AC 2008-2596: SUBURBAN OUTDOOR CHALLENGE FOR AUTONOMOUS MOBILE ROBOTS

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Suburban Outdoor Challenge for Autonomous Mobile Robots

Abstract

An outdoor robot design contest, the Mini Grand Challenge, was developed at the Penn State Abington campus to promote advances in robotics education, computer vision, and rapid prototyping. The contest is partly inspired by the DARPA Grand Challenge, but our contest emphasizes low-cost hardware and software solutions, accessibility, spectator interaction, and education. The contest requires autonomous mobile robots to navigate unmarked, paved pathways on a suburban college campus and reach GPS waypoints. Robots must avoid obstacles and robots are also awarded points for interacting and entertaining spectators. A successful robot platform constructed for less than $300 and controlled by a laptop running MATLAB software was developed by undergraduate students. The contest, offered annually, was first offered in 2005 and is open to students at all levels of education (K-12 and college) and beyond. This contest can be used to successfully introduce computer vision and other robot technologies into the undergraduate curriculum.

1. Introduction

An outdoor robot design contest, called the Mini Grand Challenge, was developed at the Penn State Abington campus to promote advances in robot education, computer vision, systems engineering, and rapid prototyping. The contest is partly inspired by the DARPA Grand Challenge [1], but our contest emphasizes low-cost (yet sophisticated) hardware and software solutions, accessibility to a wide range of participants, spectator interaction, and education.

The contest requires autonomous, electric mobile robots to navigate unmarked pathways on a suburban college campus and reach GPS waypoints. Robots must avoid obstacles and robots are also awarded points for interacting and entertaining spectators. The contest is open to participants of all ages and educational backgrounds - K-12, college, and beyond. Any hardware or software solutions are permitted to be used in the development of a robot for this contest. A functional robot platform constructed for less than $300 and controlled by a laptop running MATLAB software was developed by undergraduate students at the Penn State Abington campus [2].

Design and development of a robot for this contest has been integrated into a lower-division robotics design course and is also the focus of undergraduate research activity at our campus. The current educational initiative consists of three objectives: 1) the outdoor robot contest which is offered annually and open to the public; 2) providing strategy for construction of a low-cost autonomous robot platform, and 3) providing educational

resources (example: database of campus pictures) to facilitate development of control and vision algorithms in a MATLAB environment.

The contest was first offered in the spring of 2005 with only 4 participants. In spring of 2006 and 2007, there were 7 and 9 robots participating, respectively. This outdoor challenge has provided lower–division undergraduate students a unique exposure to autonomous robots, computer vision, and artificial intelligence. Participants have responded very favorably to the contest experience, and interest is expanding. In the spring of 2007, a high school team was mentored for participation in the contest.

The organization of this paper is as follows. First, the paper will introduce and describe the Penn State Abington Mini Grand Challenge robot contest rules and specifications. This description will provide educators an opportunity to evaluate the contest in terms of objectives and required skills and technology. Second, the paper will provide an overview of the architecture of a successful low-cost autonomous robot solution designed by undergraduate students. This prototype can be used as a guide and as a benchmark for educators and students to assist in the development of a robot solution. Resources provided to students to facilitate the computer vision algorithm are also introduced.

2. Mini Grand Challenge Robot Contest Description

The following is a list of the key specifications of the robots designed for the Mini Grand Challenge robot contest. (A full set of specification and rules are available on the contest website [3].)

1. Robots must be electrically powered
2. Robots may be constructed from any type of materials
3. Robots should operate in the 1mph to 5mph speed range (there is no speed advantage in the contest.)
4. Robots must transport a 1-gallon container of water (payload)
5. Robots must possess an emergency off/stop switch
6. Robot size must not exceed volume of a cube 6-feet on a side
7. Robots must be able to be physically lifted and carried by two average adults
8. Robots may not communicate with any external device or humans (with exception of spectator interaction)
9. Robots should be characterized as ground robots (no aerial robots permitted)

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The first phase of the contest requires the robots to navigate along a paved path (7-8 feet wide) throughout a campus setting. The entire course is in the range of 0.5 miles or less. There are a total of 6 GPS waypoints which must be reached. The waypoints are disclosed to the robot participants prior to the contest. The first 5 waypoints are designated positions along the paved path, and the robot earns points to reaching these waypoints (see Figure 1). While the robot is on the path, it must stop all motion if it detects an obstacle (such as a human or another robot). There are orange cones which limit access to path sections along the course (see Figures 2, 3). After the 5th waypoint,

the robot departs from the paved path and crosses a field to reach waypoint (#6) – the final goal in the robot course (see figure 4).

During the entire course, the robot is encouraged to communicate, entertain, or interact with the spectators. Points are awarded based on the level of complexity and duration of the spectator interaction. Simple communication has been in the form of music playing, announcements, notifications as to position and speed of robots, etc. It is expected that the robot interaction will improve in sophistication as the contest evolves. The robot which earns the most points for navigation and spectator interaction is declared the winner.
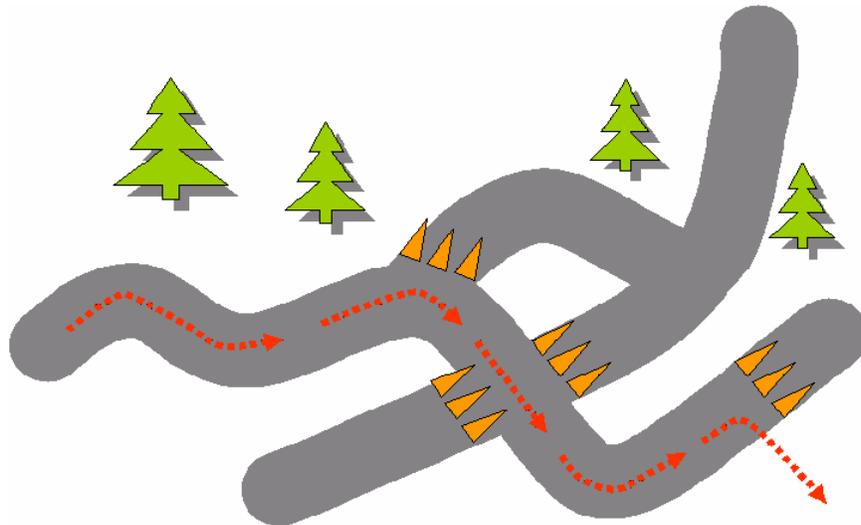

Figure 1 Campus Path for Robot Contest

Figure 2: Campus Path Section

Figure 3: Campus Path Showing Orange Cones

Figure 4: Off-path Field Crossing Area

3. Architecture of an Outdoor Robot

This section will describe the key elements of a successful robot platform and solution designed by lower-division undergraduate engineering and Information Sciences and Technology students at the Penn State Abington campus.

The base platform is a modified PowerWheels™ electric car which has been modified to operate under computer control. The steering is accomplished a by a simple, high power servo motor, and the drive motors are controlled by an inexpensive high-current hobby-grade electronic speed controller (ESC). The steering and speed control is accomplished via an inexpensive microcontroller (Pontech SV 203) which is connected through a serial port to a laptop running MATLAB® under Windows XP. The microcontroller also drives a sonar unit and relays distance information back to MATLAB. An inexpensive USB web camera and a GPS unit (serial connection) are also interfaced to the laptop and information from these sensors is accessed directly by MATLAB for processing. An amplifier and external speakers are connected to the laptop to provide sound and music at a level necessary for use outdoors. All drivers for accessing images, serial port communication, and text-to-speech are readily available for the MATLAB environment. A block diagram of the architecture is shown in Figure 5 below.
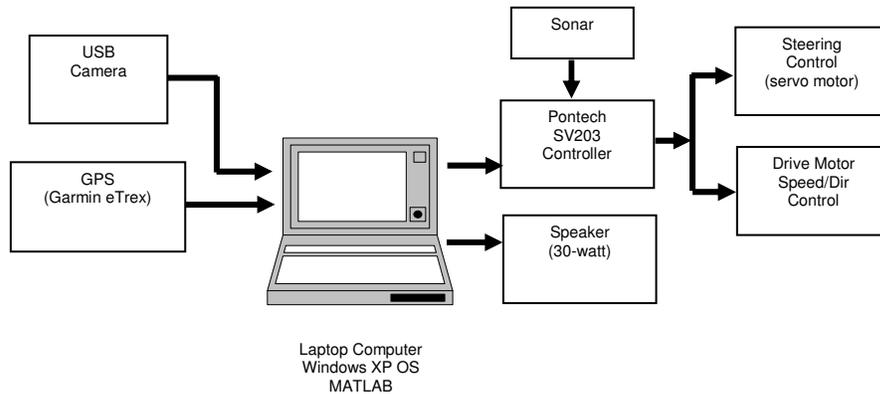
Figure 5: Robot Architecture

The MATLAB platform performs all of the control and vision computing required to operate the robot in the contest. A simple path following vision algorithmic was developed in MATLAB (using Image Processing Toolbox) using built-in edge detection functions and some heuristics. A collection of campus path pictures is available to facilitate the design and testing of the computer vision algorithm. The advantage of using MATLAB for control and vision is that there is no need to convert software or cross-compile software to another platform. All of the development and deployment occurs in the same interactive MATLAB environment. This development approach greatly simplifies the design and testing process and allows for rapid prototyping of solutions. Due to the relatively low speed of the robots, the MATLAB is sufficient to provide adequate control for navigation, obstacle avoidance, and sound and speech generation. Although the details of the vision and control algorithms are beyond the scope of this paper, the robot platform and software development environment described here is an important result.   This result demonstrates the feasibility of developing a successful, functioning robot at low-cost and with widely available tools that are accessible to a wide range of students, including lower-division undergraduate students. Pictures of the Penn State Abington robot at the 2007 contest are shown in Figure 6 and 7. This robot was capable of reaching 3 of the 5 on-path waypoints and achieved adequate points overall to be declared the winner at the 2007 event.

Figure 6: Penn State Abington Robot in 2007Contest

Figure 7: Penn State Abington Robot in 2007 Contest

It should also be noted that the Mini Grand Challenge robot contest does not require the use of the equipment and MATLAB software tools described above. Any hardware and software tools can be utilized to achieve a solution and it is hoped that the contest will support a variety of technical approaches based on a variety of educational goals. One of the advantages of allowing and encouraging a wide range of solutions is that students can benefit from exposure to a variety of creative approaches and technologies at the contest. A few of the other participating robots in the 2007 contest are shown below in Figures 8 and 9.

Figure 8: Participants in 2007 Mini Grand Challenge

Figure 9: Participants in 2007 Mini Grand Challenge

4. Summary and Conclusions

The goal of the Mini Grand Challenge contest is to provide an educational resource and research tool to enhance robotics education, computer vision, artificial intelligence, systems engineering and rapid prototyping to the educational community. A key objective is to provide a challenging robotics design problem while allowing the use of low-cost hardware and software solutions. This approach allows participants to focus on algorithm design and also increases participation from diverse backgrounds. The unique feature of the spectator interaction allows educators, researchers, and students to explore human-robot interaction in the field. In the future, useful robots and automated vehicles will need to operate safely and interactively in environments inhabited by humans.

The contest has been successfully integrated into an undergraduate robotics course and into an undergraduate research activity. Educational resources, such as a database of campus path pictures, are available to facilitate the computer vision algorithm development.   An example of a successful robot platform and a software development environment (based on MATLAB) has been provided. This prototype can be used as a guide or as a benchmark for educators and students to assist in the development of a robot solution. Additional resources can also be found on the website for the contest [3].

Overall, the contest has been very well received. Interest in the contest is growing each year and the event attracts students and professionals from a wide range of backgrounds.

It is hoped that the discussion of the outdoor robot contest in this paper will encourage educators to participate in this challenge and incorporate the contest objectives in innovative ways into the curriculum. We also hope to increase K-12 involvement in the near future.

6. References

[1] DARPA Grand Challenge website: http://www.darpa.mil/grandchallenge/
[2] Avanzato, R., "Mini Grand Challenge Contest for Robot Education, " Proceedings of AAAI Spring Symposium Conference, Robotics Education, Stanford University, March 26-28, 2007.
[3] Mini Grand Challenge website:
http://cede.psu.edu/~avanzato/robots/contests/outdoor/index.htm