Human-Robot Interaction using a Multi-Touch Display

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Abstract

Recent developments in multi-touch technologies have exposed fertile ground for research in enriched human-robot interaction. Although the technologies have been used for virtual 3D applications, to the authors' knowledge, ours is the first study to explore the use of a multi-touch table with a physical robot agent. This baseline study explores the control of a single agent with a multi-touch table using an adapted, previously studied, joystick-based interface. The field test shows that multi-touch interaction does not in any way impair the performance of the user in a navigation and search task. In fact, our results show an increase in learnability over the original design using joystick and keyboard-based control mechanisms. Further, we analyzed users' interaction styles with the multi-touch interface in detail to isolate mismatches between user expectations and interaction functionality.

Introduction

To our knowledge, this study represents the first use of a multi-touch table with a physical agent. By removing the joystick, mouse, or keyboard from the interaction, we increase the degree of direct manipulation, thereby increasing interaction by removing a layer of interface abstraction. In the case of human-robot interaction, the multi-touch should allow users to more directly interact with the robot and affect its behavior. Many unexpected events occur when a system contains a moving, semi-autonomous physical object that is affecting the world. As such, we must determine if multi-touch interaction decreases the performance of systems in the real, dynamic, and noisy world.

A mature and well-studied joystick interface forms a baseline for comparison [Key07]. The University of Massachusetts Lowell (UML) urban search and rescue (USAR) interface system encompasses a wide range of user functionality and autonomy capabilities. While leaving the visual presentation the same, this system was ported from a joystick and keyboard interface to a Mitsubishi DiamondTouch [DL01]. A detailed description of the original joystick design is provided in Section [Key07]. The similarity in design enables us to test whether we are impairing performance with the new interaction method.

This study assists in the evolutionary process by providing a detailed analysis of users' varied interaction styles. Beyond establishing a baseline, the new DiamondTouch-based interface will need to evolve as we learn more about how to best take advantage of the multi-touch technology. Our analysis sheds light on how users perceive the interface's affordances and highlights mismatches between users' perceptions and the designers' intentions. These mismatches point towards design changes to better align users' expectations and interface realities.

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. Placing these requirements and user expectations in the context of a multi-touch interaction paradigm has led us to several research questions:

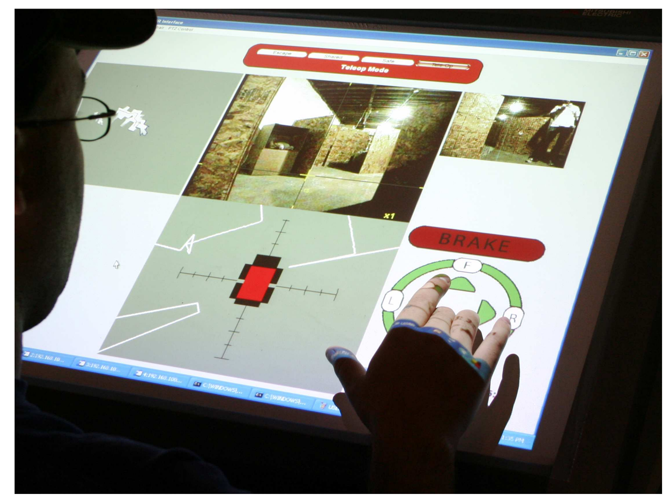
What is the added value of moving interfaces from mouse/keyboard/joystick control systems to a multi-touch system? As robots and sensors are constantly becoming more complex, their control interfaces may have outgrown such independent input systems as mice, keyboards, and joysticks. A multi-touch display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

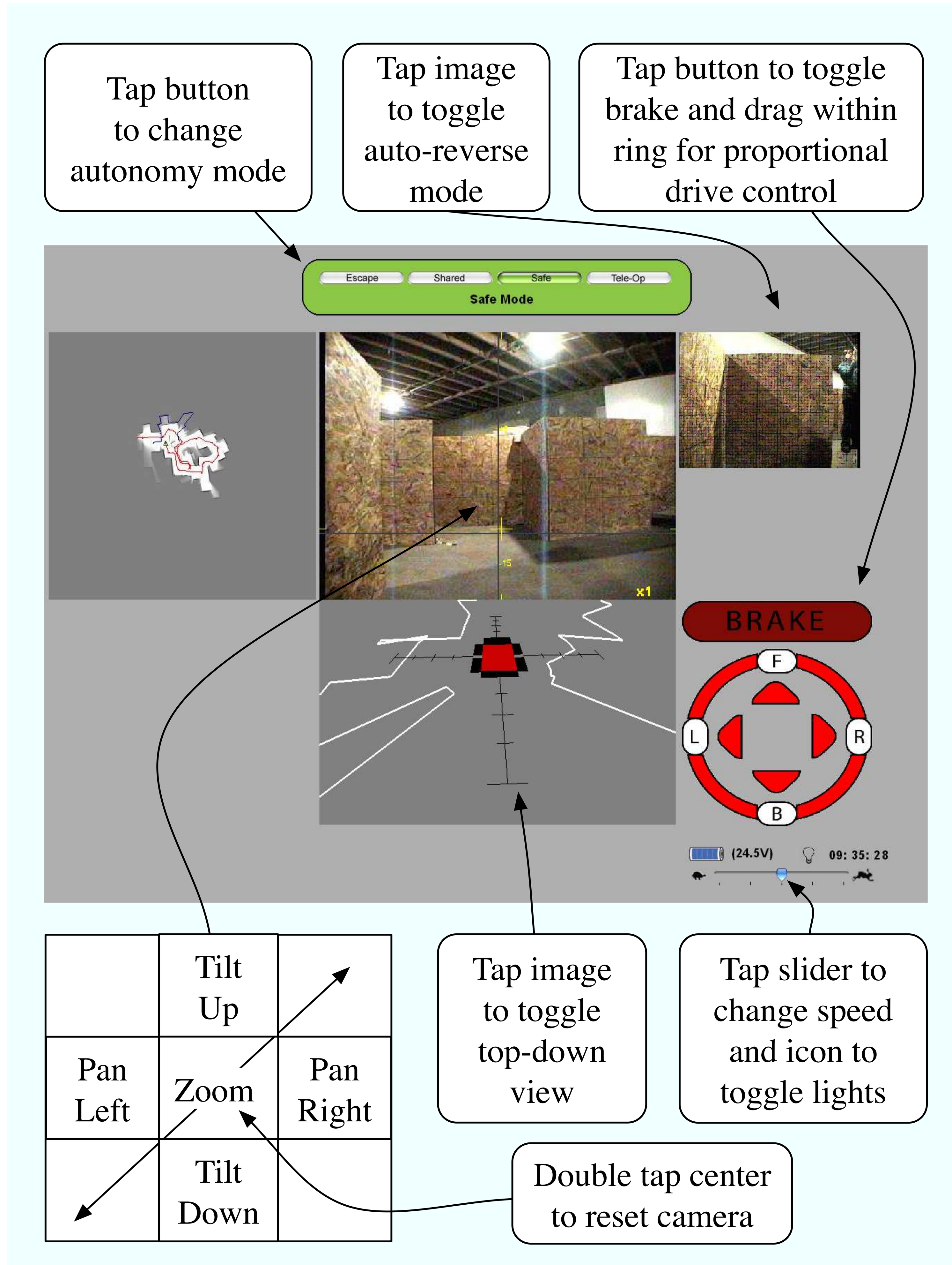
What changes need to be made to the interfaces to accommodate and exploit differences between classical input devices and multi-touch devices? The multi-touch breaks classical paradigms for HRI, but it is also bound by user expectations. These expectations should be accommodated where needed, but we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

Interface Design

The UML USAR interface (left) is shown with a participant using the multi-touch configuration. This interface allows the user to operate the iRobot ATRV (right) though the NIST USAR course using the gestures that activate interface features and autonomy modes (below).





Performance

We assessed the positive, or constructive, aspects of performance based on measuring the number of victims found and the amount of new or unique territory the robot covered. The table below shows that participants explored an average of 376 square feet and found an average of 5 victims when using the joystick-based interface. The DiamondTouch interface shows remarkably similar results: participants directed robots to 373.3 square feet of territory and found 5.7 victims. Thus, there is no difference in the constructive performance of the two interfaces.

	Joystick Interface		DiamondTouch Interface	
Participant	New Area Discovered	Victims Found	New Area Discovered	Victims Found
1	272	3	304	6
2	288	3	288	2
3	352	3	240	3
4	480	8	480	7
5	384	7	464	6
6	480	6	464	10
Average	376	5	373.3	5.7
Std Dev	90.4	2.3	107.4	2.9

We also assessed the negative, or destructive, aspects of performance. We categorized the destructive incidents as pushes (moves an obstacle away from its normal position), scrapes (brushes up against an obstacle), bumps (impacts an obstacle), and e-stops (emergency stops). While there are more scrapes and bumps using the joystick interface and more pushes and e-stops with the DiamondTouch interface, none of the differences are significant. Thus we confirmed that there was no difference in constructive or destructive performance when using the two interfaces as they are currently designed.

	Joystick Interface				DiamondTouch Interface			
Participant	Pushes	Scrapes	Bumps	E-stops	Pushes	Scrapes	Bumps	E-stops
1	1	1	1	0	0	0	0	0
2	5	5	20	6	2	0	4	3
3	0	0	1	0	11	0	1	6
4	0	0	0	0	1	1	0	0
5	0	0	0	0	6	2	0	6
6	1	0	1	0	1	0	1	1
Average	1.2	1.0	3.8	1.0	3.5	0.5	1.0	2.7
Std Dev	1.9	2.0	7.9	2.4	4.2	0.8	1.5	2.8

We found that five of the six participants asked a total of eight questions about the joystick interface and one participant asked two questions about the DiamondTouch interface ($p = 0.072$, dof $= 5$ for paired, 1-tailed t-test). This result, while again being on the edge of significance due to the small sample size, tends to support the contention that the DiamondTouch interface is easier to learn than the joystick interface.

Conclusions and Future Work

Where the joystick limits the user through mechanical constraints, the multi-touch surface serves as the "blank canvas" on which control surfaces are dynamically created. However, the designer must carefully choose control methods that give extremely clear affordances and appropriate feedback to the user. While the system designers intended the interface to evoke a joystick and button affordance, the participants also demonstrated motions similar to those they would use with mouse track-pads, piano keys, touch-typing, and sliders. We are confident that more can be done to enrich the user experience because we no longer are limited to the constraints of the degrees of freedom of a joystick. Our future work will center around the lessons learned from this experiment as drawn from the interaction characterizations. Additional functionality not explored in this study such as direct map manipulation and "point to send the robot here" commands should provide for ease of navigation.

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[DL01] P. Dietz and D. Leigh. Diamondtouch: A multi-user touch technology. In *ACM Symposium on User Interface Software and Technology*, pages 219–226, November 2001.

[Key07] B. Keyes. *MS Thesis: Evolution of a Telepresence Robot Interface.* Univ. of Massachusetts Lowell, Lowell, MA, 2007.