Are Tangibles Really Better?: Keyboard and Joystick Outperform TUIs for Remote Robotic Locomotion Control

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ABSTRACT

Prior work has suggested that tangible user interfaces (TUIs) may be more natural and easier to learn than conventional interfaces. We present study results that suggest an opposite effect: we found user performance, satisfaction, and ease of use to be higher with more common-place input methods (keyboard and joystick) than two novel TUIs.

Categories and Subject Descriptors

D.2.2 [**Software Engineering**]: Design Tools and Techniques—*User interfaces*

Keywords

Collocated Teleoperation, Tangible User Interfaces

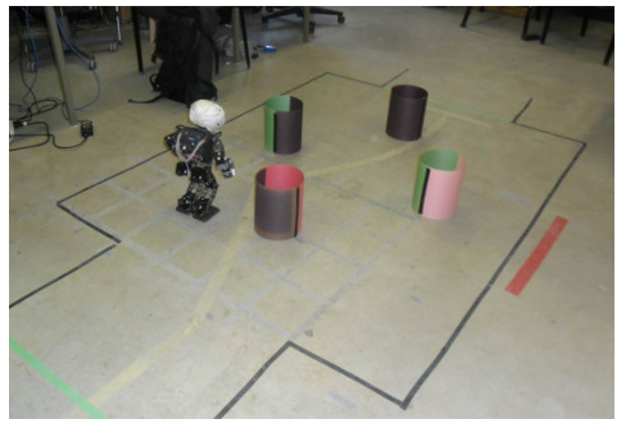

Figure 1: The navigation course and the robot.

1. INTRODUCTION

Remote-controlled robots are becoming widely used in military, search-and-rescue (SAR), and other applications. For this reason, it is important to establish methods of remote control that result in improved performance while maximizing ease of use. In these applications, the operator will sometimes be collocated with the robot, rather than controlling it from afar. Prior work has established that in these cases, tangible user interfaces (TUIs) may be more natural and easier to learn than conventional interfaces such as the keyboard [3]. We find evidence to the contrary, whereby user performance and satisfaction may be higher when using established methods such as the keyboard or joystick.

In this work, we studied the effects of various input methods on remote-control robotic navigation tasks. We present evidence that TUIs may not always be ideal input methods when compared to other techniques.

Teleoperated robots are being developed and employed in applications such as SAR [5] and ordnance disposal [1]. Much of this work involves robots which are far from the operator, where information is conveyed by cameras and sensors. Our work instead focuses on robotic remote control where the operator is collocated with the robot.

There are many methods developed for controlling collocated robots. Previous methods include the use of TUIs [2, 3], keyboard input [3], and controls resembling dog leashes [6]. Of particular interest to us is evidence that tangible interfaces may be preferred over, and result in higher performance than, more common-place ones [3]. Our goal is to replicate these findings in a similar study.

2. STUDY DESIGN

In our study, participants navigated a humanoid robot through an obstacle course (Figure 1) using a mix of common-place input techniques which leveraged existing training, as well as various TUI methods (similar to previous work [3]), which recent evidence suggests may be more natural and easier to learn. Obstacles were placed so that one had to navigate around them. Participants were instructed not to move the robot out of the arena bounds. Navigation time, the number of obstacles hit, and the number of out-of-bounds occurrences were all recorded as dependent measures.

We conducted our experiments as a within-subjects study using participants from our department (11 male, 3 female). Incomplete Latin-square counterbalancing was used to compensate for learning effects. Figure 1 shows the obstacle course and the robot used in our study.

We asked participants to complete a 7-point Likert questionnaire inspired by NASA's TLX survey [4], to rate their

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feelings of control, accuracy, physical demand, recall, and enjoyment of each method. Results are shown in Table 1.

2.1 Input Methods

Keyboard – The arrow keys were used, where holding *left* or *right* turned, and *up* or *down* walked forward or backward. Keys could be combined (to walk while turning) and releasing keys stopped immediately.

Joystick – Tilting forwards or backwards caused the robot to walk forwards or backwards, and tilting sideways turned the robot in place. The speed of the robot could be influenced by how far the joystick was tilted.

Tank TUI – Users tilted motion-sensing remotes (Wii-like, constructed in-house) to drive using a common tank metaphor (detailed visually in Figure 2).

Steer TUI – Similar to *tank*, but the left remote was tilted forwards or backwards to control the forward or backward motion of the robot, while the right remote was tilted to either side in order to make the robot turn in place (Figure 2).

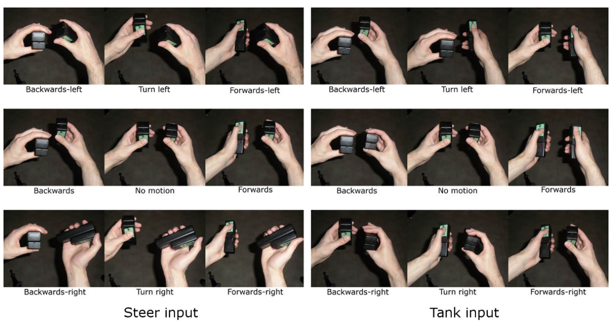

Figure 2: The TUI input methods and motions.

3. RESULTS AND DISCUSSION

A repeated-measures ANOVA (with Greenhouse-Geisser correction for sphericity) found an effect of input type on task completion time, $F_{1.46,16.09}$=14.71, p<.001. Post-hoc pairwise comparisons (paired-samples t tests) with Bonferroni correction show that both the joystick (M=26.5s, t_{12}=4.95, r=.82, p<.001), keyboard (M=26.5s, t_{12}=4.23, r=.77, p<.01), and steer condition (M=28.92s, t_{12}=3.32, r=.69, p<.05) times were faster than tank (M=36.5s). Using Friedman's ANOVA on the non-parametric data, no effect was found of control condition on number of collisions with the environment or times going out of bounds.

An effect was found of control method on how much participants felt in control (χ^2_3 = 19.6, p<.001), how accurate they felt they were (χ^2_3 = 12.89, p<.01), how demanding they found the interface (χ^2_3 = 15.53, p<.001), how easy the controls were to recall (χ^2_3 = 17.82, p<.001), and how much they enjoyed the interfaces (χ^2_3 = 8.19, p<.05). Post-hoc Wilcoxon signed rank tests (with Bonferroni correction) show that participants reported feeling more in control with the keyboard than either of the steer (T=2, p<.05) or tank (T=0, p<.05) conditions, and felt that they were more accurate with the keyboard than the tank (T=0, emphp<.05). Further, participants rated the steer (T=2.5, p<.05) and tank (T=2.5, p<.05) as more demanding than the keyboard, and the keyboard (T=0, p<.05) was easier to recall than steer. No other effects were found.

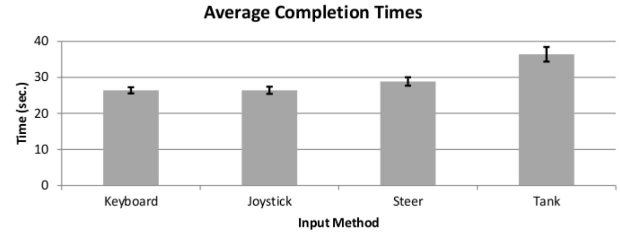

Figure 3: Average completion times with standard error.

Table 1: Participant ratings for each input method. (* = p < 0.05, ** = p < 0.01, *** = p < 0.001)

Method	Control***	Accuracy**	Demand**	Recall***	Fun*
Keyboard	6.5	6.4	1.8	7.0	5.9
Joystick	5.5	5.5	2.5	6.8	5.8
Steer	4.8	4.9	3.4	5.5	4.8
Tank	4.1	4.4	3.8	5.6	4.8

Our results contrast with those of Guo and Sharlin [3]. We believe the difference can be explained by the complex keyboard controls used in their study, which required two hands and twice as many keys. This was done to help make their keyboard commands more analogous with their tank input, which featured strafing. Our own study does not support strafing, resulting in simpler keyboard controls, which may contribute to significant differences with previous work.

4. FUTURE WORK AND CONCLUSION

We believe that TUIs offering feedback may improve performance. Vibration or LED indicators are all possibilities worth investigating as potential feedback methods.

In this paper, we described an experiment involving the use of traditional interfaces and TUIs for remote-controlling a collocated robot. Our results show that TUIs may not be the better choice. We hope that through additional experiments, we can learn more about preferred methods of robot control and which techniques better support this goal.

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