The Integration of Robotics in Grade School to Promote Interest in Math and Science

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Abstract

Can taking robots into grade school classrooms promote excitement within younger children to do well in math and the sciences? Yes! When children in grade school are exposed to the modern applications of math and science through robotics, they are more excited about learning and doing well in these subjects. This in turn stimulates interest in pursuing a college experience in the engineering and technical fields. Many young women and minorities lose interest in math and science in grade and middle school. Engineering and robotics can give them the flame they need to ignite their pursuit of engineering through robotics. We want to encourage them to continue to be excited about their math and science training through grade, middle, and high school and even through college.

Introduction

Integrating robotics into grade school curriculum is an easy and fun way for children of all ages to get involved and excited about engineering and the sciences. Research suggests that there is a need to introduce children, especially females and minorities, to technology at a young age [Mills, 1996].

Current research suggests that young women and minority students tend to lose interest in science curriculum during the middle school years [Greenfield, 1997]. The theory proposed in this research is that by integrating and involving children in the modern applications of science and technology while in grade school, they will strive to do well in preparation for college. This will also encourage them to pursue degrees in the sciences and engineering when they arrive at a university. This research was started by Scott Jantz and Aamir Qaiyumi in November of 1997, and has been evolving over the years to reach a new level recently. The experimentation pat of this research is done at schools near the University of Florida.

The TJ and RoboBug robots (shown in Figures 1 and 2) provide students with experience through hands on learning and experimentation in math and science concepts. Students are equipped with programmable robots with which to delve into the synthesis and experimentation of biology and ethology while using elementary trigonometry and algebra. These artificial creatures are used to instigate an appreciation and excitement for a solid foundation in math and the sciences.

Experimental Platform

TJ Robot

For most of our experiments, we used a small robotic platform designed by students at the Machine Intelligence Laboratory (MIL) at the University of Florida called Talrik Junior, or TJ (Figure 1). A completed TJ has a 7-inch radius and 3.5 inch height. It is constructed from 5-ply Birch model aircraft plywood and rides on wheels and a rear skid. Two gearhead motors mounted underneath the platform drive the wheels, one motor per wheel. The microprocessor controlling TJ is a Motorola 68HC11. TJ has 256 bytes of RAM and 2 Kbytes of EEPROM [Qaiyumi, 1998].

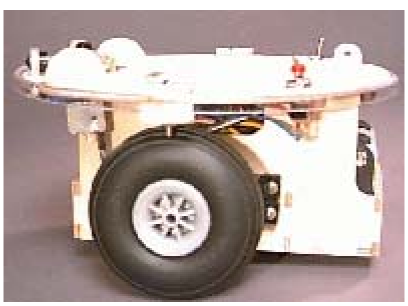

Figure 1. Talrik Junior Robot

Most of TJ's electronics fit under a removable top plate that hinges in front and locks down in the back with a wooden key. TJ possess two infrared (IR) detectors and two IR emitter headlights in the front. An IR emitter taillight mounts in the back underneath the plate. A wooden bumper encircles TJ's waist. Four contact switches, three in front and one in back, allow TJ to detect front or rear collisions.

TJ can support more sensors to help it determine more about its environment, but these were not needed for our experimentation. Programming TJ requires additional hardware and a personal computer. A serial communication link allows the user to upload and download TJ data and programs from a PC.

Figure 2. Robobug 6-legged Robot

The preprogrammed avoidance and following behaviors used by the students were written in ICC11, while the Logo byte-code compiler was written in Java.

Pogo

We used a Logo byte-code compiler, named Pogo, to meet the following criteria:

- simple, consistent, and complete syntax modeled after Logo
- direct constructs for intuitive control of robot's actuators and sensors
- point-and-click user interface
- retain platform independence on the PC side

These design goals, and the severe restrictions placed on us by the robotic platform (only 256 bytes of RAM!), led us to the following architecture. The TJ robot runs a byte-code virtual machine that takes advantage of the space efficiency possible in interpreters. Yet it is small since it implements a small set of robot specific instructions, (i.e., go forward, turn right) plus the necessary constructs to insure completeness (subroutines, if statements, loops, etc.) in byte-code format. The compiling to byte-code is handled in a graphical, integrated development environment that is written in Java to take advantage of the Java Virtual Machine's architectural neutrality. Finally, the byte-codes are downloaded to the robot. The compilation and downloading are all handled transparently; the user simply clicks a single on-screen button and the robot is ready to run their program. [Qaiyumi, 1998]

Case Studies

Over the past six years this research has included between five and six thousand elementary through high school students. When the research was started there was only an interest in reactions from children and how MIL students thought they could improve the robots. As the excitement levels increased in MIL demonstrations and more students became involved, there was a realization that this might prove to be a tremendous means to encourage students of all ages, races, and sexes to get involved in math and the sciences. By getting them involved at an early age they are more likely to continue doing well in courses in these areas and striving for success in order to achieve success later at the college and university level. With the increasing standards of entrance into Universities, students need something that will light a fire under them to do well in middle and high schools. Without this encouragement to do well and something to look forward to, many students, especially women and minorities, will give up their pursuit of high grades and high achievement by the time they reach high school. Based on these realizations, we have continued to evolve the research stated and make it easier for math and science teachers within various school systems to integrate robotics into their curricula. The reaction and fervor that has come from this integration has spawned a new era in math and science education.

Tuesday, February 18, 2003

Professors A. Antonio Arroyo, Eric M. Schwartz, and undergraduate students Ian A. Arroyo and Amelyse A. Arroyo held a field trip for approximately five hundred elementary school and middle school students during a college sponsored event called the Engineering and Science Fair. These students were highly diversified in the areas of race, sex, and status.

The field trip started by the students being introduced to robotics by asking questions and watching some various experiments performed by other robots from our laboratory. For the students, they immediately became excited and voiced their enthusiasm to do the experiments designed for them. These experiments included determining the robot's response to certain stimuli by using mazes and colored objects. Collisions and well know programming traps predicted before they occurred, enthused them greatly. They were led to explore the robot's response to each other and to the obstacles put in their way (including the students themselves).

The students were then asked to explain in their own opinions, what a computer is. This generated a wide variety of responses including web surfing to a work station. When explained to them that a computer is really an electronic brain that processes information, they began to understand that computers are not just the boxes that sit on their desks at school or at home. This in turn wet the appetite of interest and curiosity for a more in depth knowledge of the use and true meaning of computers. They were then introduced to the basics of programming by doing experiments with the POGO Logo byte-code compiler in which they designed a set of circles and lines using angles and times to make Spyrograph-like designs on paper. (Spyrograph was an exciting toy popular in the '70's.) This introduction to programming allows students a very in-depth look at computers and technology, which in turn puts to rest any underlying fears or misconceptions of artificial intelligence and robots.

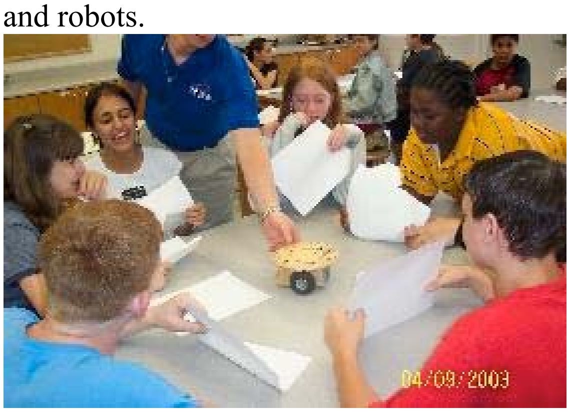

Figure 3. Students from Westwood middle school attempt to keep TJ on the table.

The last activity the students completed was to find the difference between robots that would follow IR and those that would shy away from it. This was a way to show them the effects of IR light and the electromagnetic spectrum (EMS). They were taught that many modern day appliances use IR to accomplish tasks, e.g., the relationship of a television to a TV remote control. This sparked many new questions about the robots. Some of these questions were very insightful. By studying the TJ's response to the IR radiation with both the avoidance programs and the IR following programs, they began to understand the true value of EMS and electronics in everyday life. This was spawned by the synthetic interaction between robots and humans.

Wednesday, April 9, 2003

Undergraduate students Ian Arroyo and Amelyse Arroyo, from the Machine Intelligence Laboratory at the University of Florida, visited the seventh grade science and technology classes taught by Mr. Curtis Ericson and Mr. Dennis Scott at Westwood Middle School.

Figure 4. Seventh grade students at Westwood Middle School discover the true meaning of a computer.

These students were first asked to explain the basics of a computer outside of web surfing and word processing. They were then asked to define robotics in daily life. The generated responses were fairly generic.

Movies and movie characters were brought up as examples of robotics. What then took place was a small introduction to true robotics and artificial intelligence. The students were then assembled in groups around several different tables and given a TJ per table and sheets of colored paper and poster-board. The first required activity was for the students to guess and make a list of what the sensors on the TJ were and what each one did individually. Throughout this time of learning and discovery the students were taught the beginnings of light radiation and the EMS as well as some simple algebraic and geometric concepts. After all of the students had made their lists and guesses, the TJ's, preprogrammed with simple obstacle avoidance, were turned on and the task at hand was to keep them on the table using the different colored sheets of paper and the poster-board. After a few minutes the students were then required to set up mazes and attempt to create an entrapment in which the TJ could not escape.

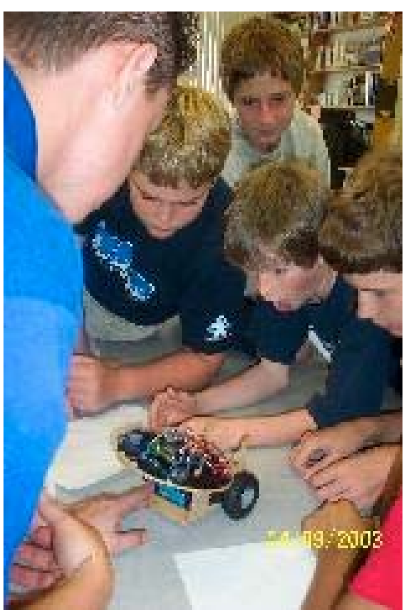

Figure 5. Students at Westwood middle school start to take a TJ apart.

As they tried for minutes to trap the robot, they began to get more and more excited about what they were doing. After 10 minutes one group of students discovered the Braitenburg trap (a well know oscillation of a robot stuck in a corner). This yielded enthusiasm within the whole class, including the teachers.

There were many questions remaining. What made the TJ go? As the robots were turned off we began to take the TJ's apart piece by piece and explain the importance and significance that each component had to its use and existence. As we took these robots apart and put them back together, there was a light in many of these student's eyes and many of them expressed a desire to be able to go to college and pursue engineering degrees. At least half of these responses were from women and minorities.

Results

The key to igniting a flame of interest and excitement in young students, especially females and minorities, in science and engineering is to integrate modern technological concepts and experiments into the curricula of engineering, mathematics, physics, and experimental biology. When students are exposed to and work with hands on material which illustrates the concepts of lecture, they are quicker to study and more apt to do well in these courses. Young students need hands on learning as well as book learning. It is much easier to excite young students about the science and math fields when they can see the results of the concepts they are studying and involve themselves with scientific experiment-ation. This promotes a desire and a will to get into the science and engineering fields in college. Many of the original middle and high school students involved in this research in the mid-90's, are now at the University of Florida, and other universities, pursuing engineering and science degrees.

Conclusions

The positive responses from students involved with this research are astounding. Their responses have proven that integrating robotics into public school math and science curricula is a certain way to excite young students about math, science, and engineering, as well as a college education. Students have come back and shared that they are now pursuing engineering, science, and robotics degrees due to this type of education. Many have been women and minorities. We now have the proof that this integration is not only good for students, it is absolutely necessary if we want to equip the next generation of engineers. We are persuaded that through this blend of both lecture and hands on learning, students will be fully prepared to enter a university system ready for both book work and research.

Future work

We are currently working with several science and technology teachers in the local schools to include robotics as a part of their regular curricula. Many teachers from around the state have expressed an interested in being a part of this research. What we expect to see is a classroom revolution of sorts, in which all science and technology classrooms have robots and programming stations for students to experiment on their own and also as a part of sets of curricula. We are considering an expansion of this program to all of the local middle and high schools in and around the University of Florida. If the research continues as it has in the past, we would like to expand to other counties within the state of Florida.

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