MARS ROVERS IN MIDDLE SCHOOLS

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ABSTRACT: We have developed an innovative curriculum using one sixth replicas of the rovers currently on Mars. Each student receives hands-on experience by performing missions in a simulation program. These missions allow students to relate to the process of controlling the actual rovers. Furthermore, students have an opportunity to remotely program and control the replicas in a realistic Martian landscape created in the basement of a middle school. Programming robots in this landscape is the centerpiece of a technology curriculum in all four middle schools in the Allentown School District as well as a summer and Saturday program at Lehigh University.

1. Introduction

Space has been a major area of research for centuries. NASA has been promoting space as an education initiative for years. The Jason project has made curriculum available for space education. Currently, NASA has two rovers, Spirit and Opportunity, on Mars. By using replica rovers in the classroom we can increase the student's interest in an already high interest area of robotics.

This paper focuses on an innovative curriculum for teaching robotics at the middle school level. Students learn how to design missions which become programs for replicas of the Mars rovers. A local middle school has converted a basement storeroom into a realistic model of a Martian landscape on which the rovers perform their missions. This hands-on experience generates excitement as students learn about space, engineering, practical applications of mathematics, and computer science. Through exciting missions, the students gain experience by using a realistic model of the NASA control room.

The remainder of the paper is organized as follows. Section 2 introduces two outreach programs designed to introduce technology into the classroom. Section 3 describes the replica rovers and their environment, including a student friendly interface and a simulation program that lets students try out rover programs. Section 4 discusses early results and finally section 5 concludes with plans for dissemination and future work.

2. LV STEM and Launch-IT

LV STEM (Lehigh Valley Science, Technology, Engineering, and Mathematics) is an NSF GK-12 project which sends graduate students into local schools to help develop innovative research-curricula for those schools (see www.lehigh.edu/stem). The first author is one of eight NSF Graduate Fellows for this project and the second author is the Principal Investigator. LV STEM seeks to widen the pipeline of PhDs who are advocates for K-12 education and of K-12 students who can communicate complex concepts of STEM disciplines through writing and multimedia. Graduate Fellows, Lehigh faculty, STEM school teachers, and volunteers from local corporations work together on teams to develop novel curricula in Lehigh Valley schools with substantial majorities of students from under-represented minorities. The LV STEM project began developing the Martian landscape project and curriculum at a middle school in the Allentown School District with 76% minority and 86% low income students.

These efforts have generated tremendous enthusiasm within the school, the district and beyond—Harrison-Morton Middle School (HMMS) is now a NASA Explorer school and the Mars Yard has been featured in the March 10, 2006 edition of *The Chronicle of Higher Education*.

Launch-IT is an NSF ITEST project whose vision is to “launch at-risk middle and high school students in the greater Lehigh Valley toward college and careers in Information Technology (IT)” (www.lehigh.edu/launchit). These students are bussed to the campus of Lehigh University once a month during the school year and for three weeks during the summer. Sixth and seventh graders are working on the robotics team, learning how to conduct science, math and technology ‘missions’ using remotely controlled robots in the Martian landscape at HMMS.

A number of K-12 outreach projects have used mobile robotics as a theme, typically using LEGO MindStorms™ robots targeting high school students (e.g., Erwin et al. 2000, Genalo et al. 1997, Gerovich et al. 2003, Lau et al. 1999, Nagchaudhuri et al. 2002). Our approach makes two innovations: 1) using robots that closely simulate a current and realistic application of mobile robotics in space research, and 2) targeting middle schools, where we can reach a broader range of students, including girls and underrepresented minority students who are required to enroll in technology courses. (In high schools, on the other hand, most computing or IT courses are electives in which few girls and minority students currently enroll.) Our preliminary results give us reason to believe that our approach can help to widen the “incredibly shrinking pipeline” of such students entering information technology or engineering fields" (Camp 99, Robb 2003).

Several new developments have recently enhanced the Martian landscape program. Replica rovers have been developed and a technology class room has been remodeled to look like the NASA control center for Spirit and Opportunity. A more realistic environment leads to more realistic scientific missions and increases interest among the students. Launch-IT is incorporating these new technologies into their program as well. The vision of the Allentown School district is to expand the use of the new curriculum under development to all four Allentown middle schools.

3. Methodology

The new technology being introduced is creating excitement for the students. These new technologies consist of replica rovers, an interface to control them, and a simulation of their operation.

3.1 Replica Rovers

Since arriving on Mars in 2004, Spirit and Opportunity have been sending images, temperature readings, and other measurements back to Earth; students can view exciting images on the NASA web site. The rovers have outlasted their expected operational time by years, making them one of the most successful science and engineering projects of our time. Although only expected to travel one kilometer, Spirit has traveled 7 kilometers and Opportunity has traveled 12 kilometers. The rovers are programmed via commands sent from Earth.

The replica that GEARS Robotics developed specifically for this project is one-sixth the size of the actual rovers. The replica has eight wheels which can be controlled individually or simultaneously. For the interface, the wheels are controlled simultaneously. Each wheel has a motor mounted inside of it, along with motors to rotate wheels for turning. For sensing, the replica has a camera and a science probe. Although the replica moves slowly, it still moves faster than the full scale rover. The relatively slow speed is also part of our curriculum’s emphasis on realism and the importance of testing mission designs in simulation. The replica has the same suspension design as the full scale rover, allowing for travel over rough terrain. For remote communication, a wireless connection is used to transmit commands.

For a more realistic experience, an environment for the replicas called the Mars Yard was built. An unused storage room in the basement of a school building was converted into a Martian landscape. Several features provide a realistic environment. A canvas painting of Martian terrain decorates the walls to create a panoramic view. For the 800 square foot floor, red concrete and gravel imitating the surface of Mars also adds to the experience. When entering the room, you pass through an air lock style door. To allow remote access to the room, a camera is mounted on the ceiling. Together, these features create a unique experience. These resources have been featured on the local *Tempo!* television program (show #340, see www.wlvt.org/tempo/WebInfo.htm) and article in the *Chronicle of Higher Education* (March 10, 2006, Volume LII, Number 27, page A5).

3.2 Interface

The replica rover's original interface was complex and difficult for students to use. The first author designed and implemented a simpler interface for the rover in Java. This interface was designed with two modes for communicating with the replica. First, commands may be sent separately so control decisions can be made in real time. Secondly, a more advanced control allows for users to drag-and-drop commands into a queue for the entire queue to be executed in sequence. This advanced control is the standard way of communication. The advanced controller has to be simple enough for the students to use, but must also be complex enough for the students not to lose interest. To create a visually pleasing interface, graphics were produced. Along with the graphics, the skill levels of the students must be taken into account. Since the students vary between sixth and eighth grade, they have varying levels of skill. To meet the needs of every student, the interface must have different levels of difficulty. The control system is simple enough to only require the four basic controls. These controls are forward, back, left, and right. However, an advanced student can be more efficient if he/she uses additional controls that are a combination of the basic controls. Students may also adjust the speed and length of time for executing a command.

Another feature for teachers is the time elapsed. This feature allows a teacher to monitor how fast a student is working. The ability to time the process also creates a competition between students to push them harder. In future work, the interface will allow a student to create and execute a series of commands in the form of the code that the replica rover actually receives.

3.3 Simulation

Since there are only three robots in the Mars Yard, the student-to-robot ratio creates a problem. To solve this problem, a simulator was developed (see figure 1). This allows students to each work on their own simulator to test their ideas before running them on the actual replica rover. Actual pictures of the Mars Yard and replica rover are used in the simulation.

The simulator has some features that focus on helping teachers monitor students. Due to the large class sizes (one teacher to 20-30 students), it is difficult to monitor the controls a student is using. To address this problem, the multiple screen have a different colors making it easy to see when a student is on a screen designed for a different project than the one the teacher is currently conducting.

If the tracking feature is turned on, the robot leaves a trail. This feature allows easy tracking of where the robot has gone during the simulation. The teacher then does not have to observe the entire simulation run in order to know what the student has accomplished. Once the run is completed, the teacher just looks at the trail for the results of a student's simulation.

There are eight commands for controlling the rover (forward, backward, right, left, forward and right, forward and left, backward and right, backward and left). These commands are dragged and dropped from the Movement Controls box (under the Elapsed Time indicator) to the queue of commands on the left (which currently contains seven commands). To execute these commands, one would click on the GO button. In the simulation, the rover leaves a trail from the starting position to its current location—the blue line behind the rover in figure 1. This output is used for quick grading or to teach shapes using the simulator. The DRIVE MODE button sends one command at a time, rather than a queue, so students can observe the result of each step safely. To send commands down to an actual rover in the Martian landscape via an Internet link one selects a "connect to robot" button at the startup of the program. The student will then be able to watch the rover execute the commands, via a web camera mounted on the rover and a "sky" web camera mounted on the ceiling of the landscape room.

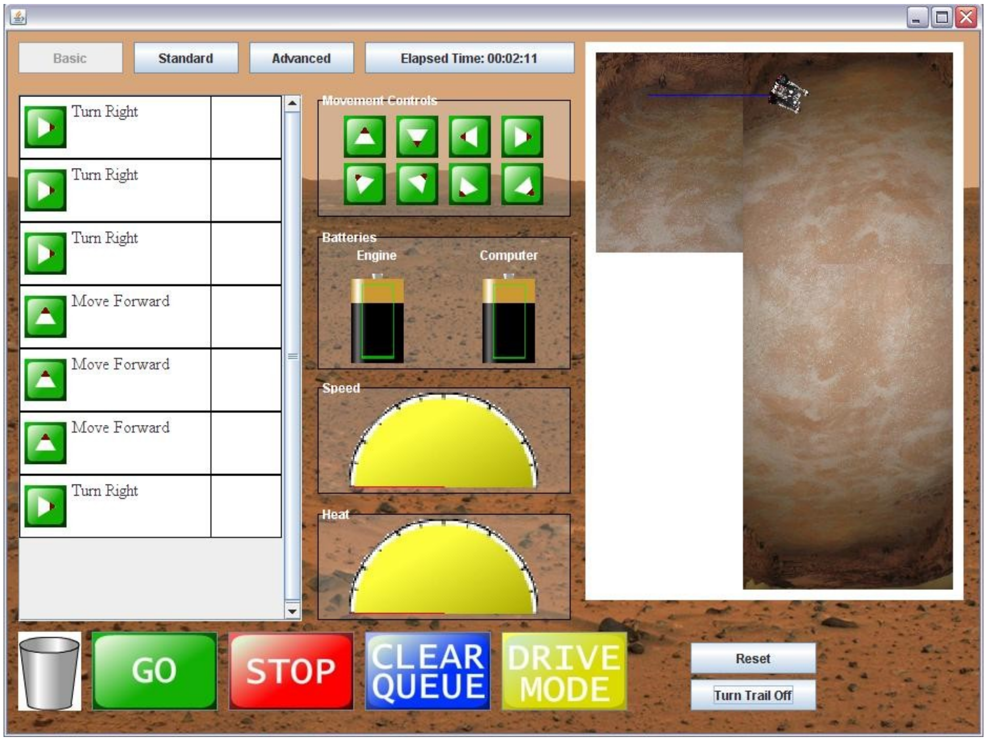

Figure 1: Simulation of a replica rover in the Mars Yard

4. Preliminary Results

The Launch-IT students were the first to work with the replica rover and its interface during the summer session of 2007. After building one of the rovers from a kit (two other rovers were already assembled), the students drove the replica rover in a hallway at Lehigh University. To control the replica rover, students sent single commands initiating each of the replica rover's actions.

The simulator has been used by Launch-IT students in both the summer and fall program of 2007. Students were given several missions to complete on the simulator. These missions ranged from simple missions such as moving to a point in the room to more complex missions such as creating an equilateral triangle in the room.

Assessment showed that Launch-IT students on the robotics team developed a high level of excitement about "working with computers" (3.5 on a 1-4 Likert Scale) and all students successfully constructed rover simulation programs. The only complaint the students had was the slow speed of both the replica rover and the simulator. However, this feature was intentional, providing an opportunity to teach students about reasons why the real Mars rover moves at even slower speeds. The students were excited to use both the simulation and the replica rover. They found linking a sequence of commands together to complete a mission to be a challenging but fun task. Also significant is the impact on at risk students recruited into the Launch-IT program, of whom 71% were from underrepresented minorities and 58% were girls.

Future Work and Conclusions

The new rovers and simulation give the students a bridge between their science classes and current technology used by NASA. Both the rover and its simulation have grabbed the attention of middle school students, including high percentages of at risk, minority and female students. These results show potential to achieve the goals of both programs to increase the enrollment of students in technology areas and prepare them for the next level of education.

In future work, improvements will be made to the interface and simulation to create a more realistic experience. The command set will be expanded to include sensors and decision commands. The simulation will be enhanced to provide a virtual view from the rover's perspective. The web camera for the replica rover will be integrated with the interface as well.

Allentown School District plans to work with the LV STEM team at HMMS to expand the scope of the Martian rover curriculum to all four of its middle schools. This simulation program can be used as is or it could be adapted for use with different robots at other schools that might be interested in applying similar technology. The program is designed for a robot that uses telnet to receive commands through a network. One module (a Java class) of the program can be modified without much difficulty to reflect the differences in the commands used to control the robot. If a school wishes to use this replica rover or the program, please contact one of the authors.

Acknowledgements

LV STEM has been sponsored by NSF grant numbers 0231768 and 0639664. Launch-IT is sponsored by NSF grant number 0624553. Pennsylvania Infrastructure Technology Alliance (PITA) grants provided supplementary funding for both projects and also sponsored the acquisition of the Mars rovers and Mission Control Center. Additional funding was also provided by GEARS Educational Systems and LLC. Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation or PITA. The authors also express their appreciation to teacher Don Stahl, Graduate Fellow Chris Janneck and Co-PI Dr. Henry Odi for their invaluable help with this project. The second author also wishes to give thanks to God for inspiring these projects.

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