TeRK

Development and Dissemination of Disruptive Tools for Educational Robotics

Motivation

Something is dangerously wrong with science and engineering education in the United States. At a time when total college enrollment is booming, most science and engineering departments are seeing decreasing student interest in majoring in technological fields. For example, interest in Computer Science among incoming freshmen dropped by about 60% from 2000 to 2004. [1] This is occurring at a time when science and engineering enrollment is climbing in nearly every other part of the world. Many industry leaders now fear that the continuation of these trends will precipitate a workforce shortage in high technology fields, causing the United States to lose its technological edge. [2]

We believe that there are two underlying reasons for this decline. First, science and engineering fields have failed to engage women, shrinking the pool of potential applicants by half even though women make up the majority of undergraduate college students. Second, high school and introductory college courses in science and engineering often bore or act to weed out students, when they should be inspiring and exciting them.

Robotics has recently evolved into an effective tool for education and presents a sound opportunity for solving the problem of motivating and exciting students.

Our Background

Over the past four years, the Personal Rover Project at Carnegie Mellon University has designed robots, processor boards, and educational curricula for the real world. We have taken these products to both formal learning venues, from middle school to college, and informal learning centers, including the Smithsonian Air & Space Museum, the San Francisco Exploratorium, and the Japan World Expo. Through our Robotic Autonomy Summer Course [3] and Personal Exploration Rover Exhibit [4] over 200,000 children and adults have interacted directly with our robots. Formal educational evaluations of the resulting learning, conducted by University of Pittsburgh's UPCLOSE/LRDC, have yielded statistically significant results in the area of gender retention, identification with technology, and lifelong-learning skills acquisition [5,6,7,8]:

- Girls entered coursework with lower confidence with technology, but were not discouraged and in fact gained confidence more quickly than boys, *even in the context of robot programming challenges*.
- Students showed significant gains in teamwork, problem-solving, identification with technology, and specifics of mechanism and computation—all key science, technology, engineering, and math (STEM) issues.
- In museum samples, 71% of girls and 61% of boys at the exhibit engaged with collaborative robot exploration.
- In museum samples, 98% of users continued using the robot for several minutes, conducting a complete robotic exploration.

Figure 1 – A team of high school girls programs their Trikebot to complete a challenge.

Figure 2 – Children operate the Personal Exploration Rover at the Exploratorium.

Our results to date have demonstrated that robotics is up to the task of playing a pivotal role in curriculum: robot reliability and richness of interaction has reached an important breakaway point in the curve of this relatively recent technology. Our results have also demonstrated that robots serve as a compelling tool for education both at college and pre-college levels, bolstering critical gender retention chances and facilitating lifelong learning. Given the timely discussion of STEM gaps and technology illiteracy today, the effective role of robots in education offers an encouraging sign of hope in stemming today's trends.

Project Plan

Building on the knowledge, experience, and technology of the Personal Rover Project, TeRK [9], which stands for Telepresence Robot Kit, is an ambitious plan to develop and disseminate disruptive tools for educational robotics.

Consider the most recent wave of technology breakthroughs: high-speed ARM microprocessor technology at never before seen price points; ARM-FPGA proofs-of-concept for robot control demonstrated in the national BotBall contest; USB Camera functionality available at low price points; and custom board and chassis prototyping facilities now available.

We know robotics is an educational home run, and these technological advancements mean that today's technological leading edge, if used to design new robot kits, new robot processor boards and new infrastructure for robot connectivity, can lead to the introduction of educational robots with more capability and a lower price than we have seen in the community before.

We intend to create a new class of robot and processor board that can trigger a small revolution in the role of educational robotics, and we intend to facilitate the birth of a community of users that will give educational robotics a healthy and rapidly growing life of its own.

Our Vision: To catalyze creativity, foster technological empowerment, and inspire learning by transforming robotics into an accessible and collaborative tool for exploration.

Our Mission: To design, create, and disseminate robotics curricula and technologies that motivate young women and men to actively explore science and technology.

We believe that:

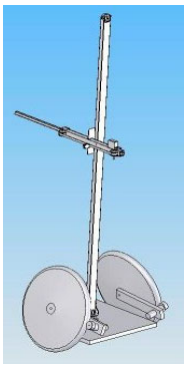
- Girls have as much natural ability in technology and engineering as boys, and unlike more classical science and technology instruction, robotics education captivates girls and boys equally.
- A key reason for low diversity in technology fields is a poor retention rate among women. Our classroom studies demonstrate that robotics-based curricula strengthen the appeal of science and technology to women, stemming low retention and creating true diversity.
- Early adoption of robotic systems in learning leads to a conceptual understanding and lifelong appreciation of science, technology, and engineering.

Our plan:

Technologies for ubiquitous and portable computing have reached a critical mass, allowing us for the first time to create affordable robotic systems that are sophisticated and rewarding. These systems present the potential for a small revolution in the usage of robotics and allow us to formulate learning experiences and curricula *which use robots, but impart knowledge that is applicable beyond robotics.* By openly providing robot designs, documentation, and software, we will lay a foundation for self-sustaining communities that contribute to and evolve both the technology and the curriculum well beyond what we initially create.

We plan to achieve our mission through work along six interrelated research and development thrusts.

Robot Reference Design Library



Our research has shown that educational engagement is maximized when students are exposed fully to all of the mechanical, electronic and computational challenges of robot systems science. We are designing a set of robot building recipes for diverse robot structures using commercially-available off-the-shelf parts and hand tools. From our previous experience with the Palm Pilot Robot Kit [10], we know that online instructions will allow each recipe to be built from raw materials by an end-user, or produced as a kit by robotics manufacturers. Robot reference designs in year one include an articulated arm, a large telepresence robot, and a small quick-build desktop robot.

Robot Embedded Electronics Package

In order to make robot recipes that are affordable and easy to animate, one needs an affordable and easy to use robot controller. Utilizing the same low-cost technology as a PDA, we are creating a single board computer and interface electronics to provide all required functionality for a diverse set of robot platforms. The electronics are being designed in cooperation with Charmed Labs LLC, and will be commercially released in early 2006.

Robot Connectivity and Development Software

To enable early and rich, rewarding interaction, the embedded electronics package will come with out-of-the-box internet connectivity.

When built, a robot can be immediately connected to the internet, enabling diagnostic control, telepresence control, and programming of the robot from *any* internet-enabled PC. We are developing the 802.11 driver software as well as the server software on-line to provide this level of immediate connectivity. We believe this is a crucial step in catalyzing user creativity and enjoyment, leading to high rates of retention and exploratory use.

Community Curriculum Design Effort
So that educators may easily and effectively make use of robotics in their classrooms, we are developing a library of curricula to accompany the TeRK robot recipes. We have engaged a number of partners at the high school, community college, and college levels to co-write curricula with us for iterative development and dissemination. This effort includes creation of curriculum dissemination structures as well as standards for solution set materials.

Pilot Education and Evaluation Rollout
In cooperation with our partners at the University of Pittsburgh UPCLOSE/LRDC, we are planning a formal rollout and educational evaluation process which we will use to measure the efficacy of the TeRK package in college and pre-college educational settings. Early pilot experiments, combined with *in vivo* evaluation as the community builds, will enable follow-on refinements of the TeRK package.

Web-based Community Dissemination
Due to its flexibility, the TeRK platform has the potential to make a broad impact. In order to achieve this potential, we need a plan for disseminating the recipes, curricula, and ideas that we and our users create. We are working with our colleagues in web design at LotterShelly Inc. to create an online community site that will be accessible and efficient for the various users of TeRK. We implemented such a design approach with great success for the Personal Rover Project museum interface, now in use across the world.

Progress is underway along all thrusts; see the Personnel section for details on our staff and partner organizations. Assuming appropriate funding, we plan to release the first TeRK reference design and curriculum, together with an available electronics package, in early 2006. Following this release, the project focuses on educational evaluation, curriculum refinement, release of additional robot designs, and community-building. By late 2006, we expect the TeRK approach to have taken on a life of its own.

Personnel
Our team includes roboticists, computer scientists, designers, educators, and engineers. Their diverse talents, experience, and expertise will help make the TeRK project a success.

Our core team members are:

Illah Nourbakhsh is Associate Professor of Robotics at Carnegie Mellon University and was Principal Investigator of the Personal Rover Project, which was funded by Intel Corporation, NASA/Ames Autonomy and National Hispanic University. He has many years of experience using robotics as an educational tool [11].

Ben Brown is a Project Scientist at Carnegie Mellon University. He was the designer of the single-legged hopping robots of the Raibert Leg Laboratory which eventually moved from Carnegie Mellon to M.I.T. Ben is responsible for the TeRK robots' mechanical design.

Rich LeGrand is founder of Charmed Labs LLC and was previously a researcher at Nomadic Technologies, Inc. Rich developed the Xport Gameboy-FPGA processor system for programmable robotics, and has most recently developed the robot controller used by BotBall.org in contests around the U.S. He is leading development of the embedded electronics for TeRK, including a custom FPGA-ARM9 board with a specialized high-speed communications bus and the robotics daughterboard.

Emily Hamner is Senior Research Associate for the Mobile Robot Programming Laboratory at Carnegie Mellon University. She served as the research and execution hub of the Personal Rover Project and will fill the same role for TeRK. Emily is leading development of the community curriculum and TeRK web resources.

Tom Lauwers is a PhD student in Robotics and was previously president of the Robotics Club at Carnegie Mellon. He is also a founder of Botrics, LLC. Tom is leading the educational material development effort together with partner institutions.

Brian Dunlavey is a Research Associate at Carnegie Mellon University. He is a former robot programmer of Mobot, Inc. and was recently vehicle team leader on the Red Team, a competitor in the DARPA Grand Challenge. Brian is leading the TeRK firmware development efforts.

Steve Shamlian, Lei Feng, Geoffrey Dixon-Ernst, and Zack Menegakis are students working on the project. Steve, a senior in electrical engineering, is working to design and test robot recipes. Lei, a Masters student in Information Systems Management, is leveraging his previous experience at Philips to develop firmware for the embedded controller. Geoffrey, a freshman in electrical engineering, is helping with firmware development. Zack, a Masters student in electrical engineering, is working on robot simulation.

In addition to our core team, we have partnered with several institutions to develop a library of robotics curricula. Massachusetts Institute of Technology, Columbia University, University of Massachusetts Lowell, Harvey Mudd College, Chatham College and Ohlone College are developing college level robotics courses for the fall of 2005 and spring of 2006. We have also partnered with the Anita Borg Institute, Sally Ride Science, the Carnegie Mellon Institute for Talented Elementary and Secondary Students (C-MITES), the Expanding Your Horizons Network, Women@SCS, and several local high schools. These partners will aid us in designing and testing a library of curricula that will accompany the TeRK robots. The University of Pittsburgh UPCLOSE/LRDC will work with us to perform formal evaluation of the educational impact of these curricula.

Our international partners include Michel Xhaard, a teacher and open source code developer in France, and Professor Paolo Fiorini of the University of Verona. Professor Fiorini's group is developing TeRK robotics programs in cooperation with three Verona high schools.

Funding Needs

We have received seed funding from Microsoft, Intel, and NASA Ames for 2005. The project's ambitious and long-term goals will require several hundred thousand dollars in additional annual funding. We currently need funding for a wide range of activities, including:

- Design and prototyping costs of the robot embedded controller
- Development of user interface software and controller firmware
- Curriculum development
- Outside evaluations of classroom curricula
- Robot recipe design, prototyping, and instructional materials
- Design of a web site to support dissemination and community development
- Building a seed stock of robots to launch communities

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