The Personal Rover Project

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Abstract

In this paper, I summarize a new approach for the dissemination of robotics technologies. In a manner analagous to the personal computer movement of the early 1980's, we propose that a productive niche for robotic technologies is as a creative outlet for human expression and discovery. This paper describes our ongoing efforts to design, prototype and test a low-cost, highly competent personal rover for the domestic environment.

1. Motivation

As with most leading technological fields, robotics research is frequently focused upon the creation of technology, not on creating compelling applications. Although the search for new technologies is a valid scientific process, one important aspect of robotics is not appropriately explored in this manner: human-robot interaction.

Robotics occupies a special place in the arena of interactive technologies because it combines sophisticated computation with rich sensory input in a physical embodiment that extends well beyond the desktop. Moreover robots can exhibit tangible and expressive behavior in the physical world.

In this regard, a central question that occupies our research group pertains to the social niche of robotic artifacts in the company of the robotically uninitiated public-at-large: *What is an appropriate first role for intelligent robot-human interaction in the daily human environment?* The time is ripe to address this question. Robotic technologies are now sufficiently mature to enable long-term, competent robot artifacts, at least in prototype form, to exist [4,7].

We propose that an appropriate first application for robotics within the human social domain is as a creative and expressive tool rather than a productive tool optimized for consumer use. Consider the history of the personal computer. In the early 1980's, advances in low-cost computer manufacturing enabled individuals to purchase and use computers at home without specialized knowledge of electrical or computer engineering. These early computers were tools that forged a new creative outlet for programmers of all ages. Before long, video games as well as more business-savvy applications were born from the tinkerings of these intial computer hobbyists. In effect, the early adopters of the personal computer technology constituted a massively parallel effort to explore the space of possible computer programs and thus invent new human-computer interaction paradigms.

The goal of the Personal Rover project is analogous: to design and deploy a capable robot that can be deployed into the domestic environment and that will help forge a community of create robot enthusiasts. Such a *personal rover* is highly configurable by the end user, who is creatively governing the behavior of the rover itself: a physical artifact with the same degree of programmability as the early personal computer combined with far richer and more palpable sensory and effectory capabilities.

Our goal is to produce a Personal Rover suitable for children and adults who are not specialists in mechanical engineering or electrical engineering. We hypothesize that the right robot will catalyze such a community of early adopters and will harness their inventive potential.

As in the toy industry, the first step toward designing a Personal Rover for the domestic niche is to conduct a User Experience Design study. The challenge in the case of the Personal Rover is to ensure that there will exist viable user experience trajectories in which the robot becomes a member of the household rather than a forgotten toy relegated to the closet. Contracting with Emergent Design, Inc., we produced an internal experience design document that describes the interaction of a fictional child, Jenna, with her Rover over the course of several months.

The user experience design results fed several key constraints into the Rover design process: the robot must have visual perceptual competence both so that navigation is simple and so that it can act as a videographer in the home; the rover must have the locomotory means to travel not only throughout the inside of a home but also to traverse steps to go outside so that it may explore the back yard, for example; finally, the interaction software must enable the non-roboticist to shape and schedule the activities of the rover over minutes, hours, days and weeks.

In Sections 2-4, this paper describes the ways in which we are working to satisfy these constraints. In addition, Section 5 describes our first, early user experiment with the Personal Rover: 30 children are being introduced carefully to new robots, and will then take them home. We, in turn, will then follow their use of these rovers during a one-year longitudinal educational study.

2. Sensing: Low-overhead Perception

The single most important sensor for a Personal Rover is clearly vision. Images are sufficient for basic robot competencies such as obstacle avoidance and navigation [1,2,3,6,8,9,10]. But even more importantly images are an exciting data collection tool: the Personal Rover can become a video and photo documentarian. At the interaction design level, a robot that responds visually achieves a level of lifelike behavior that is somewhat magical. In all of our built prototypes, the fact that the rover can play *fetch* visually has been of extreme interest to every age group.

A critical challenge in the toy market has always been overcoming the high price of robot vision. To this end, our lab has developed a new, low-cost CMOS-based visual processor that is rapidly gaining acceptance throughout the hobby robotics community: CMUcam [5].

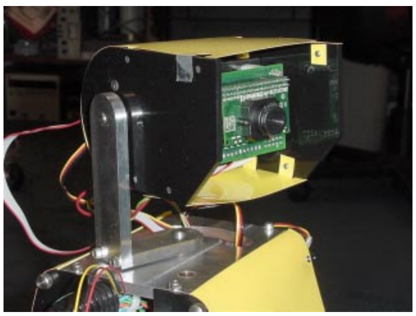

Figure 1: CMUcam attached to the rover's head

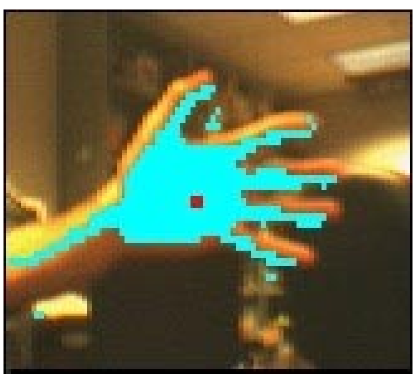

Figure 2: Hand segmentation using CMUcam

The CMUcam board employs a 50MHz Scenix microprocessor and a consumer CMOS chip (Fig. 1). It evaluates real-time image frames in-line at an average rate of 18 FPS and can acquire statistics regarding any subregion of the image, including average hue, saturation and luminosity values as well as range values. CMUcam can also track any color at 18 FPS, providing position, size and confidence information via RS-232 (Fig. 2).

With visual competence on-board, the Rover's daily possibilities broaden to include many creative vision-based activities: create a time-lapse videocollage of the growth of a plant; follow the cat all day and create an image-based summary of where it went in the house; wait outside at 2:00 AM and take pictures of things that move when everyone is asleep. In effect, the rover can become an extension of the user's perceptual system, observing and documenting beyond the user's own physical or temporal reach. CMUcam is thus a versatile technology, providing basic robotic competence together with documentary capability.

3. Mobility Mechanism

One of the biggest engineering challenges in deploying the Personal Rover is creating the locomotory means for a robot to get around the house. Houses have steps and a variety of floor surface types. Most homes have staircases, doorjambs between interior rooms and steps between rooms and outside. Imbuing a Personal Rover with the locomotory competence to tackle most homes while maintaining an affordable price point is one of the most daunting goals of this project, and so we invest significant effort in the creation of new mobility mechanism.

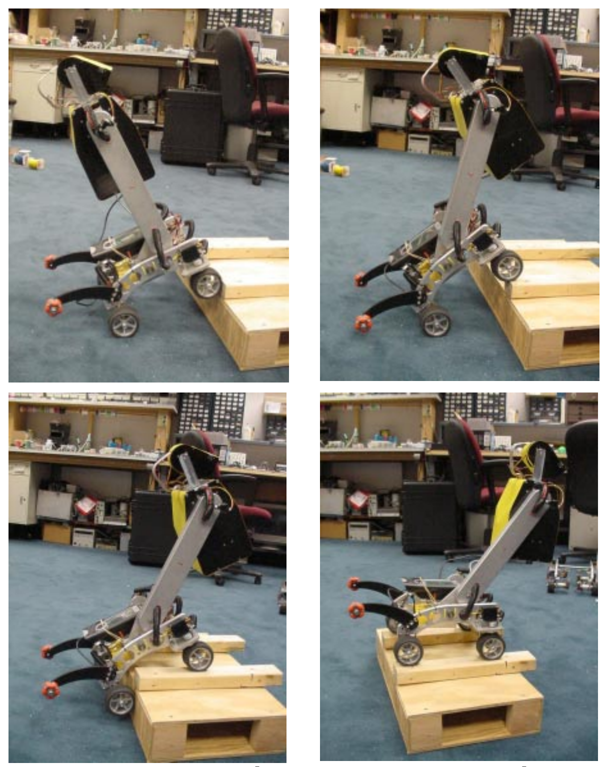

Figure 3: Step traveral using a swinging COM boom

Looking to biological solutions that exist in the natural world, one finds that terrain locomotion frequently demands that a creature actively control its center of mass (COM). In keeping with this principle, the Personal Rover prototype has a highly variable weight distribution combined with an actively adjustable COM. Using a fore-aft swinging, cable-driven boom, the rover can detect step topology using back-EMF sensing at individual wheels and can then move its boom to maintain appropriate wheel contact pressure during step ascent and descent. The rover has demonstrated reliable autonomous step traversal over a 7 inch single step.

To further increase terrainability, the four independently driven rover wheels are separated laterally by a differential. Thus, the rover can accomodate severe terrain pitches with relatively small motions of the boom and head (Fig. 4).

Figure 4: A central left-right differential accomodates large vertical wheel swings.

Finally, it is critical that the mechanism allow for small turning radii as may be required in doorways and other tight spots. To this effect, the rover employs independently steered front wheels. This enables conventional, Ackerman-type steering whereby the center of rotation (COR) can be placed on any outside point along the line extending through the rover's rear wheels (Fig. 5).

Figure 5: Ackerman-mode conventional steering

In addition, steering the front wheels in opposition enables all internal COR positions as well, effectively enabling the rover to rotate in place about the rear axle (Fig. 6). Thus the Personal Rover's wheel arrangement and degrees of freedom enable the COR kinematics of a standard differential-drive robot but with the traction of a four-wheel, independently powered arrangement.

Note that two omni-wheel casters provide a pitch guard during step traveral, but also provide a third locomotion form: that of a differential drive vehicle as is common in research robotics (Fig. 7).

Figure 6: Rotation with an internal COR

Figure 7: Differential locomotion

In summary, although not Holonomic, the Personal Rover enjoys significant degrees of locomotory freedom combined with a pan-tilt head and a moving COM in order to tackle a number of terrain features that may be found in domestic circumstances.

4. Human-Robot Interaction Design

The user experience design task is fundamental to the success of this project. This project is unusual in that user experience design and evaluation extend not only to the educational content of the robot and its resulting community of users, but also to the long-term relationship between creative human users and their Personal Rovers over months of interaction.

First, the interface must enable the user to codify desired rover behavior over the course of minutes, hours, days and even weeks. The interface must facilitate *teaching* the rover new types of tasks to perform, diagnostic transparency into the rover's current status and interactive means for the rover to ask for and receive guidance from the user.

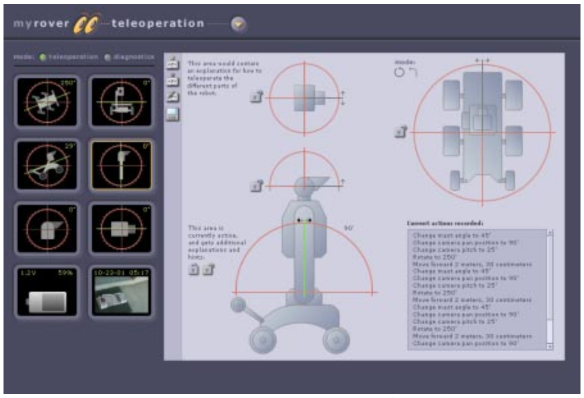

Figure 8: A Teleoperation interface for Rover

Figure 8 presents an example of transparency at the teleoperative level. Of course, the user needs such visibility at multiple levels. Figure 9 presents an example of status at the mission level, in this case supposing that one has designed a mission in which the rover documents the daily growth of a bean sprout in water.

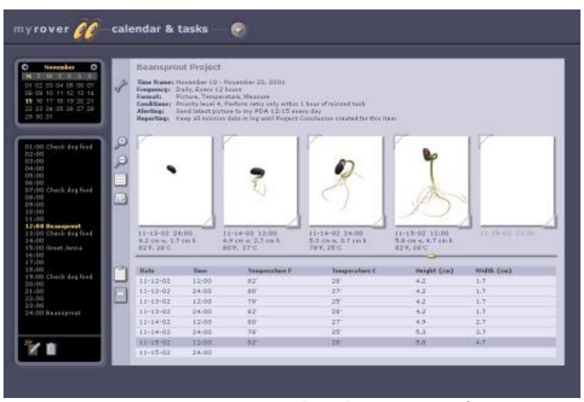

Figure 9: A mission-level user interface

With the steady increase of portable, internet-enabled computing devices, a natural way for the Personal Rover to interact with its user will be through wireless communication, as depicted fancifully in Figure 10. In this example, the Personal Rover requests help when faced with a new or uncertain situation.

Preceding all of this functionality is the need for an interface to enable non-robotics experts to define and control missions for execution by the Personal Rover. Our group has begun developing such a teaching interface by once again focusing on the visual competence of the rover.

In this *teaching* interface, the user is unable to directly manipulate the rover's degrees of freedem. Instead the user is constrained to the perceptual primitives available from CMUcam.

Figure 10: A Rover diagnostic message

Using a graphical wizard-based interface, he or she can only command the rover in relation to perceptual landmarks observable by the rover itself. This is a promising means of teaching because as long as one designs each such perceptual control loop to be locally stable to perturbations in rover position, lighting, etc., then any sequence entered by the user will be reproducible by the rover, at a later time, autonomously.

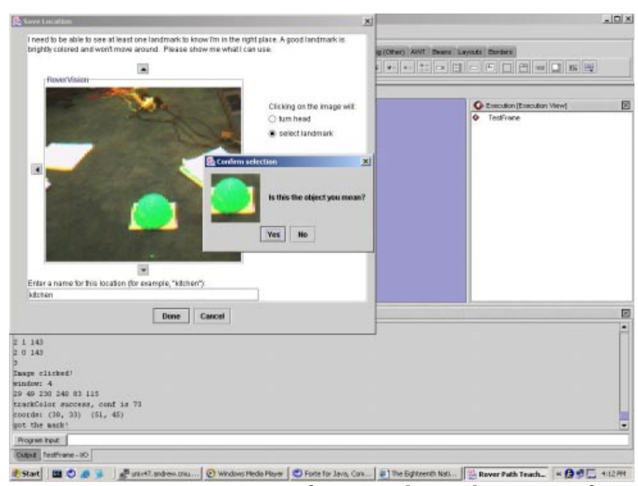
Figure 11: A prototype, functional teaching interface. Here the system verifies the user's landmark selection.

In Fig. 11, for instance, the user is confirming that they have selected the intended visual target for landmark-relative rover motion.

This autumn, we plan to conduct usability testing of this teaching interface with naive individuals in order to measure its efficacy and expressiveness from the user's point of view.

5. Educating a New Group of Robot Users

In parallel with further rover development efforts, our group has designed and fabricated 30 simplified personal

Figure 12: The Robotic Autonomy class

rover fast-build kits to begin an outreach teaching and observation activity. Beginning on July 1, 2002, thirty students in the San Jose, CA area were selected to participate in *Robotic* Autonomy, a seven-week, full-time summer course at NASA/Ames (Fig. 12, 13, 14).

Figure 13: Team PowerPuff Girls in Robotic Autonomy

Twenty of the students are underpriveledged minorities attending the course under scholarship. In this course, students work in teams to build and program their custom Personal Rovers, named Trikebots, from fast-build kits.

In the first week, the students were introduced to the mechanism and electronics comprising their trikebots. Following that introduction, the students are learning how to develop autonomy software for their trikebots, which have both back-EMF motor sensing as well as CMUcam sensors on raised pan-tilt heads. The student progress may be reviewed at:

`http://www.cs.cmu.edu/~rasc`

The robot design, robot firmware, interaction software and course curriculum will all be open-sourced on this site.

Figure 14: A student tests the Trikebot's obstacle avoidance program that he has written.

At the conclusion of the course on August 16, each student took home and kept a complete Trikebot, including the laptop, wireless cards and iPAQ that complete the software and control architecture. The students have already learned to open-source their robot software using a documentation process that includes prose, images and video. Throughout the ensuing year, these students will take part in a longitudinal educational study observing their behaviors and attitudes with respect to science and engineering as well as the role of Trikebot in their home.

6. Conclusions

The Personal Rover project is a one-year-old project that hopes to define and demonstrate a social niche for robots as creative outlets in domestic environments. This is a step toward pushing a community of robot users into the direction of making interesting and useful robotic products years into the future. This effort is expansive, covering low-overhead robot perception, robot mobility mechanism, human-robot interface design and long-term outreach activities to create and feed a real user community.

Within a year, this project will produce educational data regarding the results of an early experiment in placing such Personal Rovers in thirty households in San Jose, CA. We eagerly anticipate these educational results as well as further research results.

Acknowledgements

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