Human-Robot Interaction using a Multi-Touch Display

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Abstract

Recent advances in digital tabletop touch-and-gesture-activated screens have allowed for small group collaboration. The newest generation screens simultaneously support multiple users, multiple contact points per user, and gesture recognition. To the authors' knowledge, this technology has never been applied to robot control. We envision that an interactive multi-touch screen display for robot control would improve human-robot interaction (HRI) and increase efficiency. To this end we have adapted several interfaces for use on the MERL DiamondTouch. In this paper, preliminary findings and observations from user testing with one such interface are presented.

1. Introduction

Mitsubishi Electric Research Lab (MERL) began development on the DiamondTouch screen in 2001. The screen has an array of antennas embedded below the laminated surface, which transmit a synchronized radio signal relative to the respective x and y coordinates. These signals are transmitted back to the DiamondTouch hardware via radio signal receivers, with which users must remain in contact. The use of multiple receivers allows for unique identification of individuals [1]. From these signals, the computer software is able to determine who is touching the interface where, and at how many locations.

MERL donated a DiamondTouch display to our lab in August 2006. Since that time, we have conducted a performance validation of the display, including Fitts' law and cursor position time [2], as shown in Figure 1. We have also prototyped a Command and Control interface with registered satellite images of Biloxi Mississippi, both pre- and post-Hurricane Katrina.

2. Research questions

Our research represents a significant paradigm shift for human-robot interaction (HRI) developers. Most fielded robot operator control units (OCUs) use a combination of joysticks, switches, buttons, and on-screen menus to facilitate HRI. While these interfaces have proven themselves in the field, they are not directly portable to tabletop technology. This has led us to several research questions:

What is the added value of moving interfaces from mouse/keyboard/joystick control systems to a multi-touch system? As robots and sensors are constantly becoming more complex, their control interfaces may have outgrown such independent input systems as mice, keyboards, and joysticks. A multi-touch display removes these multiple input methods and removes the interaction abstraction between the input device and the display, providing a single input and output apparatus. Experiments using Fitts' law have shown that speed and efficiency may improve [2].

Figure 1. A user interacting with the MERL DiamondTouch screen. The DiamondTouch was evaluated in regards to task completion time and accuracy. A standard mouse was used for comparison.

What changes need to be made to the interfaces to accommodate and exploit differences between classical input devices and multi-touch devices? The multi-touch breaks classical paradigms for HRI, but it is also bound by user expectations. These expectations should be accommodated where needed, but we must also exploit differences in the input methods.

What gestures, if any, should be used? To the authors' knowledge, no multi-touch tabletop gesture paradigms have been applied to mobile robot control. Gestures may provide enhanced usability above and beyond current input devices, providing an entirely new area of research for human robot interaction.

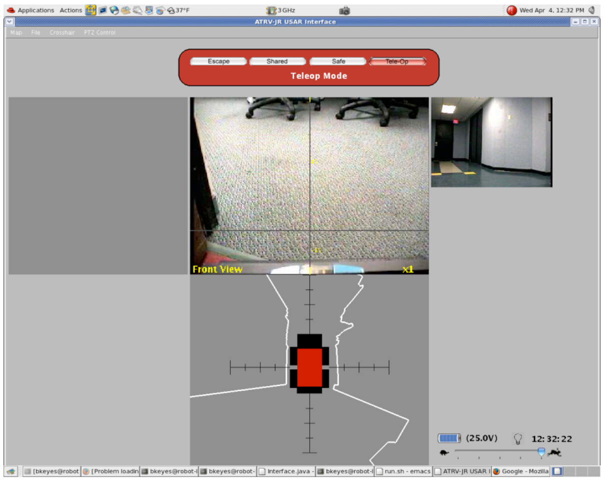

Figure 2. Screenshot of the original UML USAR interface. The multi-touch adaptation uses the video (center) for camera control and gray area (right) for robot control.

3. Interface

We have investigated these questions by adapting an existing interface for USAR. This interface was developed in-house, using a flight simulator style joystick and keyboard to control an ATRV-JR, with an emphasis on information presentation and sensor fusion [3] [4].

The multi-touch prototype uses the lower right hand corner as a driving area and the center video window for camera control. The first gesture set uses the convention that a finger placed in the positive y quadrants of the driving area relates to forward motion and a negative y is reverse. The x-axis is used to rotate the robot chassis left and right. In this respect, the user drives by placing one finger on the coordinate system and "pushing" the robot in the direction he or she wants it to go.

The camera is controlled in a similar manner. A finger placed in the camera view relates to the vertical and horizontal components of movement. The x-axis relates directly to pan. A left movement rotates the camera left. Conversely, a right movement rotates the camera right. The y-axis can operate in two modes. In the first mode, a positive y component indicates an upward camera tilt. This exploits the user's expectation that they are "pointing in the direction that they want to see." The second mode uses the opposite approach. An upward movement of the hand lowers the camera, giving the effect of "moving the picture to the area that the user wants to see."

These two styles correspond to our findings that some users prefer the flight control style of camera movement, while others prefer a more direct approach [3]. It is currently unclear which of the positive or negative y-component methods is preferred.

We expect novice users who do not have previous experience controlling robots to learn much more quickly with this system. By removing the joystick abstraction for the camera pan and tilt, the user now appears to directly manipulate the robot. Additionally, experienced users should see an increase in usability, since their single joystick hand is not overloaded with multiple controls for all robot functions. Rather, they can use one hand to control the robot and another hand to control the camera mechanism.

Our early prototypes have already empirically given evidence that there seem to be gestures that humans find intuitive for such interaction. For example, zooming the camera by placing two fingers together on the board and pulling them apart feels natural. This "pre-wired" gesture set needs to be further studied and exploited by HRI developers.

4. Conclusions

After extensive user testing with this interface, we will create design guidelines for adapting HRI to multi-touch displays. This style guide reference will give the best-in-breed for this unique application of multi-touch technology.

5. References

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