PERFORMANCE IN A HAPTIC ENVIRONMENT

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ABSTRACT

For most computer users the human – computer interface is a visual environment in which the user depends on the sense of sight to interact with a graphical user interface. The most common device for interaction with a graphical user interface is the mouse. The user perceives objects in the environment visually and using hand-eye coordination moves the cursor to the desired object to interact with it. While a visual interface is sufficient for most human-computer interaction, the addition of other senses in the cognitive process of target selection can assist the user in making the selection decision. Our initial studies examine the use of a mouse in a haptically enhanced environment. A series of pilot studies have been completed to consider the feasibility and refine the experiments. The results of these pilot studies and future directions will be presented.

Keywords: haptic, mouse, performance, GUI, tactile

INTRODUCTION

The sense of touch has been used throughout time to augment sighted manipulations [2]. Today we still use the sense of touch to augment our day-to-day activities. For most users, typing is a sight-touch activity as we hunt and peck our way around the computer keyboard. When driving a car, the sense of touch tells us how much pressure is needed to turn the wheel a desired distance. Currently the human-computer interface provides a mostly visual environment for the user. A logical progression for human computer interaction is to add tactile feedback.

Many types of haptic devices have been developed over the past decade. Most of these devices are expensive and provide a large range of haptic interaction with the interface. The haptic glove provides the user with tactile feedback to the palm and all five fingers [8]. The Phantom by SensAble Technologies provides tactile feedback to one finger [6]. Braille boards provide blind users with a Braille interface for the computer [6]. The haptic mouse represents a simple group of haptic devices suitable for interaction with a Graphical User Interface (GUI). The differences among these technologies are in the range of tactile cues they are able to produce and the cost.

Definition: **Tactile feedback** is any feedback from a device that is perceived through the sense of touch. **Force feedback** is a form of tactile feedback that provides force vectors from the haptic device. The amount of force and the number of possible vectors can vary among devices.

Each tactile device will provide the user with a range of sensations. Suppose the user, when using a tactile device, encounters a virtual wall. Each device will provide a different sensation (tactile feedback) to the user. Wearing a haptic glove, the fingers would be immobilized in the direction of the wall. The Phantom would not allow motion in the wall's direction. The haptic mouse would vibrate as long as the cursor is in contact with the wall.

Many haptic mice are capable of a small range of vibrating tactile cues. The Logitech iFeel™ mouse is an inexpensive haptic device, costing less than one hundred dollars. With the development of an affordable haptic device, it has become a realistic augmenting technology for human computer interaction.

A haptically enhanced environment can provide increased targeting accuracy in a human computer interface [1]. The increased targeting accuracy caused by added haptic cues may make it possible to reduce the size of targets in a GUI. The benefit of reducing the size of target objects is to free up interface space for more targets or other uses. This research proposes to investigate targeting accuracy using a haptically enhanced mouse in an environment with objects of varying size.

BACKGROUND

A mouse enables a user to manipulate the computer environment through hand eye coordination. The user visually perceives objects in the environment and moves the cursor by applying pressure to the mouse until the cursor is over an object. The iFeel™ mouse provides tactile feedback in the form of vibrations, short bursts of force feedback in an upward vector, when the cursor is over haptically enhanced objects. This project investigates tactile feedback in a computer interface to determine additional benefits from its use.

Definition: **Targeting** is the act of moving a cursor to a desired object by controlling the mouse in a GUI.

It has been shown that haptic environments can be created that benefit targeting in a GUI [1]. Oakley [6], Oakley [7], and Adams [1] have all found improved targeting when using a Phantom in a GUI. Oakley [6] enhanced several buttons each with a different haptic effect to study targeting accuracy, Oakley [7] enhanced menus with haptic effect to study distractions, and Adams [1] designed an entire haptic environment to study environmental stability and the haptic effect. However, results of the research have been inconclusive when considering other factors such as speed and fatigue [6].

Use of a Phantom requires the user to hold their hand in an unnatural position. The hand is suspended in the air without any support and the finger inserted into the device. The unnatural hand positioning required by the Phantom render targeting results from experiments performed by Oakley [6], Oakley [7], and Adams [1] unusable in an everyday GUI.

Most haptic devices, while capable of a wide range of tactile cues, provide an unfamiliar interface to the user. Haptic mice, although limited by a reduced range of tactile cues, can produce similar targeting results as other haptic devices. Use of a haptic mouse will minimize the factors that can lead to reduced productivity (movement time) and fatigue (from the unnatural hand positioning) in devices like the Phantom or the glove. Oakley[6] even suggests the possibility of a haptic mouse to solve these problems.

> Definition: Any **object** (icon, button, menu item) in a computer interface is a **target object** if the user's goal is to select that object. **Targeting Accuracy** is the successful selection of a target object. **Targeting Performance** is the time taken for the user to move the cursor from the starting location until they *correctly select* the target object.

Rarely will a computer interface contain a single object. A normal interface has many objects that a user may select by clicking the mouse. In a haptically enhanced environment, each object will cause tactile sensations for the user when the cursor intersects with that object. Because not all objects in the environment are target objects at the same time, several issues arise:

1. Is targeting accuracy enhanced by the tactile effect?
2. Is targeting performance enhanced by the tactile effect?
3. Will the user be confused or distracted as the cursor passes over an object on the way to the target object?

Most research into haptically enhanced targeting has found increased targeting accuracy in the haptic tests [6][1][7]. A targeting error occurs when the user clicks on the mouse and there is no target object below the cursor. There are three possibilities for this type of error:

1. The cursor can be over empty area. (Figure 1a)
2. The cursor can be over another object in the environment. (Figure 1b)
3. The user could have had the cursor correctly positioned over the target object and then missed the target object in one of the two previous manners, called a **slide over error** [6]. (Figure 1c)

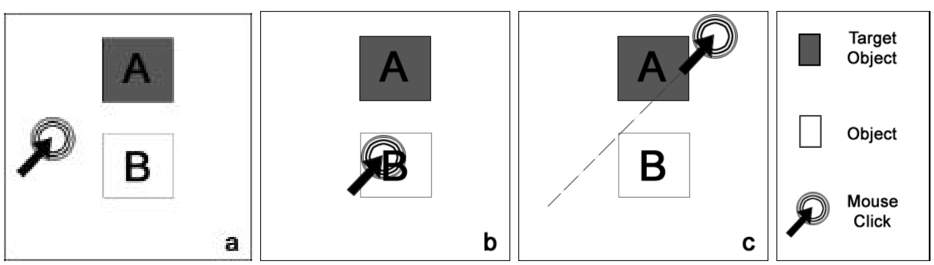

Figure 1 – Error Categories

a) mouse click in blank area b) mouse click on non-target object c) slide over error

There are an many possible causes for a slide over error; the user becomes distracted during the selection process, dirt on the mouse pad disrupts the user's motion, the screen flickers at the time of selection, just to name a few. The addition of haptic cues to an interface creates the possibility of a new slide over error caused by haptic feedback. In the case of vibrating feedback, the mouse could vibrate the pointer off of the target object before selection. Therefore this research will track the number of slide over errors in order to determine the effect of haptic cues on user error.

Fitt's Law describes the relationship between movement time and difficulty when targeting an object [5]. Fitt found the difficulty targeting an object is related to the size and distance of that object from the starting location. The smaller or more distant an object the harder targeting becomes. In addition, he found it takes longer to successfully target smaller or more distant objects.

Definition: **Movement time** (MT) is the time taken to move the mouse cursor from its starting location to a target object.

Fitt's developed the following relationship for movement time:

$$\mathbf{MT = a + b\ ID} \qquad \mathbf{(1)}$$

where

1. **ID** is the Index of Difficulty for the target object.
2. **a** and **b** are the intercept and slope of their relationship.

The Index of Difficulty may be calculated using the equation:

$$\mathbf{ID = \log(2D/W)} \qquad \mathbf{(2)}$$

where

1. **D** is the distance to the target object from the starting location.
2. **W** is the perpendicular target width in the direction of the movement.

A normal GUI interface contains many objects of differing size and location; therefore, the user will experience the Fitt effect [5].

The remained of this paper will describe a pilot study administered to students in the computer science department at the University of South Alabama. The study attempted to identify any flaws in the experimental procedure, time collection, or learning effect.

PILOT STUDY

The test environment consists of a Pentium based computer running Windows, a mouse (either haptic or normal), and a 17" monitor. The subject is asked to sit in front of the computer, eyes level with the monitor, and place their hand on the mouse for the test to begin. The test subjects for the experiment will be computer science students from the University of South Alabama.

Each experiment in this study employs control and experimental groups of subjects. Each pair of subjects will be randomly assigned to either the control or experimental group by flip of a fair coin. The number of subjects assigned to each group will be kept equal by waiting until two people have agreed to participate in the experiment, then flipping a coin to determine to which group each is assigned. Accordingly, subjects are directed to a computer that is configured with either the control or experimental interface.

The test interface will consist of a GUI frame containing three types of objects:

1. Buttons will serve as target objects in the environment and will vary in number according to the experiment.

2. A box object will serve as the starting location for each trial.
3. A text area that displays instructions and comments to the subject.

A target object will be designated randomly from among the other objects in the environment by changing its color. As each button becomes a target, it is removed from the algorithm as a possible target to eliminate the chances of identical targeting tasks.

Two identical interfaces will be developed using Java 1.3.1 and the Touch Sense Developer Toolkit from Immersion Corporation. The control group will navigate the interface with no haptic effect. The experimental group will navigate the interface that has the haptic effect.

Data collection for each experiment will be of two types: targeting accuracy and movement time. The movement time is the interval between the time the cursor leaves the mouse starting location and the time the subject makes a selection. The targeting accuracy will be recorded as a Boolean value of true if the selection is on the target object and false if it is not. Because Java does not provide a high-resolution timer JNI was used to incorporate the high-resolution timer provided by the Windows operating system to achieve a granularity of 2ms.

The overall results computed and presented consisted of the average total time, average decision time, and average accuracy for each group for each experiment. These preliminary results of this pilot study will be discussed in the next section.

RESULTS

The average times will be presented. Future administration of the experiment on a larger scale will allow for statistically viable conclusions from the data. A larger group will also allow for study of other factors such as distractions and size reduction.

Table 1 displays the averages for the three experiments of the pilot study. There were fifteen participants for each group.

DISCUSSION

The results of this pilot study will be used to adjust the experiments for future administration. These results will also assist in the evaluation of the timing instrument used to time the responses, however a granularity of 2ms for the timing device seems reasonable. The small sample size does not allow for the complete comparison and analysis desired. Additional statistical analysis will also be performed on the improved experiment. However, these preliminary results do provide some interesting insight on the use of a haptic mouse.

Experiment one consisted of five buttons of 40 X 40 pixels at an equal distance from the starting location. Each button in the environment was targeted once. The average accuracy of the experimental group was slightly greater than that for the control group, average decision time was significantly less for the experimental group when compared to the times from the control group, and the average total times were less for the experimental group. The results of experiment one show an increase in performance from the use of a haptic mouse when targeting objects of a normal size.

Experiment two consisted of twelve buttons of 40 X 40 pixels arranged in an array of 3 X 4 buttons. Each button in the experimental environment was enhanced with haptic feedback. Only buttons within the array were targeted maximizing the chances of the participant crossing non-target buttons on the way to a target object. These results show very little difference between the groups. It is possible the small sample size for the pilot study resulted in un-usable data from this experiment.

Experiment three consisted of five buttons of 40 X 40 pixels at an equal distance from the starting location. Each button in the environment was targeted once per trial. There were four trials and each trial the size of the button was reduced by fifty percent. The average accuracy for the experimental group was lower than that of the control group for each trial. The final trial with a button size of 5 X 5 pixels resulted in the greatest difference in the average accuracy. One possible cause of this lower accuracy could be from the hapic effect itself as described earlier in the paper. However, decision times for the experimental group in all four trials was lower than that of the control group showing positive results when considering decision times using a haptic mouse.

When the results of the pilot study are viewed all together a positive trend for decision times can be seen. In each of the experiments a trend of lower decision times is apparent, however the results of the accuracy averages show little or negative trends for the haptic mouse. A larger sample size will be used to determine if these trends are statistically feasible.

Table 1 - Results

2ms Granularity	**Haptic**	**Control**	**Haptic Improvement Diff ms**
Exp 1			
Accuracy	4.92	4.85	0.07
Decision Time	208.76	291.15	-82.39
Total Time	927.76	1068.12	-140.36
Exp 2			
Accuracy	5.92	5.78	0.14
Decision Time	217.93	225.07	-7.14
Total Time	883.41	909.08	-25.67
Exp 3			
Trial 1			
Accuracy	4.76	4.92	-0.16
Decision Time	220.73	239.59	-18.86
Total Time	830.88	880.20	-49.32
Trial 2			
Accuracy	4.61	4.92	-0.31
Decision Time	203.48	250.31	-46.83
Total Time	908.42	1026.47	-118.05
Trial 3			
Accuracy	4.53	4.78	-0.25
Decision Time	181.95	229.16	-47.21
Total Time	1045.58	1111.09	-65.51
Trial 4			
Accuracy	3.84	4.14	-0.30
Decision Time	157.00	245.92	-88.92
Total Time	1076.78	1148.16	-71.38

FUTURE RESEARCH

The long-term goal of this research is to determine the accuracy and decision benefit from the use of a haptic mouse. This initial work is being used to fine tune the experimental process and determine if the granularity of the measuring device is low enough to measure the differences between the two groups.

Haptic devices are currently in use around the world. Most haptic devices are expensive and bulky. The haptic mouse is the same size as a non-haptic mouse and is relatively inexpensive. Once the haptic effect can be identified it will be possible to apply that effect to enhance anything from day-to-day activities to specialized tasks. The ultimate goal of this research is to identify what the haptic effect is in a measurable fashion.

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