Augmented Tele-robotic Control:

Advantages of Multi-touch vs. Joystick Control Systems.

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ABSTRACT

The focus of this research was to test whether a multi-touch interface is more effective than a joystick controller for telerobotic control. Customarily, joysticks are used with tele-robotic operations. However, multi-touch interfaces can potentially create a natural experience for the operator, causing an improvement in his/her performance during complicated tasks. Our participants completed search tasks using the two interfaces and we compared the resulting data. Initial results show that the multi-touch interface is helpful in controlling the robot's path.

Keywords: Teleoperation, Telepresence, Telerobotics, NASA TLX (Task Load Index) SART (Situational Awareness Rating Technique), Interface, Multi-touch.

1. INTRODUCTION

Graphical user interfaces can reduce the operator's workload and enhance his or her performance during target acquisition. They allow the operator to visualize information from the tele-robot in ways that are impossible with live streaming video alone. The problem at hand is creating a GUI that is effective and natural in order to reduce workload and make the most of the information received by the tele-robot. Touch screen interfaces are becoming an increasingly popular form of input. The goal of the research was to test whether a joystick controller or a multi-touch interface enhanced the operator's experience.

1.1 Problem Area

The research in developing effective and natural interfaces is becoming increasingly important. It is extremely important that the user is able to navigate and understand (natural) the interface as they use it without wasting time (effective). Robotic control technology wants to explore this area in order to successfully make an efficient multi-touch interface. In different fields of study it is important to use robots to find substances or possible threats to humans. Effective and natural robotic control research has become essential for any user no matter what previous knowledge they have in that area. For example NASA's use of robotic control is crucial as they explore space and planets. Also the military uses telerobotic missions to go into in search of land mines that would be a potential danger to the soldiers [2]. Those are just a few of many reasons that there are needs for effective and natural interfaces to be developed for robotic control.

The interface for robotic control must be easy to learn for multiple persons who may not have much experience with tele-operation and yet still be effective to accomplish what the robot is programmed to do. There are many interfaces that are not very effective or natural and the result is interface confusion along with the technology's failure. Using multi-touch technology we have attempted to create a natural and effective interface alternative to traditional joystick control systems. In our study we ask the following question: How can a multi-touch interface, compared with a joystick controller, utilizing tele-robotic systems for target acquisition, be affectively implemented in order to enhance human comprehension and sense of presence? In the following sections we will answer this question.

1.2 Telerobotics

Teleoperation allows reconnaissance, inspection tasks, identification, search missions, surgical procedures, space exploration and more [8]. Within teleoperation there is telerobotics which allows the operator to control the robotic system off site. It is important to remember "telerobots, teleoperators, and remotely operated vehicles belong to a class of machines used to accomplish a task remotely, without the need for human presence on site" [5]. One area that is crucial when dealing with telerobotics is the human operator. The operator needs to be aware and in control of the robot in order to successfully accomplish the goals. Telepresence is a key factor in the operator's success. The *Human Role in Telerobotics* says, "telepresence means that the information about the remote environment is displayed to the operator in a natural manner, which implies a feeling of presence at the remote site. A good degree of telepresence guarantees the feasibility of the required manipulation task" [1]. There are different ways to measure telepresence but it is important to remember that the operator needs to feel "immersed" and "involved" when controlling the robot [1]. Research in this area focuses on the needs of the operator and how aware and in control of the robot he/she is in order to successfully accomplish the goals.

1.3 Multi-touch Interfaces

Trends in the development of graphical user interfaces are affected by the emergence of multi-touch interfaces. Touch screen interfaces are becoming an increasingly popular form of input. A mouse and keyboard only offers two dimensions of input. Multi-touch interfaces enable high-degree-of-freedom interaction techniques. In other words, it allows the user to carry out a task with a variety of motions, making the experience similar to that of the real world. For example, peeling a banana with just four fingers can be done, but it is not efficient and natural. However, peeling a banana using all ten fingers is much more natural and allows different ranges of motion and momentum, which enhances efficiency. Research has been conducted to study the effectiveness of using two hands versus one hand and multiple fingers versus one finger. Results of such studies have shown that one-handed manipulation is more effective than two-hand manipulation for tasks that require the highest level of coordination [9]. On the contrary, two-handed manipulation is more effective for faster and more dynamic tasks [9]. These conclusions will be taken into consideration in order to create an experience similar to that of the real world for the operator of the tele-robot.

2. METHODS

The design of the user interface can reduce the operator's workload and enhance his or her performance during target acquisition [2]. Rafael Aracil states in *the Human Role in Telerobotics* that "the goal is to achieve the maximum possible degree of telepresence in order to increase the performance of the telerobotic system" [1]. The problem at hand is creating an interface that is effective and natural in order to reduce workload and make the most of the information received by the tele-robot. We will compare whether the joystick controller or multi-touch interface is more effective in terms of human awareness and overall task performance.

2.1 Sparsh UI

The Virtual Reality Applications Center at Iowa State University developed a platform-independent multi-touch API for individuals seeking to create multi-touch applications. It consists of three components: the Gesture Server, an input device driver, and a gesture adapter. The input device driver passes touch point information to the gesture adapter. The gesture adapter transforms that information and makes it specific to a particular GUI framework. These transformations are sent to the Gesture Server, the main part of the API. The Gesture Server processes gestures and passes relevant information to the client application. It supports basic gestures such as touch, drag and zoom gestures and can extend to user-defined gestures.

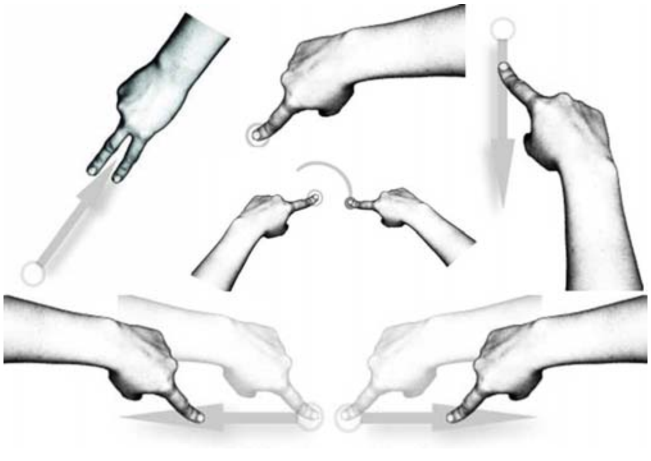

Figure 1. Built-in gestures supported by Sparsh-UI Gesture Server. Multi-point drag (top left), touch (top middle), rotate (center), drag (top right), zoom (bottom).

2.2 Telerobot

In this experiment we utilized and programmed a real world telerobotic system. By so doing we captured the complexity and fidelity issues associated with actual telerobotic operations. The telerobot being used for this experiment is designed for outside/rugged environments. It has two camera capabilities, GPS, an arm that can pick up to 8oz of weight and skid steering.

Figure 2. During the experiment, all participants were given thirty minutes to search and find ten commonly lost items. Participant finds an item (blue chap-stick) next to a light post in the field.

2.3 User Study

To determine which interface is more effective we found 23 participants, who were at least 18-45 years of age. We chose to have 23 participants due to the findings in the research from Nielsen and Landauer who are experts in Psychology and Human Computer Interaction. They discovered that approximately a minimum of 16 participants are necessary to find most of the usability problems within interfaces. It turns out that the finding of usability problems by experiment follows a poisson distribution. After doing an experiment with 16 participants the research showed that it is not cost or time efficient to do many more experiments [11]. Our participants were comprised of students and the general population from the Iowa State University campus. These participants were solicited via word of mouth, and general email list serves. We randomly assigned participants to one of two experimental groups (joystick or multi-touch interface). All participants were trained for 10 minutes. This means the participants were introduced to the interface. The participants would see something similar to what the screen capture shows in figure 4. There was a basic map of the area they were to search as is updated approximately where they were located on the map. Also the map had a specific search pattern they were supposed to follow if possible. The items were not directly on the path but the path covered the whole field, and if followed correctly they would be able to see the whole area and all the items. Also there was a speed widget and a compass widget to help guide the participant. The background was the first camera view that would update as the robot moved. If the participant wanted to change to the second camera view they would push the camera button on the left side of the screen and a menu would come out where they could switch between cameras if they wanted. Lastly, if they were using multi-touch they would use the wheel widget at the bottom right corner which would control the speed and movement of the robot. The participants whether joystick or multi-touch saw exactly the same screen items the only thing different was whether they controlled the robot with the wheel on the screen or the joystick which was a separate attachment. We explained each component of the interface and its uses, especially the component that was used to “drive” the rover. We showed the participants how to change camera views. For the multi-touch interface, we showed the user how to do the various gestures it supports. For the joystick controller, we explained how it is used. All participants were given basic training in target search and acquisition operations.

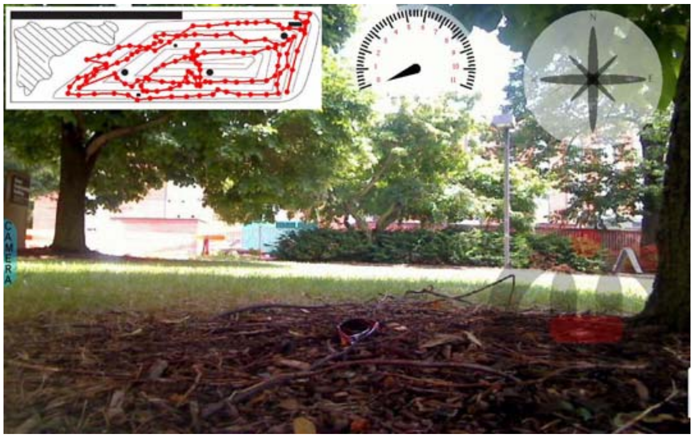

Figure 3. GUI used by both groups, containing a map of the field with identified obstacles such as trees and posts, a speedometer showing the speed of the robot, and a compass (from left to right). Blue camera tab at the left below the map allows the user to switch camera views. Even though joystick group were not able to use the multi-touch control at the bottom right, all participants saw this exact view.

During training no measurements were taken and experimenters acted as a trainer to ensure that the participant properly understands the system they were working with.

2.3.1 *Experimental Task*

Participants were asked to conduct a search for items that are commonly lost. The lost items were the following: wallet, sun glasses, chap-stick, pacifier, golf ball, hot wheels car, hair clip, USB, cell phone, and an ID card. Half of the participants used the joystick controller while the remaining half used the multi-touch interface. The entire time for each participant was approximately one hour. The first 10 minutes the participants were given instructions and getting used to the interface they're given. They had no more than 30 minutes to complete the search task. The rest of the time they had to fill out the surveys and questionnaires. During the experiment, we measured the number of errors made by the user, the time for each item found, the number of items found in the allotted time and the number of times the robot hit an object in the field. After each participant completed a task, we measured his or her mental workload and situational awareness. We chose these measurements because they affect the participant's performance. A user will carry out a search operation more effectively if he/she is relatively tranquil and has a sense of presence within the explored environment. According to Susana Rubio, "In order to ensure the safety, health, comfort, and long-term productive efficiency of the operator, a reasonable goal is to regulate task demands so that they neither underload nor overload an individual [13].

2.3.2 *NASA TLX*

To measure the mental workload, the participant filled out NASA Task Load Index (NASA TLX). NASA TLX measures mental demand, physical demand, temporal demand, performance, effort, and frustration [13]. We chose to use this technique (versus SWAT) due to its sensitivity. When filling out the index the user needed to rate each section on a scale of low to high scale based on what he/she felt was the mental demand. Afterwards the user was asked to rate which sections were more important over the other sections.

2.3.3 *SART*

To measure situational awareness, we used the Situational Awareness Rating Technique (SART). SART tests the participant's knowledge of the environment in which the robot was sent [3]. SART is a subjective testing method that is applied after the task is finished. The other option which is more objective is Situational Awareness Global Assessment Technique (SAGAT) [3], but with that method we would need to stop periodically in the middle of the task. This would create confusion with the time pressure as well as breaking the concentration of searching for the lost items. The users were asked to rate the specific questions on a scale from 1to 7. The questions would assess how the user felt about the instability of the situation. Was the area and situation they were in unstable and involved frequent changes? It also asked about the complexity of the situation. How hard it was to complete the task? Also other areas it tested were awareness of the variability, arousal, concentration, division, capacity, info quantity, info quality, and familiarity.

3. RESULTS

The data was analyzed using a series of ANOVAs followed by Turkey's post hoc comparison tests. The results will indicate if the use of the different interfaces is significant in terms of hit error rate, mental workload or situational awareness.

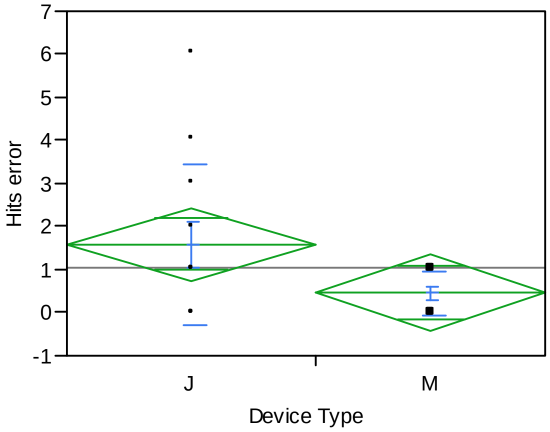

Figure 4. There is a significant difference in hit errors between the two groups.

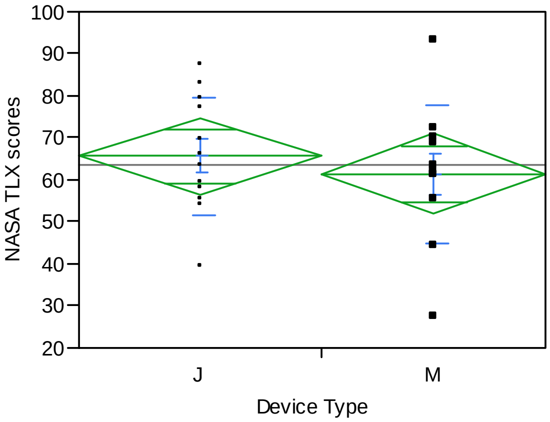

Figure 5. There is small significant difference in mental workloads between the two groups.

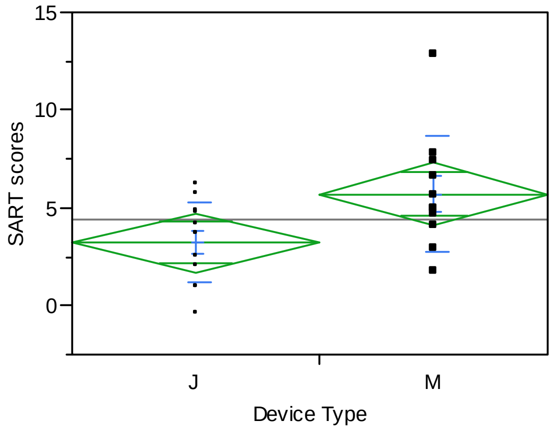

Figure 6. There is a significant difference in situational awareness between the two groups.

Figure 4 shows that 90% of the time, users with the multi-touch interface were less likely to hit obstacles in the field. There was no significant difference between the mental workload of the multi-touch and joystick groups (Figure 5), although participants using the joystick control were more frustrated than those using multi-touch (Figure 7). Figure 6 shows that 95% of the time, users with the multi-touch interface had a better environmental perception of the field than those with the joystick controller.

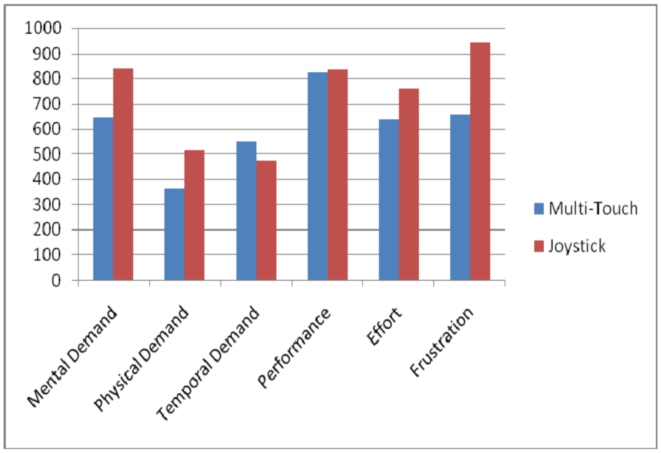

Figure 7. There were six different categories evaluated in measuring workload. Participants using the joystick control were more frustrated than those using multi-touch. However, they felt less pressed for time (temporal demand).

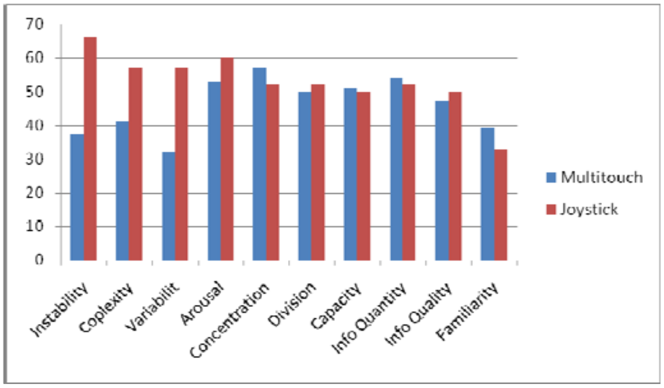

Figure 8. Ten different categories were evaluated during the assessment of situational awareness using SART. The first three categories (instability, complexity, and variability of the situation) are factors that hinder the user's performance. Participants using the joystick control were greatly affected by these factors while multi-touch participants seemed to handle these factors more successfully.

4. DISCUSSION

We expected for there to be a more defined difference between the mental workloads of the two groups. Chiefly due to the fact that our participants all had previous experience using joystick technology and as such would have achieved a level of comfort not present with a new multi-touch control system. However, in this experiment we found no significant difference between the two parties. We believe that this is due to the design of the multi-touch interface. The reason multi-touch interfaces are popular is they enable high degree-of-freedom interaction. Our multi-touch interface design contains a control at the bottom right corner (see Figure 3). This control actually limits the user's movements, which causes the experience to feel unnatural.

This experiment provides evidence that a properly designed multi-touch interface can increase situational awareness. As shown in Figure 8, the multi-touch interface decreased the affects of the factors that hinder responsiveness. This enhances the user's potential to learn the environment. We believe that this interface allowed movement of the robot to more closely match the intended movement of the user than did the joystick interface. Participants in the multi-touch group were able to rotate the robot in their desired direction while participants in the multi-touch group often rotated the robot in circles. Consequently, those using the multi-touch interface were able to avoid hitting trees and posts in the field.

4. CONCLUSION

Although this experiment shows no significant difference in mental workload of the two groups, data shows that the multi-touch interface is more effective in increasing situational awareness and consequently in increased task performance. Those who used the multi-touch interface were more aware of where they were in the field, even without a GPS system.

5. FUTURE WORK

Future work involves improving the design and aesthetics of the interface so that there aren't any controls confined to one area, limiting the degrees of freedom. Also an important issue that we will pursue is integration with differential GPS technology which will allow the user to know the exact location of the robot. A touch gesture will be made so that the user will be able draw paths and search patterns on the map to follow with the aid of GPS. Research will be done to create a gesture that is natural for navigating the robot. Another aspect is incorporating the robot's arm capability and performance capacity. Future research will also include creating an addition to the interface that allows the user more freedom with pan/tilt and zoom options for the camera.

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