Using PDAs on Autonomous Robots to Promote Engineering to Middle School Students

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Abstract

The utilization of robots and handheld PDAs (Portable Digital Assistant) to promote the teaching of science and engineering along with a specific experiment and a future experiment will be discussed in this paper. Students are introduced to how valuable science and engineering are to our society by bringing the science to the students through the use of such learning agents as robots. Robots can facilitate learning by intriguing and holding onto the student's interest. Working directly with the robots can help students to formulate an improved knowledge and understanding of the importance and relevance of science and math. All the work discussed in this paper has been developed through the implementation of several experiments developed at Binghamton University for use in local middle schools.

Introduction

The research discussed in this paper is focused on developing a robot and curriculum that can be easily integrated into the math and science courses of 5th and 6th grade students. The prototype robot for this research was first introduced and tested by students from public schools in Binghamton and Vestal, New York. Students in the 5th and 6th grades from local schools spent time at Binghamton University over their '02 summer break to participate in "Exploring Engineering". "Exploring Engineering" is a weeklong event that engages students in real engineering situations and exposes students to many facets of engineering and science. During this weeklong event, among other activities, students are exposed to robotics and mechanical engineering by building and testing simple remote-controlled robots. Students also gain an insight to the history and world of mechanical engineering while attending a presentation given by a mechanical engineering professor.

The prototype robot

The prototype robot used in "Exploring Engineering" is a robot named the CD-Robot. The CD-Robot is a remote-controlled robot that has its body fabricated from scrap compact discs (CDs). Scrap CDs were chosen as the primary building material for the CD-Robot due to their easy availability and inherent need to be recycled. A picture of the CD-Robot is shown in figure 1 below. The cost to build a CD-Robot is approximately $65.

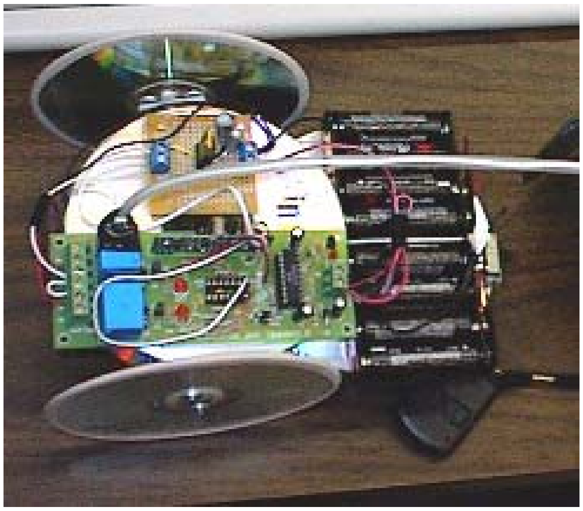

Figure 1. The CD-Robot.

The CD-Robot is controlled by a two-channel UHF transmitter and receives the transmitted commands with a UHF receiver that has been modified to operate in a momentary mode rather than its original toggle mode. Each button on the transmitter is capable of momentarily collapsing a corresponding relay on the receiver board. Since we are limited to only two channels on the UHF transmitter/receiver the robot can exhibit the following motion: go forward, spin left, or spin right. It is possible to use a UHF transmitter/receivers with more than two channels, but the cost is significantly greater and one of the objectives of this research was to develop a low cost robot.

The drive mechanisms used for the CD-Robot are two modified standard hobby servos. Standard hobby servos were chosen for this robot due to their availability, low cost, and ease of implementation as a drive train for a small robot. Hobby servos are limited to approximately a 180° range of rotation, however some servo brands have a slightly larger or smaller range. For this application the servos needed to be capable of continuous rotation. To accomplish this task all mechanical stops within the servo must be removed. This is as simple as opening the servo and cutting out the mechanical stops. Traditionally the motion of a servo is controlled via pulse width modulation (PWM). In this case we wish to control the servo's motion by setting the polarity on each of the servos motors. To accomplish this, the position feedback circuit within the servo must be removed and the red and black wires must be soldered directly to the small dc-motor within the servo.

The remainder of the CD-Robot comprises two 4-AA battery packs, one SPST switch, one nylon caster wheel, four scrap cds, and a small voltage regulator circuit. All the components are attached using double-sided foam tape. A complete set of instructions has been developed for making the modifications and assembling the CD-Robot. The instructions include templates that aid in the correct placement of the robot's components. The instructions and templates can be downloaded from the CD-Robot website, which is located at the following URL: http://bingweb.binghamton.edu/~bj92854/cd_robot.html.

The UHF transmitter/receiver was purchased in a kit form and modified to operate in a momentary mode rather than its original toggle mode. The kit was modified and soldered together ahead of time so that the students could easily assemble it to the CD-Robot. The decision to use a pre-existing UHF transmitter/receiver kit was made since the kit is low in cost as compared with buying raw components and developing our own. Several infrared transmitter/receiver kits were considered, but these kits were rejected since the transmitter and receiver must be properly aligned for communication to take place. The possibility of a radio frequency (RF) transmitter/receiver was researched and it was decided that this would be a costly alternative as compared with the UHF kit.

"Exploring Engineering" a case study

"Exploring Engineering" was a weeklong event that focused on giving 5th and 6th grade students a more detailed sense of what engineering encompasses and exactly what engineers do in their careers. Throughout the week students participated in numerous hands-on activities such as building wooden structures to withstand a simulated earthquake and assembling and testing remote-controlled CD-Robots. Exploring Engineering was organized by Eileen C. Way (Professor, Systems Science and Industrial Engineering Department, Binghamton University) and Cathy Jeremko (Mathematics Teacher and Coordinator of MathCounts math club, Vestal Central School District, Vestal Middle School). It was funded by the Vestal School Foundation. Thirty-seven 5th and 6th grade students from several local middle schools participated in the event.

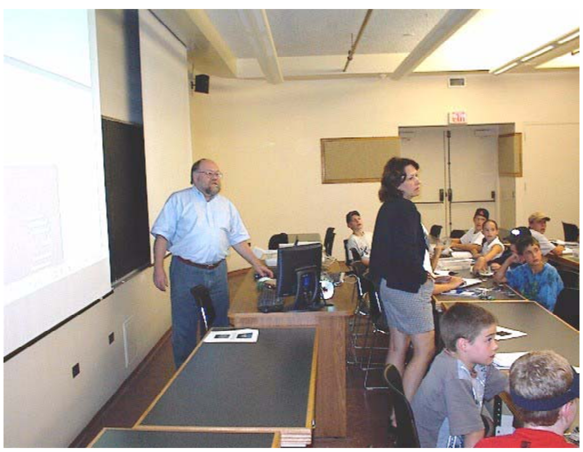

Figure 2. Professor McGrann and Mathematics Teacher, Cathy Jeremko.

The students worked with the robots all of one day. During this day, a presentation on mechanical engineering started the project. The lecture supplied the students with a better understanding of mechanical engineering and set forth several example careers for a mechanical engineer. During the presentation students were asked where they thought a mechanical engineer might be found in the workplace and some of the answers were quite surprising. The responses ranged from working in factories to working on planes and trains. However, some of the students were able to give an exact job description since one of their parents worked as an engineer for one of the local engineering companies. It was satisfying to learn that the students had a fairly accurate idea of where mechanical engineers can be found in the workplace.

Figure 3. CD-Robot Parts Kit Layout.

After the presentation, students were organized into groups of three or four students and each of the groups was given a CD-Robot Kit, such as the one shown above in figure 3. Upon receiving the kits, students were instructed to remove all the components from their kit and check to be sure that they had all the needed parts by using a supplied parts checklist sheet. Once all the groups had verified their kits completeness, each of the groups was given an instructional assembly manual for the CD-Robot.

Figure 4. Students checking the completeness of their kits.

After all the instruction manuals had been handed out, the student groups were then asked to follow along as each of the assembly procedures was first explained to them before they were asked to try the actual assembly. Graduate student and inventor of the CD-Robot, Abraham Howell, led the students throughout the explanation and actual assembly process of the CD-Robot. Cathy Jeremko, a mathematics teacher from Vestal Public School, also helped to guide the students throughout the assembly process. Several high school interns and another graduate student from Binghamton University helped the students with minor questions and difficulties throughout the assembly process. Each student within the group took a turn assembling their CD-Robot Kit to ensure that all the students got to participate.

Figure 5. Abraham Howell explaining the assembly steps.

The only difficulty in the assembly process occurred when the CD-Robots needed to have their wires connected. One of the groups accidentally reversed the polarity of their wires to the voltage regulator circuit and burned out their regulator. This was an easy fix since the robots were designed to accept different voltage regulators so that the speed of the robot could either be increased or decreased as needed. Once a new regulator was found and the wires were correctly connected the CD-Robot sprang to life.

Once all the groups finished the assembly of their robots, they were gathered together to build a simple slalom course for the robots so that each of the groups could test their robot and driving skills at the same time. Students built the slalom course by using small rectangular wooden blocks each placed a small distance apart. With the slalom course in place, each of the groups was ready to see who could traverse the course with their robot in the fastest time.

Figure 6. Robot slalom course races.

Each of the students received a certificate for completing the assembly of their group's robot along with a certificate for completing the slalom course. The students were also allowed to change their voltage regulator from a +5volt to a +8volt regulator. Some of the students that did change their regulator were not happy with the results since the increased speed made their robot more difficult to control for the slalom course and increased their run time.

Some of the students also discovered signal interference between robots. The students found that, when two robots were operated in close proximity to each another, there was interference between the two transmitters. This was due to an inherent conflict in the fundamental operation of the receiver circuits. Even though two robots operated on completely different frequencies there were erratic results when two transmitters transmitted at the same time. This was because the receiver would decode all signals coming in and a bad signal code would tie up the receiver while a valid code was being transmitted. The students observed and learned that problems often arise in engineering and that this is part of what makes engineering interesting and fun.

Conclusion

Even an inexpensive robot such as the CD-Robot can stimulate and maintain students' interest while teaching them fundamental aspects of mechanical engineering and science. Students gained tremendous hands-on knowledge by assembling the CD-Robot and also discovered that, in engineering and research, things do not always work the first time through. Sometimes on the spot troubleshooting is required, as was with the case with the burned out voltage regulator.

Many of the students identified the CD-Robot as a "real robot" since it had its wires and circuit boards exposed. This feature of the CD-Robot encourages students to tinker with the robot since, in their mind, they feel that the CD-Robot not just another toy. Many of the students were interested in building a CD-Robot of their own and were provided with a copy of the assembly and building instructions along with a complete list of the needed parts.

Future work

We are currently working to completely redesign the CD-Robot so that it can operate in an autonomous mode and provide the teacher with a vast array of learning tools accessible through one robot. One of the other objectives of this redesign is to keep the cost of the new robot to a minimum so that all schools may afford it. The newly redesigned robot will be called the "CDbot" and will be controlled in one of two possible methods: (1) using a handheld PDA (Portable Digital Assistant) in conjunction with a micro-controller (2) or using only a programmable micro-controller. This allows the CDbot to be flexible and cost effective in its use since some schools will not have access to handheld PDAs. The cost for the CDbot using a handheld computer is approximately $150, while the non-handheld version is around $110.

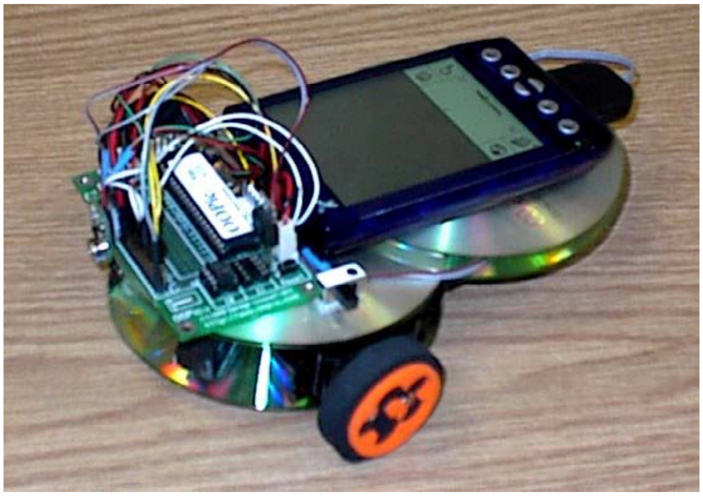

Figure 7. Picture of the CDbot Robot under development.
(Note: PDA and connector.)

The CDbot will be able to teach students various topics in robotics, programming, math, and science. Students will also learn to operate a PDA if the school can gain access to one or more PDAs. Several programs that reside on the PDA are under development and one of the programs has been completed. This program allows the CDbot to wander around its environment and record the changes in its body velocity along with the time stamp for when these changes occurred. Once the robot has collected data, the students can view the data directly on the handheld or save the data to two separate memo-note files. One of the files will be named "Velocity Data", while the other will be named "Time Data". Later students will learn how to extract the data from their PDA and create graphs of 'Velocity vs. Time' and 'Distance vs. Time' on a desktop computer.

Figure 8. Screenshots of the handheld program for collecting velocity and time data.

To extract the data from the handheld, students only need to hot-sync their handheld with a desktop or laptop computer. Once the files have been downloaded to the desktop/laptop, students can easily open the two memo-note files and then copy and paste their data directly into a spreadsheet. With the data in a spreadsheet, students can create a graph of Velocity versus Time. Students will also learn to create a graph of Distance versus Time from their Velocity versus Time graph. Students will hold a discussion of their graphs and learn how the graphs can tell a story about where the robot was going and how it got there. Students will gain direct experience with robots, handheld computers, spreadsheets and graphs, and possibly robotics programming.

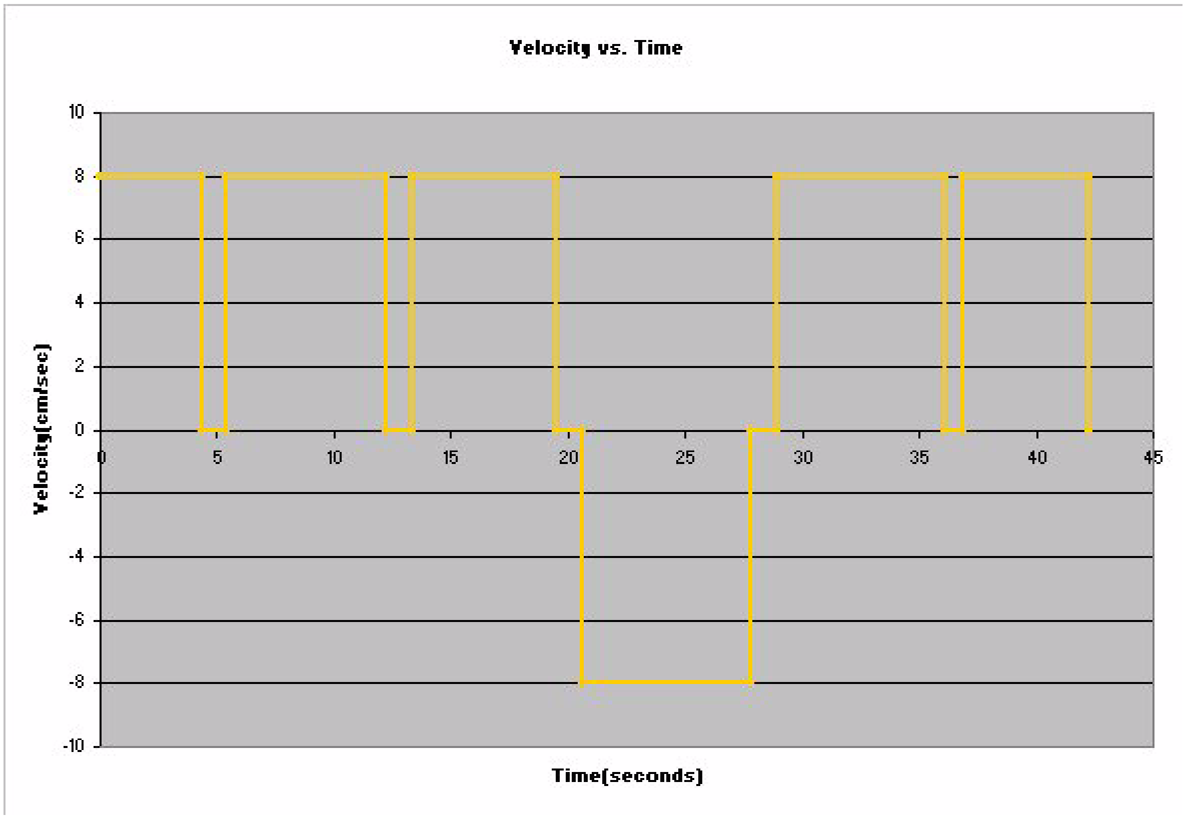

Figure 9. Sample graph of Velocity versus Time.

A second handheld program is being developed for the CDbot that helps to teach students about introductory statistics. Again the students interact with the robot through the handheld computer. To make use of this program students should be situated around a table or allowed to form a large circle by sitting on the floor. The CDbot will be placed in the middle and allowed to begin roaming freely. A message will be displayed on the robot's handheld screen, which reads, "Tap Me and I will Stop To Collect Your Data!" To initiate interaction with the robot a student only needs to tap the handheld screen and the CDbot will stop. Once the CDbot has stopped it will prompt the student using several predefined questions which will ask the student to pick their favorite color, pet, ice-cream flavor, etc. After collecting all the required data, the student sends the CDbot back on its way by simply tapping the appropriate button on the handheld screen. This process will repeat until all the students have gotten a chance to enter in their own data. Once all the data is collected, it can easily be viewed directly on the handheld. This lab works best if the students are partitioned into groups of four or five and each of the groups has their own robot. Each of the groups would be responsible for their own set of data but would have to work with the other groups so that they could obtain a complete tally for the entire class. The collected data can then be used to teach such introductory statistical concepts and formulas as the mean, average, median, and possibly standard deviation depending upon the level of the students being taught.

Figure 10. Several screenshots for the CDbot statistical data collection program.

Future software development will produce GUI programs for a desktop or laptop computer such that the student will be able to program specific behavior into their CDbot without actually writing code. This software will also allow the CDbot to be operated exclusive of the expensive handheld computer, thereby providing a lower cost alternative to schools without access to handheld computers. The CDbot will retain its data collection capabilities through the addition of a small EEPROM chip to the robot's micro-controller. Data will be downloaded from the EEPROM chip to a desktop or laptop computer using a specially designed serial download cable and data downloading software.

Currently, the CDbot utilizes a readily available micro-controller, the OOPic, but work has begun to create a low cost micro-controller specifically designed for the handheld version of the CDbot. Firmware will be developed for this new micro-controller so that a handheld computer can easily control it and read the status of connected sensors. This will help to reduce the overall cost of the handheld version, while maintaining the benefits achieved when using the handheld. One drawback will be that a handheld must always be connected to the new micro-controller for proper functioning of the CDbot. It may be possible to design the firmware such that the controller would be programmable and not need to be connected to the handheld. The motivation behind this micro-controller design is to provide the students with a low cost and easy to use robotics programming system.

Work is also underway to integrate the CDbot into a local school's math curriculum and Math Club. There will be a total of five CDbots used to collect velocity and time data. The CDbots and handheld computers will be introduced to the students during the second week of March in 2003. Each student will have access to a handheld computer and students will be placed into groups of four or five. Each group will be responsible for collecting the necessary data using their CDbot. A teaching module for using the CDbot in a data collection lab has been developed to aide in classroom implementation. It is the second module in a series of classroom modules that will be developed for the CDbot. The module has been named "Scientific Data and Analysis Lab". The first module helps students to become familiar with the CDbot and is named "Introduction to the CDbot Lab". Once a group's CDbot has collected the required data, they will remove the handheld computer and then proceed to beam the memo-notes containing the collected data to another handheld in their group. This process will continue until all the handhelds within a group contain the memo-notes. The students will then make spreadsheets and graphs by hand, reading the collected data directly from the memo-notes on their own handheld. This method is different from the one previously described, but is just as valid for teaching the students about data collection.

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