeded the expectations set by the instructor. A similar course for 3 credits will be offered in the Spring of 1997. Internet resources including the development Web pages, as well as expanded coverage of multitasking and wall-following techniques will be incorporated into this new version of the course. The competition focus will be maintained.

One particularly significant result of the course is the level to which students acquired software design and implementation skills. The physical consequences (i.e. robot movement and behavior) of the software played an important role in the high level of interest and understanding. On the basis of this result, a section of an introductory computer programming course for engineers is planned to be delivered in a robotics-based, hands-on, collaborative mode in the Fall of 1997. Although the programming style for real-time mobile robot navigation differs somewhat from conventional numeric programming, it is felt that many of these limitations can be overcome with judicious use of robot experiments.

In summary, it may be concluded that (based on 2 implementations of the course) a project-based course in mobile robotics focused on a design competition is a useful and effective instructional tool at the freshman and sophomore level in an engineering program. It has also been shown that success in the described robotics course can lead to innovative approaches to instruction in related fundamental courses such as an introductory computer science course.

Figure 1 Contest Floor Plan



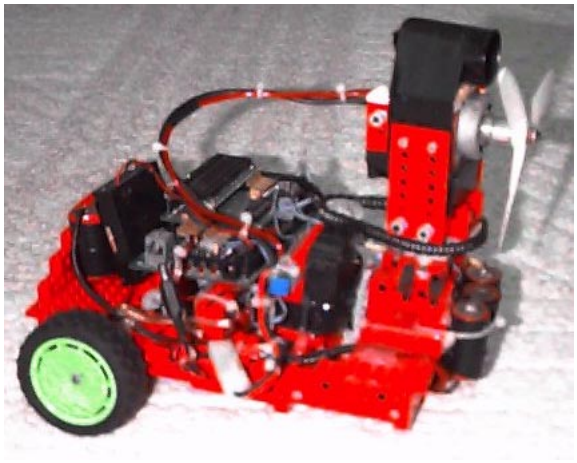


Figure 2

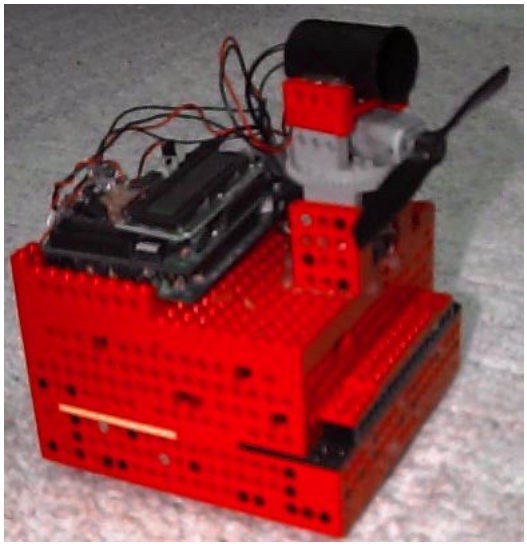


Figure 3

References
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[2] http: //shakti.trincoll.edu/~jhough/fire_robot/comp.html
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[4] Jones, J., Flynn, A., Mobile Robotics: From Inspiration to Implementation, A.K. Peters, Ltd., Wellesley, MA, 1993.
[5] http://lcs.www.media.mit.edu/groups/el/projects/handy-board/

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