Interfacing the Public and Technology:
A Web Controlled Mobile Robot

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Abstract

The public perception of technology and careers in technology is heavily influenced by mass media images. Negative images can perpetuate unfavorable opinions and detrimental stereotypes. This paper describes a project to develop an educational robotics website that is centered on a web controlled mobile robot. The intent is to engage K-12 students and the general public with positive and realistic images of the technology in hopes to foster positive attitudes toward science and technology. Taz, the central component of the project, is a semi-autonomous robot, performing navigation and localization while taking individual movement commands.

Introduction

The public's perception of technology is heavily influenced by images portrayed by the mass media (Martin 1993). Television and movies serve to spread and perpetuate negative images of both the technology and the stereotype of people who develop it. Newspapers and news shows bias their views in an attempt to make stories of technology palatable to their audience (Martin 1993). This can be detrimental in many ways. These images sway public opinion, which in turn drives our legislatures in forming policies that can effect what research gets funded or even what research can be done (e.g., fetal tissue research). These images also serve to cultivate negative attitudes toward careers in science and technology areas, which could be a one reason for the lack of diversity in these areas (Kiesler, Sproull, and Eccles 1985; Cooper and Weaver 2003).

This paper describes the development of an educational website about robotics centered on a web controlled mobile robot. By providing opportunities for the public to interact with current robot technology it is our hope to present a more realistic picture of engineering and science, and the careers they encompass. While the site and robot are available to the general public, the project was specifically designed for a K-12 audience. Participatory design methods, particularly those geared toward designing with children, were used to design the website and the web controls (Beyer and Holtzblatt 1997; Druin 1999). The website and web controlled robot have been on-line for only a short time but have received quite a bit of response and interesting feedback. In part, based on this feedback, we continue to develop the project with the goals of making the technology and the education of the technology publicly accessible.

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Web Robots

There have been a number of interesting and successful web controlled robots (See Goldberg and Siegwart 2002). These have been developed with various goals in mind from testing navigation to providing access for use in AI class projects. The most closely related to this project are mobile web controlled robots. While all of them informed and inspired this project, a full survey is beyond the scope of this paper.

The one work most directly related to this project is Xavier (Simmons et al. 2002). Xavier was an autonomous robot developed at CMU. The goal of the project was to test out new navigation algorithms. Xavier's overall task was to act like a mail messenger. The web interface allowed anyone to send Xavier a command that directed it to a specific room in the building. Commands were queued. When Xavier completed a user's command an email was sent to the person issuing the command. An additional interface indicated the room Xavier was currently in and a picture from Xavier's camera. Xavier was very successful at generating significant interest in controlling it through the web interface.

Designing with Kids

Human-Computer Interaction research has developed a number of approaches that endeavor to embrace users as active participants in the design process (Beyer and Holtzblatt 1997; Landauer 1985; Flanagan et al. 1997; Muller and Kuhn 1993). These different participatory design approaches find ways to interject the designer in the user's world and the user in the designer's world in order to develop a shared model of the task and the context in which it is being done (Muller and Kuhn 1993).

Methods of participatory design include interviewing, observation, and prototype testing. While these methods are useful in developing applications with adult users, who can articulate their intents and ideas, they prove less useful with children (Druin et al. 1999). Children, particularly younger children, cannot verbalize what they are doing, why they are doing it, or what they may want in an application. Druin, Bederson, et al. (1999), have developed modified participatory design techniques for involving children in the design process. These include informal interaction sessions, playing with objects, and crafting low-tech prototypes.

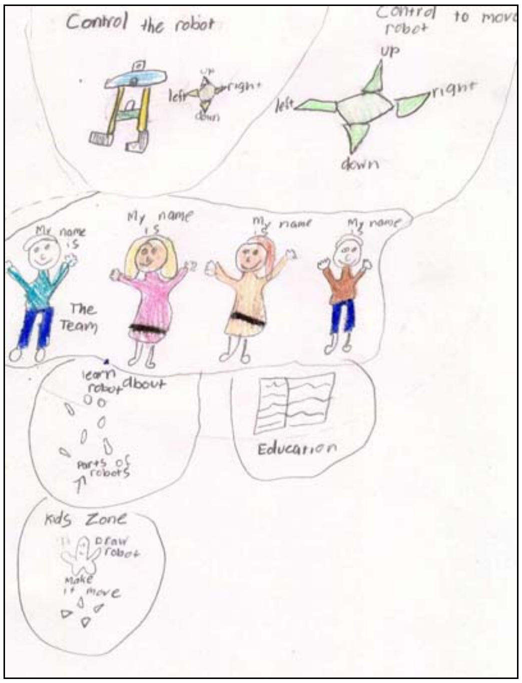

Figure 1: Prototype of web page and robot controls from 3-5 grade interviews.

Employing the modified techniques we interacted with four different groups in grades K-12: K-2, 3-5, 6-9, and 10-12. Our main goals were to illicit what they knew about robots, their opinions of robots, what they might like to learn about robots, and design ideas for a robot control. The K-9 groups were allowed to play with some small mobile robots while they described or discussed their ideas. In addition, they were asked to draw robots and robot controls. The 10-12 grade group was interviewed directly about robots and careers in technology. Additionally, this group was asked to perform a card sorting exercise that would help us design the organization of the website (Beyer and Holtzblatt 1997).

Figure 1 is an example of the kind of pictures and prototypes that the students created. Some of the more interesting results that drove the design include:

- When asked what they knew about robots, all groups initially responded with a comment about the television show "Battlebots". In the younger grades of K-9, this appeared to be their only exposure to robots.
- Beginning with the 3rd grade group, all expressed interest in knowing how robots worked. Older grades expressed interest in seeing the "guts" of a robot.
- All groups expressed interest in controlling a robot and they all had ideas of how to interface with the robot to control it. Several of these were similar to common video game controllers.

Design and Implementation

Taz, the web controlled mobile robot used in this project, is a Performance PeopleBot that was purchased from ActivMedia Robotics (See Figure 2). Taz is equipped with several features. Those that are relevant to this project include an onboard PC, wireless Ethernet connection, pan-tilt-zoom camera, upper and lower sonar grids, and a laser range finder.

Figure 2: Taz

The system for controlling Taz allows users to move Taz about the first floor of the school's Engineering Building. This system was designed with three distinct components. Each component contributes unique functionality to the system and represents a level in the communications pipeline between the end user and Taz: Control Applet, Middle Man, and Remote Control Server. The Control Applet runs on the end user's computer, the Middle Man runs on a web server, and the Remote Control Server runs on Taz's on-board PC. Users interact with Taz through the Control Applet. The Control Applet sends control commands on to the Middle Man. The Middle Man's primary function is to coordinate user requests and replies from the Remote Control Server. The Remote Control Server directly controls Taz's hardware and ensures safety.

Website

The website, which was designed primarily for children, has the goal of being both entertaining and educational (See Figure 3). The site has links to two separate pages that contain information about Taz. One of these pages contains technical information about Taz's various parts which is geared towards educating high school students. The other page contains less detail and more animation and is geared for a younger audience. It also contains links to either control Taz or watch Taz's live camera feed along with the schedule of when Taz can be controlled.

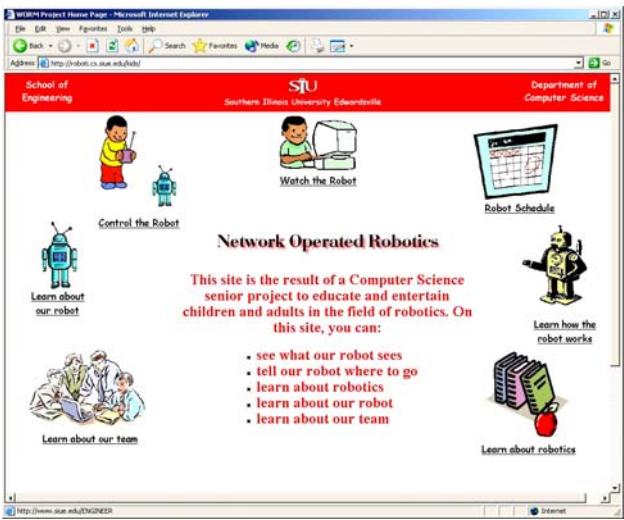

Figure 3: Website: http://roboti.cs.siue.edu/kids/

Sub-Component Communication

There is a single, bi-directional line of communication between each of the three joined sub-components: Control Applet, Middle Man, and Remote Control Server. For reasons of clarity and completeness, it is worthwhile to note that the system could be viewed as having four parts and three lines of communication. The additional component is the Pioneer 2 Operating System (P2OS) firmware with which the Remote Control Server communicates.

The Control Applet, Middle Man, and Remote Control Server, communicate by means of a Robot Control Protocol (RCP). RCP is a high-level communications language that was developed for this project. RCP commands are sent over TCP/IP connections as raw lines of ACSII text. Each line of text represents one command. Each command is composed of up to three parts separated by a single space: the type, the action, and the optional action parameters. For example "ROBOT MOVE FORWARD\r\n" would be sent to instruct the robot to move forward one unit. A diagram of the four layers of the communications layout is shown in Figure 4.

The user sends commands to the Control Applet via the mouse and receives information by visual cues. The Control Applet sends RCP commands to the Middle Man, which verifies and passes the commands to the Remote Control Server. The Remote Control Server interacts with the P2OS module through API calls.

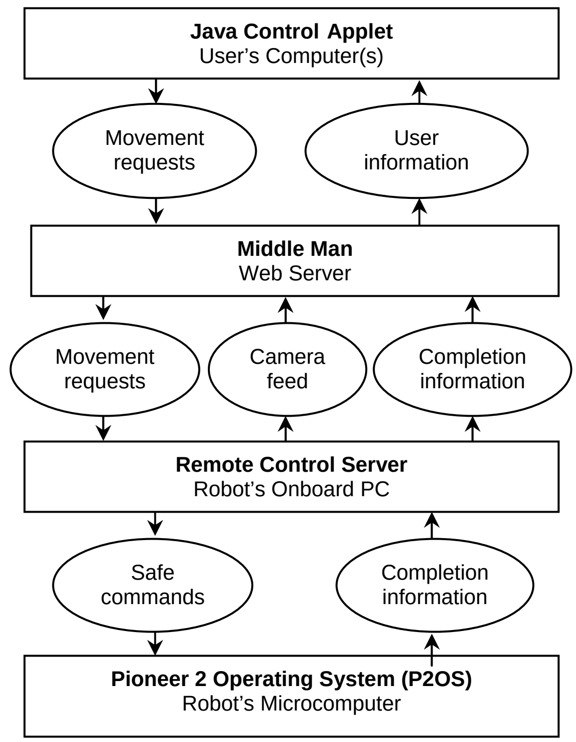

Figure 4: Communications layout.

Control Applet

The Control Applet is written in Java and has a GUI that the user interacts with, primarily by means of mouse clicks, in order to control Taz. Objects within the Control Applet include motion buttons (e.g. forward, turn left, turn right) and a waiting list. The user receives feedback in the forms of a timer, indicating when control will be received or lost; a picture from Taz's camera that is updated frequently; button presses mirroring the current controller's activities; and updates to the waiting list as people join and/or disconnect. The internal implementation of the Control Applet consists of two main sections: GUI and communication. The GUI section handles updates to the user interface. The communication section

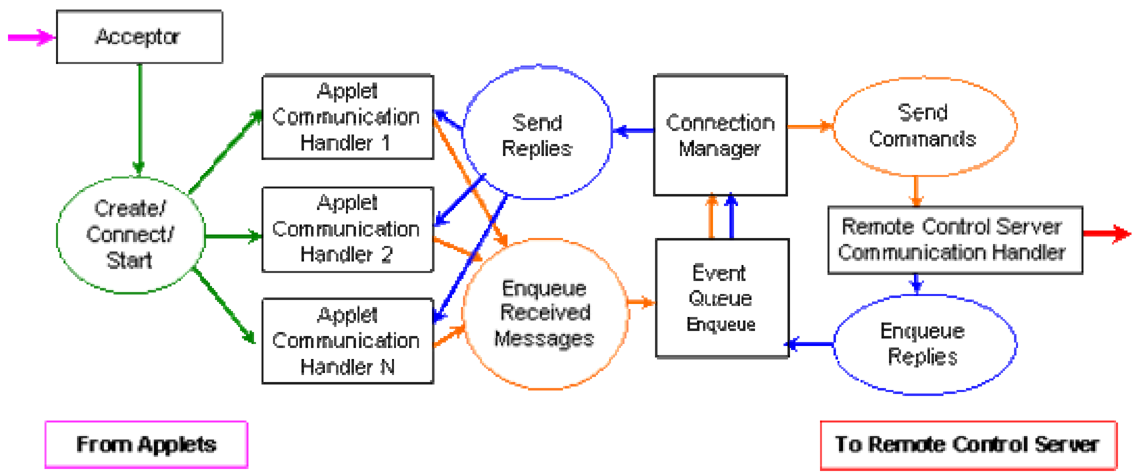

Figure 6: Middle Man Flow Diagram.

sends messages to and receives responses from the Middle Man and delivers them to the GUI. Both the GUI and communication sections run in their own threads of execution and communicate via a common class.

Figure 5: Control Applet.

Middle Man

The Middle Man is written in Java and contributes to the system by coordinating the many requests from the end users received from the Control Applets and the replies of the Remote Control Server, as shown in Figure 6. The Middle Man resides on a web server and provides a layer of security to Taz since this means that Taz does not need to be directly connected to the Internet and only receives commands from the server. The Middle Man is also responsible for keeping track of who is currently controlling Taz and the list of users waiting to control Taz. A timer is used to determine who the current controller is and each controller is allotted one minute of control time. At the end of a controller's turn, he or she is placed at the bottom of the waiting list and the user at the top of the waiting list becomes the new controller. The Middle Man sends all updates to the current controller and waiting list to all of the Control Applets.

Remote Control Server

The Remote Control Server is a piece of software written in C that contributes to the system by verifying RCP commands and passing these commands on to the P2OS module. Up to this point all communications have been made using RCP, but the final commands are sent to the robot through API calls to the P2OS module's firmware. This translation from high-level RCP commands to low-level API calls is also the responsibility of the Remote Control Server. After the command has executed, the Remote Control Server sends a message to the Middle Man indicating whether or not Taz successfully completed the command along with whether or not Taz is able to move forward from the current location. The latter of these is determined by consulting the Grid (Figure 7). The Grid is a digital map of the interior of the Engineering Building's first floor. Each point represents a location that Taz is permitted to occupy. Taz can only move between points that are connected by an edge. A laser localization module written by ActivMedia provides the Remote Control Server with Taz's location. That location is used to keep Taz on the Grid. If Taz is facing a direction that does not have a point in front of it, the Remote Control Server notifies the Middle Man, which in turn notifies the Control Applet and the controller's forward button is disabled. This prevents Taz from traveling to any potentially unsafe and/or inappropriate areas since these areas do not have grid points associated with them.

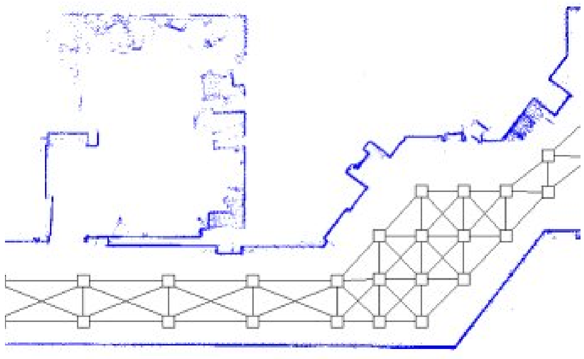

Figure 7: The Grid.

Discussion

Taz has been used in various K-12 events including class lectures, science fair presentations, after school programs, and remote class lectures. At each event we have received positive feedback from the kids and have observed them in engaging activities. Frequently at events we will see students first take control and then get interested in how the technology works. The kids will ask questions or explore the rest of the website for answers. Taz has also received a number of thank-you notes from K-5 students.

As of mid August 2003, Taz has been made available on scheduled periods to the general public. Over a two month period we have received visits from over 2000 unique IP addresses, both locally and globally. Taz has also been featured in six of the regional newspapers.

We have a number of areas for further development. These include:

- Orientation: the first thing many users do when they take control is to turn in a circle to get oriented. So we are looking into giving the users a sense of where "they" are by adding a mapping feature to the interface.
- Camera Control: providing pan-tilt options will increase interactivity and may solve the orientation problem.
- Visible AI: we hope to give K-12 students a more direct understanding of how Taz navigates and localizes by adding a representation of live calculations or demonstrations connected to the control page.
- Multiple levels of interaction: Taz is controlled at the step level, while Xavier was controlled at the room level. We are exploring other levels such as sending Taz to a point or possibly some type of "trip" planning.

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