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An Interdisciplinary Team-based Mobile Robots design course for Engineering

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AC 2011-1253: AN INTERDISCIPLINARY, TEAM-BASED MOBILE ROBOTS DESIGN COURSE FOR ENGINEERING TECHNOLOGY

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An Interdisciplinary, Team-Based Mobile Robots Design Course for Engineering Technology

Abstract

This work describes the educational experience gained during a new course in mobile robots, a fourth year elective course in the undergraduate Mechanical and Electrical Engineering Technology (METEET) Department at Georgia Southern University. The main topic of this course is concentrated on team-based, one semester-long projects in which students design and build mobile robots for different applications.

At our university, the METEET department has implemented a popular course in which interdisciplinary teams of mechanical and electrical undergraduate students build and deploy a wide range of robotic projects, ranging from small remote-controlled vehicles to totally autonomous robots. These projects expose students to the experience of working in teams, to know the interdependence among engineering disciplines, to schedule and prioritize activities associated to the development of the project, and to solve the challenges of managing the interactions of the personal working in the projects. Over the past 2 years, the engineering technology program has provided more than 70 students with exposure to robotics and control topics. This course provides exciting and compelling educational opportunities for students, offers real-world applications that naturally motivate the need for learning specific technologies, and serves a broader research and development program that utilizes the functional robotic projects to support externally funded science and technology research projects. The experience of the authors, as well as the course assessment results, show that this course provides strong student motivation for learning, offers comprehensive and valuable educational experiences, and enhances student performance. This work reviews the robotics course, highlights the role of mechanical and electrical engineering technology students in several projects, and presents the assessment data showing the positive results of this course.

1. Introduction

A mobile robot is a system that contains mechanical and electronic parts that can be programmed to perform specific functions, responding to sensory inputs under the control of an internal or external computer. The reasons to use mobile robots as the main topic for the robotics course is that in addition to involving the electrical and mechanical engineering disciplines, robotics deals with other sciences and humanities subjects, such as animal and human behavior imitation, learning techniques, and environment interactions. Robotic systems can relate to most processes in nature and human behavior[1]. Because of this, their potential as educational tools for teaching and learning various subjects in technology and sciences is unlimited. The design and implementation of an autonomous navigation vehicle requires a broad knowledge in areas traditionally not covered in a single discipline[2]. These areas include electrical and mechanical engineering, computing sciences, mathematics and other engineering disciplines. As a result, it is very difficult to train students and engineers within a single discipline to effectively design and implement complex mobile robots. Thus, we felt that it was important to offer a robotics elective course to establish an interdisciplinary framework[3] to teach the basics and offer a structured course for education in mobile robot design in which both mechanical and electrical engineering students could participate. One of the major goals of this new class was to expose students to team work, engineering design, and project scheduling.

Another objective of the course was to illustrate the benefits of developing robotic projects as an effective tool for undergraduate education. The primary goal of each project is to create an autonomous mobile robot that is able to navigate autonomously avoiding obstacles and to be capable to compete in one of the multiple existing robotic competitions such as the Firefighting Home Robotic Contest[4], the Intelligent Ground Vehicle Competition IGVC[5], the Autonomous Lawnmower Robotic Competition[6], and the IEEE SouthEastcon Hardware Challenge[7]. All the above contests promote interdisciplinary design and teamwork. Also, to accomplish the stated goal, students must integrate knowledge gained from such classes as engineering design, circuits, controls, signals and systems, computer programming, mathematics, and engineering mechanics.

Finally, this course is also used to fulfill ABET's academic outcomes that require for engineering technology students to have experience working in interdisciplinary groups, be able to work in a team, and have experience in managing a project. The paper provides motivations and background information, describes the teams' organization and the mobile robots characteristics, the paper conclude with a summary and results.

2. Motivations and Background.

Most engineering and engineering technology programs follow approaches to system design and integration that are focused primarily on the theoretical aspects of the systems. With the introduction of the mobile robots course it became possible to provide students with hands-on laboratory experiences to construct interdisciplinary and more complex systems[8]. As robotic systems have evolved in research and commercial applications, the number and complexity of these systems have also increased. A significant portion of the design process must now focus on the integration of hardware and software.

Applications of robotic systems usually involve a large number of various types of sensors and actuators connected to a real-time controller. The rapid increase of such applications requires in-depth research to correctly interface multiple sensors and actuators[9]. These applications serve as excellent case studies to motivate students and teachers. Also, fast computation speed is a major barrier for many real-time sensing and control applications, especially for sensors requesting a large amount of computation, such as obstacle detection and image sensors.

Modern robotic systems require being equipped with advanced microprocessor-based embedded systems. For example, an intelligent navigation system may use several electronic control units and multiple sensors and actuators to monitor and improve its performance. With the rapid development of new technologies for precision navigation, more sensors and actuators with sophisticated control algorithms are required by the system. Many of these sensors may be linked with a real-time network to log sensory data and provide feedback for real-time control.

Robotic systems that are designed for real-time applications such as navigation systems and process automation are very expensive to develop. To be practical for a senior class, the per-unit cost must be strictly controlled to fit within a typically constrained laboratory budget, since the cost of development of a platform for a mobile robot can become fairly expensive as the complexity of the sensors and control system are increased, it can reach thousands of dollars. In our case, early in the development process, this was a limitation that we had to work with. First, we try to establish which would be the best approach to follow in order to keep the cost of the robotic platform within the limits of the budget assigned to this class. Next, in order to reduce the implementation costs we decided to use as many devices and systems that we already had available in our labs, such as sensors, electronic devices, laptops, microcontroller cards and simulators, programming, and analysis software tools.

3. Course Organization and Teams Interactions.

The typical robotic class consisted of a group of 15-20 students that were separated into 4-5 independent design teams. Each team's goal was to design, implement, and test an autonomous vehicle that was able to navigate in an unknown environment. The membership selection to a particular team for each student was based mainly on their academic major and personal preference. Overall, the design teams received supervision from two faculty advisors. One advisor supervised the design of the mechanical base, sensor interfaces and drive motors, the second advisor supervised the programming of the robots. The block diagram shown in Figure 1 illustrates the basic components of a typical mobile robot.

For each team, every student was responsible of a specific part of the robot. a) One mechanical engineering technology student was in charge of the design and fabrication of the mechanical base, which included: the robot chassis, wheels, stability system, motors, and other small parts. All components were fabricated and/or assembled by this student to ensure that the vehicle was capable of performing the desired tasks. b) An electrical engineering technology student was in charge of designing and building all the electronic interfaces. In particular, infrared and sonar sensor interfaces were required for obstacle detection and general environment information. c) The navigation of the vehicle was the responsibility of another electrical (or mechanical) engineering technology student, which used the information provided by the sensors to control the vehicle, using various algorithms implemented in either Matlab or Basic. Each design team named a team leader. The team's leaders were selected by their peers based on their leadership, and managerial skills. The team's leaders were the main communication channel between the students and the faculty members supervising the course.

The course was organized as a 15-week long project. In weeks 1-4 students received lectures related to the theoretical background needed for the design of the different components, and 2-hour labs related to the organization and development of the vehicles. During weeks 5-8 students continue to receive lectures but dedicated full lab time to the development of their particular project. In week 9 each team give oral presentations in which they described the advances and problems they had in their projects. Weeks 10-14 were dedicated to debugging, testing, interconnecting and final assembly of the vehicle. In week 15, final oral and written reports of the completed vehicles were presented.

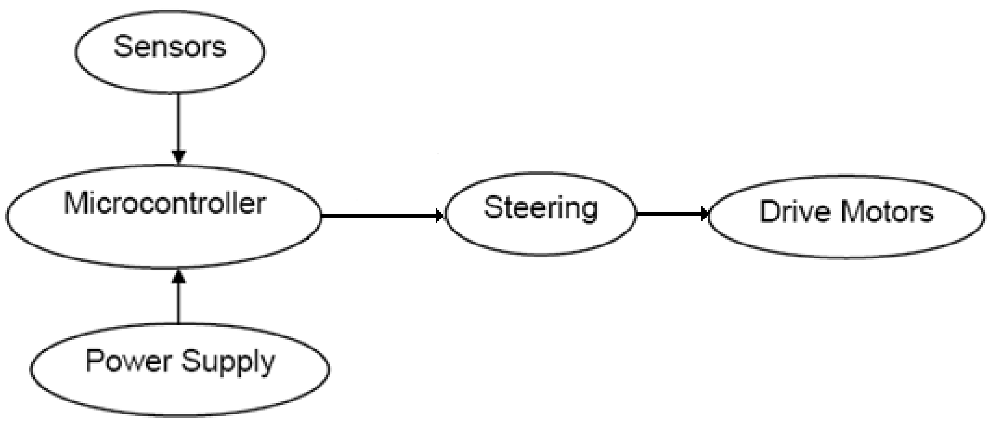

Figure 1. - Mobile Robot Basic Components

4. Course Educational Objectives.

The content of the course combines students' expertise in digital system design, signal processing, power systems and control, mechanical systems modeling and design. The course outcomes specified for this course are as follows.

Upon completion of the course students were able to:

1. Understand the function of different sensors that provide environmental information to the controller
2. Understand technical information and parameter description for electronic and mechanical components
3. Identify and design the components of a basic robotic system
4. Understand the use of DC, Servo and Step motors to perform navigation and mechanical actions
5. Use basic navigation control techniques

6. Apply basic interfacing techniques
7. Apply and implement programming techniques
8. Discuss different robotic applications
9. Complete a design project that is interdisciplinary in nature
10. Integrate the knowledge obtained in previous EET and MET classes
11. Accurate communicate his/her project results both in written report format and in oral presentation format
12. Understand how teams work and how to interact in a team setting (Understand what is like to work in industry)

5. Course Assessment Methods.

The projects were evaluated in several stages, in a gradual and continuous way. For our course assessment and evaluation, three assessment tools[10] are used: *course-level outcomes* (CLO), *continuous improvement efforts* (CIE), and *student course outcomes* (SCO). These assessment tools have been developed by EET faculty and used extensively in the continuous improvement of courses and for the ABET accreditation process. The CLO form is completed by the instructor and states each course outcome relative to the program outcomes; identifies the assessment tools used to measure the student performance, and the corresponding rubric analysis result for each assessment. The instructor completes and submits a CIE report which documents a strategy for instructional improvement for the next course offering. The SCO evaluations form is an indirect measure used to collect feedback from students based on their perception of achieving the defined course outcomes.

To measure educational effectiveness, two assessment tools were used: a) Direct measures that correlate to student performance such as grades on a final exam, and b) Indirect measures that provide feedback information such as those obtained from a student survey. Figure 2 illustrates the overall results obtained from the entire course assessment process which uses information collected from the three assessment tools (CLO, CIE, and SCO). In this graph the horizontal axis represent the 12 course-level outcomes and the vertical axis represent the average score (in a scale of 4.0), and a benchmark of 2.75 had been defined as minimum acceptable to achieve an outcome.

6. Grading

In the weekly meetings, each team presented the evolution of their projects and received orientation from the instructors. The objectives of these weekly meetings were also to have a close observation of the teams' progress and assure that each team member contributed to the teamwork. During the ninth week, 30% of the final grade was assigned, after the students presented the preliminary written report and oral presentation of the results in their progress. Another 40% of the final grade was assigned to the students during week fifteen when they demonstrated that their projects were working in accordance to the specifications. The last 30% of the final grade was assigned based on the final oral presentation, taking into account the quality and clarity of the presentation, and the completeness of the final written report.

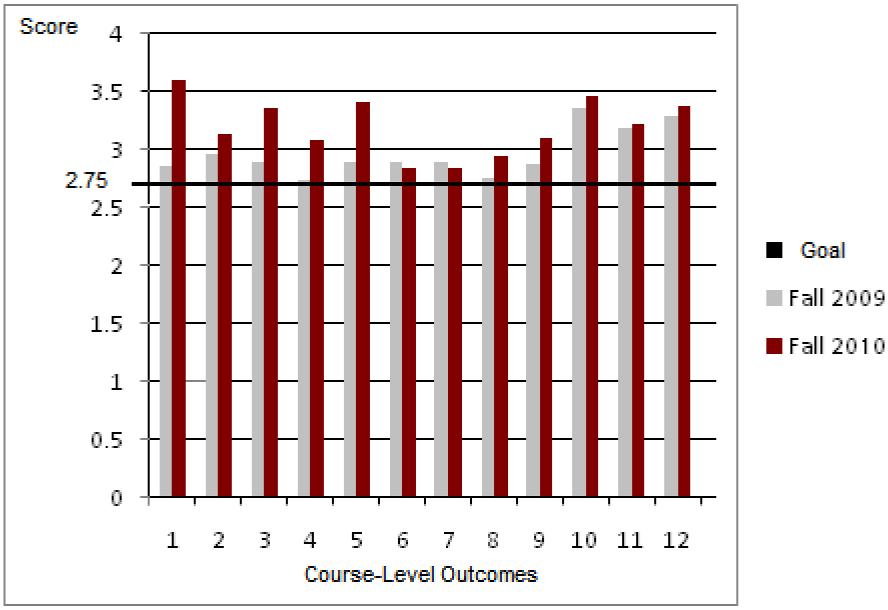

Figure 2.- Summary of Assessment

7. Conclusions

Different autonomous vehicles were designed and built (as shown in Figures 3 - 5), for the specific task of participating in several robotic competitions, and to fulfill the course requirement for the students in our department. The participation in this course gave students real-life team work experience. They experienced the application of theoretical information in different areas of knowledge to solve real engineering problems. This experience could later be used in their professional careers to solve similar engineering problems in numerous applications. The potential of real-world autonomous devices being able to control themselves is growing, and in some cases is very desirable. Throughout the process of designing and building the autonomous vehicles, the students encountered many problems and made some mistakes of their own, that had to be realized and acted on accordingly. The top challenge for students and faculty members was to manage the schedule of each project, so that they were all ready to be put together by the end of the eleventh week. It would be more desirable to have more time to construct the vehicles. In fact, the IGVC[5] documentation suggests that students developing a robot for this competition should work about two semesters to successfully complete this type of projects. Based on the time constraints that we had, along with a limited budget, the final result that we obtained were better than expected. Overall, in this course students were able to integrate electrical, computer, and mechanical engineering techniques, along with computer science and mathematics for the implementation of autonomous mobile robots. It also provided the students with a way to transfer theoretical knowledge into a practical application, which is an invaluable final step in the mechanical and electrical engineering technology programs. The final test for the projects was their presentation in the robotic Firefighting, IEEE SouthEastcom, and the autonomous lawn mower competitions. In all of these competitions, the teams managed to qualify for the finals.

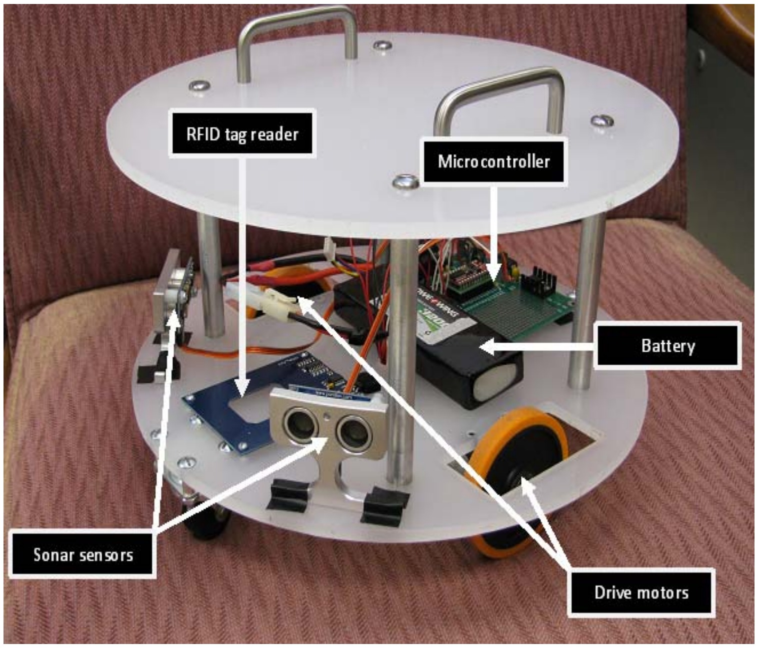

Fig 3.- RFID Controlled Robot

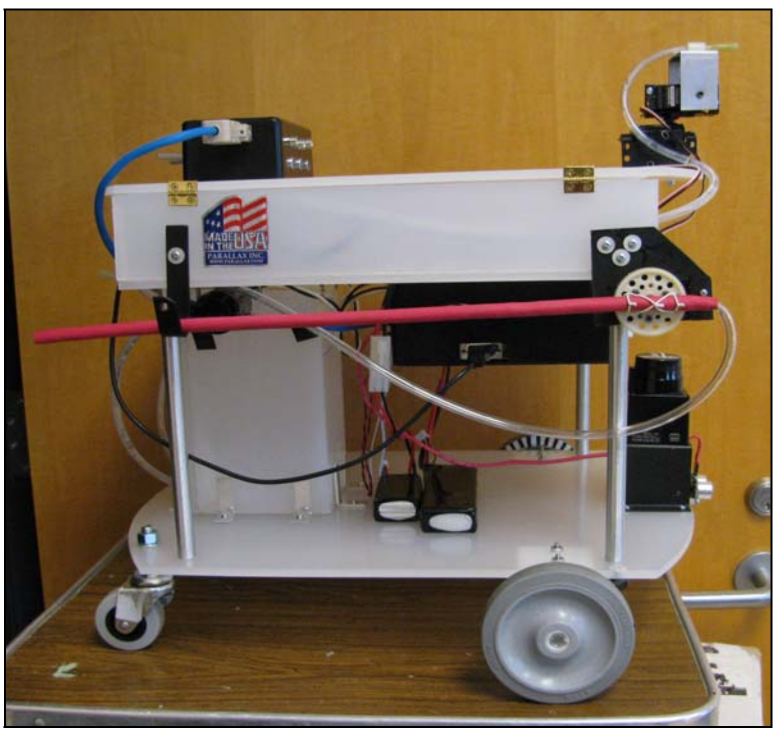
Fig.4 – Firefighting Robot

Fig.5 Autonomous Lawn Mower

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