Mobile Robotics As The Platform For Undergraduate Capstone Electrical And Computer Engineering Design Projects

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Abstract - Research grade mobile robots are no longer restricted to robotics laboratories. Now that they are available and affordable through several vendors, they can be used for undergraduate capstone electrical and computer engineering design projects. Several important educational considerations have supported this decision, including: providing students with a platform for their projects that enables integrating both hardware and software development as well as dealing with real-time programming issues. We present our experience in using the AmigoBot from ActiveMedia for capstone senior design projects. Our work has focused on integrating a variety of sensors to the robot control architecture, most notably the integration of an IEEE 1394 – Firewire – digital CCD camera. That in turn has enabled students to develop and test computer vision algorithms. Additional system capabilities included wireless communication of video streams captured by the digital camera. Integrating the ability to remotely control the AmigoBot can also enable using it for indoor surveillance applications.

BACKGROUND AND MOTIVATION

Mobile robots with advanced capabilities have been successfully sent to Mars: Opportunity and Spirit rovers have been successfully deployed for their missions for planetary exploration in late 2003 and early 2004 [1]. They will also compete in a Grand Challenge (and a $1M prize) by DARPA for autonomous navigation between Los Angeles and Las Vegas on March 13, 2004 [2].

These mobile robots are still in the realm of robotics research laboratories in academia, in government agencies, in the military and in industry. However, simpler, affordable mobile robots are increasingly available and are steadily gaining popularity in educational settings [8]. They can be built from simple kits, such as the Mindstorm Lego Robots® [3], or acquired with varying capabilities from vendors such as iRobot [4] and ActiveMedia [5].

We have therefore selected mobile robots as the platform for undergraduate capstone design projects for the following reasons:

• The ability to address issues central to electrical and computer engineering education.
• The ability to address system integration of hardware and software into a mobile robot platform.
• The ability to address real-time requirements.
• The ability to develop a variety of algorithms for the integrated robotic architecture.

In the following sections we present:

- our choice of a mobile robot platform,
- the hardware and software integration, as well as
- algorithms and applications

realized in undergraduate capstone electrical and computer engineering design projects. We conclude with our future directions for the use of mobile robots in educational settings at the undergraduate and graduate levels, as well as for outreach to K-12.

ROBOTIC SYSTEM INTEGRATION

We chose the AmigoBot from ActiveMedia® [5], shown in Figure 1, as the platform of choice for capstone design projects in the area of mobile robots.

The AmigoBot mobile robot we acquired is equipped with six forward and two rear sonar sensors that collect data about the proximity of objects surrounding the robot and wheel encoders that can be used to measure the distance traveled by the robot. The programming of the robot is done in C++ using calls to the Saphira/Colbert software libraries that in turn contain calls to the low-level robot control library, called Aria.

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October 20 – 23, 2004, Savannah, GA

34th ASEE/IEEE Frontiers in Education Conference

S2G-7
The AmigoBot is programmed using layered [prioritized] behavior-based robotic architecture, an approach that is based on robotics research developed at MIT in the late 1980s, and similar to the approach used in many commercial and research grade mobile robots today [4]. A generic robot control architecture can be simply considered as a system that implements feedback control loop, with inputs, outputs and a decision-making process. The inputs provide measurements about the environment and the internal state of the robot and are obtained using a variety of sensors; e.g., sonar, wheel encoder, compass, GPS, and CCD camera. The outputs are produced by the robots actuator’s, which, in the case of our AmigoBot are simply left and right motor signal to drive the robot. The decision-making process receives the inputs and produces the outputs. The sophistication of decision-making can range from very simple; e.g., simple behaviors to avoid collisions, to very complex; for instance, path planning for a multi-step delivery task. In robotic research terms, simple decisions are known as reactive behaviors, while complex ones are known as deliberative. Furthermore, deliberative type of decision-making that includes machine learning is an active area of investigation in robotics and artificial intelligence, including the ongoing investigation in our Developmental Robotics Laboratory – DRL [9].

**CAPSTONE DESIGN PROJECTS USING MOBILE ROBOTS**

Per ABET guidelines for accreditation of academic programs, undergraduate students in electrical and computer engineering must work on a capstone design project in their senior year in order to graduate. The main traits of the capstone experience that we provide students, similar to other engineering programs around the country and around the world, is: based on user/problem requirements, to develop a solution to an open-ended problem using hardware and software, while also addressing industry standards. Additional activities and deliverables by our students include:

- a project proposal,
- hardware and software acquisition,
- interim and final reports,
- weekly presentations and progress reports,
- developing documentation in the form of user and developer manuals – with the developer manual focusing on the technical aspects of all hardware and software used and developed for the project, as well as
- a final presentation and demonstration of the deliverable system.

Additional technical criteria that are addressed by the project include: flexibility and modularity of the resulting architecture, as well as well tested deliverables.

A senior design project in Fall 2002 has resulted in the development of an embedded digital video system (using a Sony CCD camera) that is based on the high bandwidth IEEE 1394 (Firewire) protocol – that is also an industry standard.

The system architecture is shown in Figure 2. The capabilities of this system are described in [7].

Another senior design project in Spring 2003 has succeeded in integrating a CCD camera with the AmigoBot via a notebook PC, and in developing simple path-following robot behaviors based on edge detection computer vision algorithms [9] – a demo of that project was one of the highlights in our program’s Open House in Savannah.

In Fall 2003, based on the system requirements to build indoor and outdoor surveillance robots, additional sensors and the corresponding hardware and software capabilities were integrated with the AmigoBot. For indoor surveillance, in addition to the CCD camera integration, images (Figure 3) were transmitted using TCP/IP-based wireless communication to a monitor PC. Moreover, the AmigoBot was controlled using a joystick thereby enabling teleoperation. For outdoor navigation, a GPS was integrated to provide the coordinates for the robot trajectory. Some of the insights from both projects for robotic surveillance include:

- For wireless transmission of a video stream: the conversion from JPEG frames to TCP/IP packets, and achieving a feasible frame rate for real-time wireless transmission and edge detection for hallway navigation (Figure 4).
- For the use of GPS trajectory following algorithm: taking into account the resolution provided by a low-end handheld GPS, as well as conversion of the longitude and latitude GPS coordinates to the robot world coordinates.

Final reports as well as user and developed manuals can be made available (in pdf format) via the DRL web site, located at: http://www.gtrep.gatech.edu/~drl/, and upon request from the author.

**CONCLUSIONS AND FUTURE WORK**

Mobile robots have left the realm of the research laboratories. Simple mobile robots are being integrated in educational settings ranging from K-12 and competitions for high school students to planetary exploration.

The work presented herein has demonstrated that mobile robots can be successfully used as the platform of choice for undergraduate capstone electrical and computer engineering design projects.

We also believe that we are now at an opportune moment where both educational and research objectives can be fulfilled with the same platform, as exemplified by our own experience. For instance, the AmigoBot can be used as the platform for sensor integration as well as investigating various ways for information fusion that such integration entails. While the AmigoBot has provided a platform for undergraduates to get experienced in working with a layered behavior-based robotic architecture, it is currently being used to also develop more sophisticated deliberative decision-making processes to...
incorporate machine learning algorithms that are the subject of our ongoing investigation at the DRL [9].

ACKNOWLEDGMENTS

The author would like to acknowledge the efforts of the following GTREP ECE undergraduate student advisees: Ninad Sherwala and Hai Nguyen (Fall 2003) for their senior design project on using the AmigoBot for indoor surveillance applications. Chad Shaw and Jason Carver (Fall 2003) for GPS integration for robot trajectory generation. Koutsounis Prater and Jason Baird (Spring 2003) for developing computer vision based path-following robot behaviors for the AmigoBot. Donnie Smith, Eric Mullenax and James Martin (Fall 2002) for the development and integration of an IEEE 1394-based embedded video system and related algorithms for computer vision-based surveillance applications.

REFERENCES


Ashraf Saad is associate professor of Electrical and Computer engineering at the Georgia Institute of Technology. He founded the Developmental Robotics Laboratory on the Savannah campus of Georgia Tech in 2001. He obtained his PhD degree in Electrical and Computer Engineering in 1996 from Vanderbilt University, where he was a member of the Intelligent Robotics Laboratory (1991-1996). Between 1996 and 2000, he was assistant then associate professor at the University of Cincinnati. He was Principal/Co-Principal Investigator on two NSF DUE projects supported by grants number: 9950029 and 0196015. His research interests include developmental, cognitive and educational robotics, wireless sensor networks, and embedded systems for real-time vision applications. He is a member of the IEEE, ACM, and AACE professional societies.
FIGURE 2.
DATA FLOW WITHIN AN IEEE 1394-BASED EMBEDDED COMPUTER VISION SYSTEM [7].

FIGURE 3.
ORIGINAL IMAGE USED FOR HALLWAY NAVIGATION.
FIGURE 4
EDGE DETECTION FOR HALLWAY NAVIGATION