Interfacing Handheld Computers to Mobile Robots

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Abstract

Penn State Abington has been exploring the application of handheld technology to the interface and control of autonomous mobile robots for educational purposes. The handheld or personal digital assistant (PDA) is an inexpensive computer that supports a wide range of mobile software applications, and features serial, infrared, and RF communication capabilities. In one application, undergraduate students have developed handheld-based autonomous robots for several robot design competitions. One of the benefits of the handheld-based robot is that students can enter and modify software directly on the handheld computer at the "point of operation" without the need of laptops or desktop PCs. In a second application, students investigated human-computer interface (HCI) design issues by controlling a robot remotely using the IR capabilities of a handheld. This technology has applications in areas such as mobile data collection, entertainment, emergency response, search and rescue, and assisted-living support. This paper will describe the laboratory setup required to implement these activities, present key results, and discuss the educational benefits of the handheld approach to mobile robot control.

Introduction

Starting in the fall of 1999, Penn State Abington has been actively exploring the integration of Palm™ [1] handheld computers into select undergraduate courses in the areas of computer engineering, Information Sciences and Technology, and French language instruction. The handheld computer or personal digital assistant (PDA) is an inexpensive mobile computer that supports a wide range of applications including database, spreadsheet, document viewing, graphics, programming, data collection, and web-browsing software. Additionally, the handheld features serial, infrared communication, and RF communication capabilities. A primary goal of these integration efforts is to promote active and collaborative learning in the classroom and laboratory settings, and to explore enhancements and efficiencies in the delivery of instruction [2].

During this period, the handheld computer was also integrated into an existing robotics education curriculum. Penn State Abington has been offering robotics courses and activities for freshman and sophomore undergraduate engineering students since 1995. The campus also hosts two public robot design competitions each year, and operates a K-12 outreach program in the Philadelphia, PA area [3].

Two applications of handheld-based robotics design in an educational context, as well as examples of student work, will be presented below.

Handheld-Based Mobile Robot Projects

In the first application of robot design using handheld computers, a Palm™ handheld device served as the “brain” of an autonomous mobile robot. In this design configuration, the Palm™ handheld was resident on the robot platform, and was interfaced to a commercially available controller board (Pontech SV203 [4]) by way of a serial cable connection. The Pontech board features a 5-channel, 8-bit analog-to-digital converter (A/D) and can control up to 8 servo motors. The servo motor outputs can optionally be configured to behave as digital outputs. This architecture allowed the handheld to control motors and actuators and also to receive data from a variety of sensors located on the robot. The CMU Palm Pilot Robot Kit (PPRK) [5] utilizes similar hardware, but the software approach in the Penn State robots has a different emphasis.

One of the innovative aspects of the handheld-based robot was that the technology allowed students to enter and modify control software directly on the handheld computer at the "point of operation." This was found to be particularly useful in environments, such as at a contest, in the field, or in a traditional classroom where conventional desktop and laptop computers are not conveniently available. The software product used in this work was PocketC by OrbWorks [6]. PocketC supports many of the features of the C language and includes support for graphics, sound, and the serial port. Programs are stored as Palm™ text memos and are compiled and executed on the handheld. Software programs can be entered or altered directly on the handheld device. These programs or program segments can be electronically beamed from one handheld device to another, and this feature supports collaboration among students during software development. Screenshots of the software as it would appear on a Palm™ handheld computer are shown below in figure 1.

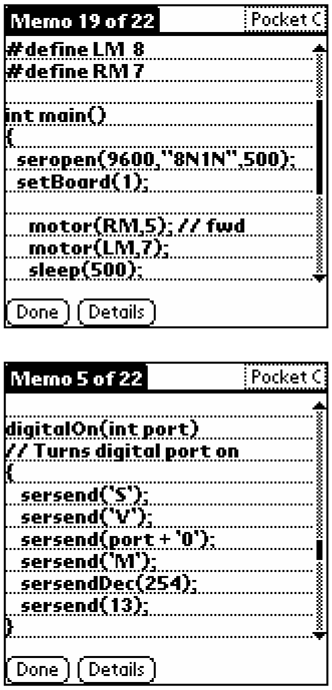

Figure 1

Several prototype robots were designed by sophomore-level undergraduates for entry in regional fire-fighting robot contests. The contest objective is to design an autonomous robot which can navigate through a maze consisting of four rooms, locate a randomly located candle, and extinguish the candle in the minimum amount of time [7]. Additional construction details and discussion of this approach to robot design can be found in [8]. Several Penn State Abington firefighting robots based on handheld technology are depicted in figures 2 and 3. A Penn State

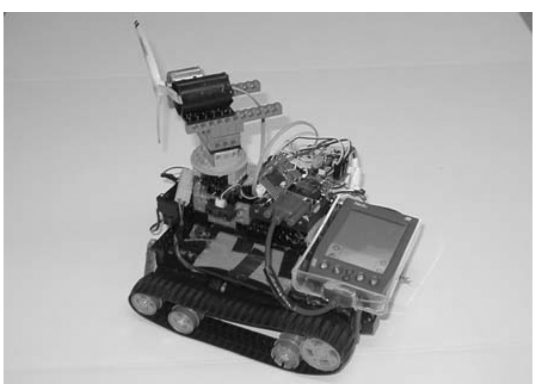

Figure 2

Abington robot developed for a robot basketball design contest was based on the CMU PPRK robot platform and is shown in figure 4.

In the second area of development, the Palm handheld was utilized as a programmable IR remote controller used by the student to direct and program the motion and behavior of existing mobile robots. The emphasis here was to engage students in the design of a meaningful graphical user interface on the handheld to effectively control a mobile robot for a specific application. In this student activity, a Lego®-based robot platform controlled by a

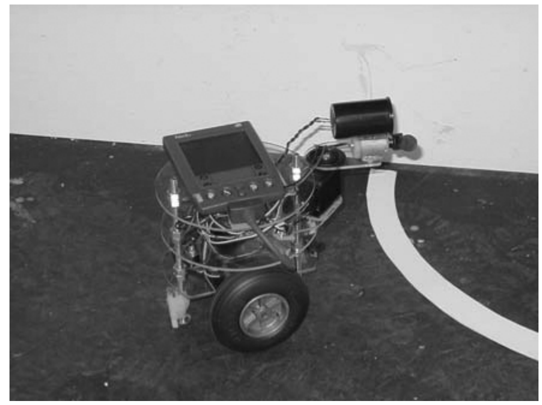

Figure 3

HandyBoard [9] controller was provided to each team of students. The software tool used to generate the IR commands on the handheld was OmniRemote™ by Pacific Neo-Tek[10]. OmniRemote™ allows the user to custom design a controller interface on the handheld screen using buttons, icons, text, macros, and multiple screens. Software libraries to enable the HandyBoard controller to respond to (TV-style) IR commands are documented and

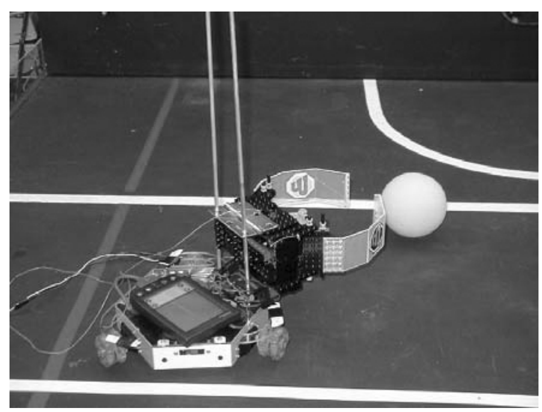

Figure 4

available from the HandyBoard website. The student teams are first required to choose a problem context such as a security robot, entertainment robot, educational robot, etc. The teams are then instructed to program and control the robot to perform a variety of low-level functions (e.g. move forward, reverse, etc.) and higher-level programmed functions (e.g. move in prescribed path, play sequence of songs, respond to specific sensors, collect data, etc.) based on specific IR codes received by the HandyBoard. The first solution step is to control the robot using a standard universal TV IR remote controller which consists of the typical numeric keyboard buttons. The second step is to design a more intelligent and more user-friendly IR controller using a GUI designed with the OmniRemote™ tool on the handheld. An example of an IR interface designed on a Palm handheld using the OmniRemote™ tool is provided in figure 5.

This laboratory experience establishes a foundation on which to pursue additional exercises in human-computer interaction and interface design issues. These activities have been received with a good deal of enthusiasm by students. The added dimension of user interaction and HCI issues has greatly improved the collaborative and creative approach to robot design in the classroom and laboratory.

In an extension to the above approach, the same IR software tool can be used to create a user interface on the handheld computer which allows a user to send a sequence of basic commands or tasks to a HandyBoard. This sequence of commands is stored (cached) on the HandyBoard, after which the stored commands are executed in sequence. In this way, a small program consisting of several commands can be entered and then executed from the handheld controller. Again, the emphasis here is to engage students in the process of the design of the appropriate interface design and command set.

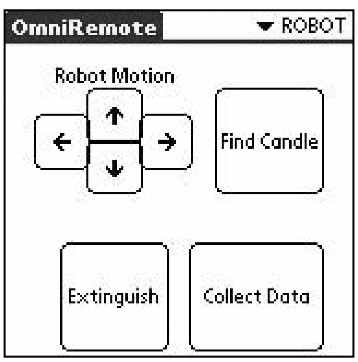

Figure 5

In both cases above, the students are provided with a functional HandyBoard program, written in the Interactive C [11] language, which detects and responds to the appropriate IR codes. This provides a template to which the students add the code which corresponds to individual robot motion or behaviors.

Although these exercises are limited to one-way IR communication from the handheld to the HandyBoard, the technology for 2-way IR communication is being investigated and evaluated for educational value.

The handheld interface to a mobile robot exercises outlined above were first developed by the author for a robotics workshop at the Pennsylvania Governor's School of Information Technology held at Penn State University Park in the summer of 2000. These exercises were subsequently incorporated into robotics and computer science courses at the Abington campus. Images of students working with robots and handheld computers are shown below in figures 6 and 7.

Figure 6

Figure 7

Summary and Future Directions

This paper provided an overview of some successful educational initiatives involving handheld computers and mobile robotics developed at the Penn State Abington campus. Several basic laboratories and student projects have also been presented. The overall educational goal is to provide students with the tools to investigate and prototype the interaction between a human operator and a mobile robot through the use of a handheld computer. The design and development of an effective user interface suitable for a handheld platform is a key to the success of this interaction. The availability of low cost software and hardware tools allows students at the lower division level to successfully investigate mobile issues of human-computer interface technology. Additional resources and laboratory exercises can be located on the Penn State Abington robot website [3].

Handhelds pose technical and usability challenges due largely to the small screen size and limited data entry capabilities. However, the advantages of a small portable computing platform (coupled with a well designed interface) allow humans to interact with robots in environments that would otherwise not be practical with the use of conventional laptops or desktop PCs. Important robotics application areas that would be facilitated by the integration of handheld technology include data collection in the field, entertainment, search and rescue, emergency response, security, and assisted living.

From an educational delivery standpoint, the use of handheld technology allows the integration of robotics exercises and laboratories to occur in many non-traditional environments including a conventional classroom and in the field. It is predicted that the availability of handheld computer interfaces to a mobile robot can have a major impact on the accessibility of mobile robotics education, programming, HCI, and artificial intelligence education at the K-12 level, where traditional computer laboratories are often not sufficiently available.

Future work includes the investigation of Bluetooth and 802.11 wireless communication technologies between mobile robots and handheld computers. Basic 802.11 communication between a Sony handheld and an AIBO® robot dog [12] has recently been demonstrated by Penn State Abington students and this technology will be investigated further. Many of the laboratory experiences have been performed with the HandyBoard robot controller and it would be beneficial to pursue educational experiences based on communication between a handheld and Lego Mindstorms™ [13] robot technology. Lego Mindstorms™ technology represents a large community of users among K-12 and college institutions.

As mobile devices (handhelds, mobile phones, etc.) improve in performance and networking capabilities, it is anticipated that opportunities for educational experiences in the area of robot interfacing will expand accordingly.

References

[1] Palm, Inc., http://www.palm.com

[2] Avanzato, R.L. 2002. Handheld Computers in the Classroom and Laboratory. *Computers in Education Journal*, Vol XII, No. 3, July-September 2002, p. 88-92.

[3] Penn State Abington Robot Website, http://www.ecsel.psu.edu/~avanzato/robots

[4] Pontech, http://www.pontech.com

[5] CMU Palm Pilot Robot Kit, http://www-2.cs.cmu.edu/~pprk/

[6] OrbWorks, http://www.orbworks.com

[7] Trinity College Firefighting Robot Contest, http://www.trincol.edu/~robot

[8] Avanzato, R.L. 2002. Controlling a Mobile Robot with a Personal Digital Assistant. *Computers in Education Journal*, Vol XII, No. 3, July-September 2002, p. 9-13.

[9] HandyBoard, http://www.handyboard.com

[10] Pacific Neo-Tek, http://www.pacificneotek.com/

[11] Newton Labs, http://www.newtonlabs.com/ic/

[12] Sony AIBO, http://www.us.aibo.com/

[13] LegoMindstorms, http://www.legomindstorms.com