Cursor Control Trace

Another look into eye-gaze, hand, and eye-hand pointing techniques

Ricardo Sol
Exact Sciences and Engineering Centre
University of Madeira
9000-390 Madeira, Portugal
rsol@alumni.carnegiemellon.edu

Mon-Chu Chen
M-ITI, Madeira Interactive Technology Institute
University of Madeira
9000-390 Madeira, Portugal
monchu@uma.pt

José Carlos Marques
Exact Sciences and Engineering Centre
University of Madeira
9000-390 Madeira, Portugal
marques@uma.pt

***Abstract*—We analyzed cursor control trace with respect to three cursor control methods: eye-gaze, hand, and eye-hand. First, we look into the mechanism that allows users to control cursor positions by hands and/or eyes. Second, we conducted an experiment in which subjects perform a searching, pointing and selection task in three different conditions (eye-only, hand-only, and eye-hand). Third, we further studied the cursor trace and analyzed the moments when users switch between eye-gaze-control and hand-control. Although different from a simpler Fitt's pointing task, our results mostly corroborate previous work. In addition, the cursor traces analysis further shows why eye-hand is more efficient, and how users progress from an inefficient pointing behavior to an optimal one.**

Keywords; pointing; accuracy; gaze; eye; tracking

I. INTRODUCTION

Hands move slower than eyes. Therefore having eye tracking instead of manual input as an interaction mechanism in digital devices can make interactions faster. However, the eye trackers developed so far have numerous drawbacks. First, current eye trackers are not precise enough to accomplish common tasks on applications or websites. Next, these systems have a delay in processing gaze position and calibration. A third problem is the 'Midas touch', a problem identified by Jacob in 1991, that occurs because it is challenging to distinguish a selection task (for example, a click) from the search task, using a purely eye-gaze approach [2]. Eye pointing is also typically associated with fixation (dwell) but this action is not stable and shows jitter.

In order to address these issues, in 1999 Zhai et al. presented Mouse and Gaze Input Cascaded (MAGIC), a technique that uses a combination of gaze and manual input [8]. First, the user uses gaze to dynamically redefine the position of the cursor. After the cursor position is redefined the user then makes a small manual input action to select the target.

The advantages of MAGIC are that it reduces manual stress and fatigue. In addition, MAGIC pointing is faster than just manual pointing. It must be noted however, that because the cursor movement is faster while controlled by the eye, the user may perceive all action to be faster even when it is not. For example the manual selection time might take longer, so overall the tasks might not be accomplished faster although the user may perceive them to be so.

MAGIC has two approaches. In the first approach, referred to as the liberal approach, the cursor moves directly over (in front of) the target that the users looks at. In the second approach, the conservative approach, the cursor moves to the boundaries of the target.

Zhai et al conducted experimental validations of the MAGIC technique. These experiments were conducted with a miniature isometric pointing stick [8]. The experimental task was basically a Fitts' pointing task. The factors manipulated in the experiment were: target size, target distance, and direction. Each subject performed the task with 3 techniques: no gaze, liberal, and conservative. The liberal technique was found to be faster and preferred by users.

While the MAGIC technique addresses some of the problems of preceding gaze input mechanisms, it is not without its drawbacks. For example, with MAGIC's liberal technique the cursor movement can be overactive, which could be distracting when reading. With MAGIC's conservative technique the user might tend to activate the cursor manually.

Our broad research goal is to improve input techniques. In this work, our contribution adds to previous work by analyzing the trace before, during, and after that manual activation, and we try to find patterns in these traces.

II. RELATED WORK

In 2000 Salvucci and Anderson presented their intelligent gaze-added interfaces [6]. They addressed accuracy problems that we also face. In their work, any target positioned where the users' eye gaze is, is a highlighted target. Then a gaze key gives the user the chance to trigger the action. The system uses a probabilistic algorithm to try to guess the targets the user will look at.

In 2003 McGuffin and Balakrishnan showed that expanding targets facilitates the pointing task [4]. Their results show that working with expanding targets can be accurately modeled by Fitts' law. They have also shown that targets that expand just as the user is about to reach them can be acquired approximately as fast as targets that are always in an expanded state. They specifically found strong evidence that the user performance is consistently aided by

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the target expansion. Similar to how we hypothesize for our work, they found that the performance is dependent on the final target size.

In 2005 Miniotas and Spakov used an expansion of targets visible to the users [5]. To facilitate pointing they used dynamic target expansion for fixing the calibration of the eye tracker. This technique has 91% accuracy, a result not expected in our work. The drawback of this technique is an increase in selection time.

In 2005 Ashmore and Duchowsky refined a fisheye lens to support eye pointing [1]. They simply hid the lens during visual search and obtained improvements in speed and accuracy. Fisheye interaction was evaluated by a visual search, and a Fitts' pointing. Unlike MAGIC pointing, where the cursor was rapidly moved to the vicinity of one's gaze prior to mouse movement, here the lens is directly slaved to gaze position. Important to our work is their finding that in combined tasks it is impossible to distinguish the precise amount of time that search consumed prior to selection.

In 2007 Kumar et. al presented EyePoint. EyePoint uses expansions of interactive targets, and uses a key for input [3]. When the key is pressed the gaze area is enlarged. When the key is released the selections are made according to where the eye gaze is. Similar as we hypothesize for our work, they found that it is possible to divide appropriate interaction techniques that use gaze without overloading the visual channel.

III. METHOD

A. Participants

The experiment was performed on 10 participants with normal or corrected-to-normal vision. All participants were regular computer and mouse users. All participants had used track pads.

B. Tasks

Three conditions (eye-only, hand-only, and eye-hand) were presented that required searching and selecting one target. In the hand-only condition the participant used the track-pad to move the cursor until it was over the target. In the eye-only condition the participant used eye-gaze to move the cursor until it was over the target. In the eye-hand condition the participant used eye-gaze and the track-pad to move the cursor until it was over the target. The target consisted of a white vertical rectangle with a plus signal in its center. This rectangle could alternate in size (2% or 4% of the screen width), and distance to the center along the screen's horizontal central axis (45% or 90% of half of the screen width), giving a total of four different possibilities. The target also alternated between sides of the screen. Each trial had one distractor with the same characteristics as the target without the plus signal. All trails started with the cursor located at the center of the screen as in Fig. 1 and Fig. 2. All trails finished with the participants pressing the space key while the cursor was over the target. Each trial had a maximum amount of time, 5 seconds, and if this expired without pressing space while on the target, the task failed.

C. Apparatus

Participants used a track-pad to complete the task (Apple Magic Trackpad).

The experimental computer ran Mac OS X version 10.7.4 and was connected to Tobii TX300 Eye-tracker. The system allowed for unconstrained head motion by seating participants approximately 65 cm (adjusted by Tobii studio running on a PC) in front of the Eye-tracker 23 inch screen (resolution 1920 x 1080 pixel). With this system the sample rate was 300 Hz.

Figure 1. Initial display of a trial that has the target (right side) with the biggest size at the farthest distance.

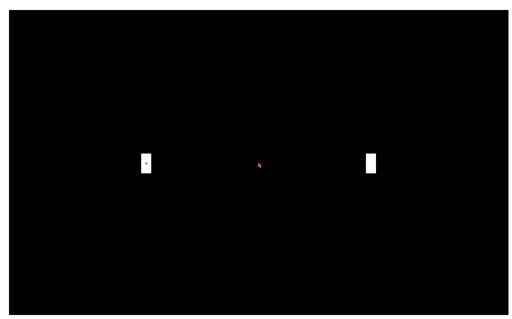

Figure 2. Initial display of a trial that has the target with the smallest size at the closest distance.

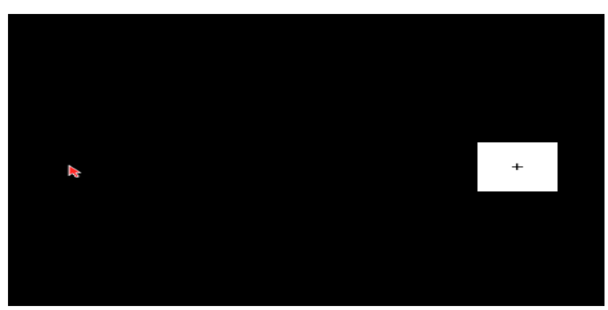

Figure 3. A zoom in of the initial display of a trial that has the target with the biggest size at the closest distance.

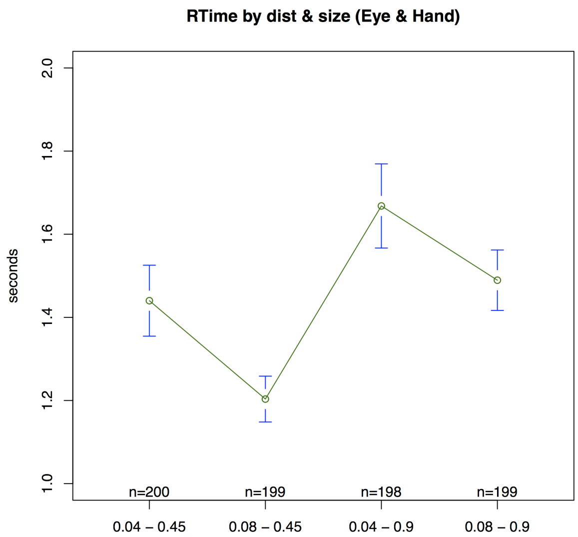

Figure 4. One trial of one task presented to the users. In this case the target is small and is farther from the cursor's original point.

D. Procedure

The user was first asked to sit in a non-mobile chair. Then the distance of the eyes to the screen was adjusted and the user was asked not to make large movements with his head and torso. After this, it was necessary to calibrate the user's gaze to the system. This calibration was made by having the user looking each time for 3 seconds to a dot that appeared in 9 different pre-selected positions of the screen. Before data collection, the conditions and task were explained, and unlimited time to practice with the 3 conditions was given. The data collection started with the conditions ordered randomly. Each participant then carried out 80 trials for each condition. Each experimental session lasted around 45 minutes including pauses between conditions.

IV. Results

Our results show that Eye-only is significantly faster than Hand-only solely when the target has the largest size and is at the farthest distance. The variance of the response time is always higher in Eye-only. Eye-only has a hit on target rate of 72%. That is, participants successfully accomplished the task within the limit of 5 seconds in only 72% of the trials in the Eye-only condition. These hits on target were lower in the smallest size and farthest distance condition.

The results also show that Eye-with-Hand is the significantly fastest solely when the target has the largest size and is at the closest distance. The variance of the response time in Eye-with-Hand is higher than in Hand-only and lower than in Eye-only, as Figure 4 shows. Eye-with-Hand has a hit on target rate of 99.50%. This is similar to Hand-only that had a hit on target rate of 99.75%.

Our results also show the trace of each trial for Eye-with-Hand. In Figure 5 we can see an early trial trace. This user is not yet sufficiently familiarized with eye-gaze control. The target is situated in the right side of the screen, that is 0.9 on the vertical axis. The user first briefly looked to the left and immediately changed direction to the right and changed it again to the left all way. Then the user changed control to the hand bringing the cursor to slightly right of the center. The users' finger then reached the right extremity of the track pad, so the user released the finger, passing automatically to the control of the eyes. The user subsequently acquired control with the track pad bringing the cursor to the extreme right of the screen. Then the users' finger reached the right extremity of the track pad, so the user released the finger passing automatically to the control of the eyes. The user then looked to the center and had to repeat the process twice, failing to press space while the cursor was on top of the target, and not completing the task in the defined time.

In the trial in Figure 6, the user started looking to the left and then looked to the right. 1 second after the beginning, the user started controlling the cursor with the hand and moved the cursor to the target and at 2.1 seconds pressed space.

In Figure 7, the user started looking to the left and then looked further to the left, then looked back to center, and back to the left again. 1.4 seconds after the beginning the user started controlling the cursor with the hand, moved the cursor to the target and at 2.4 seconds pressed space.

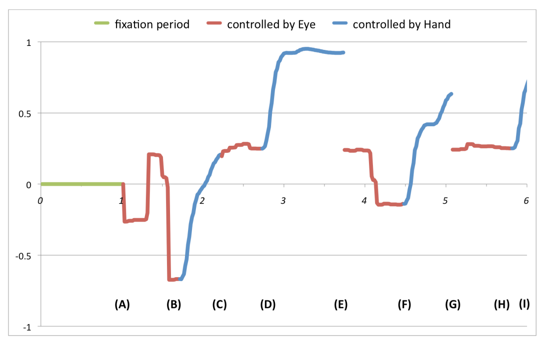

Figure 5. Eye control and Hand control shown over Time as a function of Distance. Early trial.

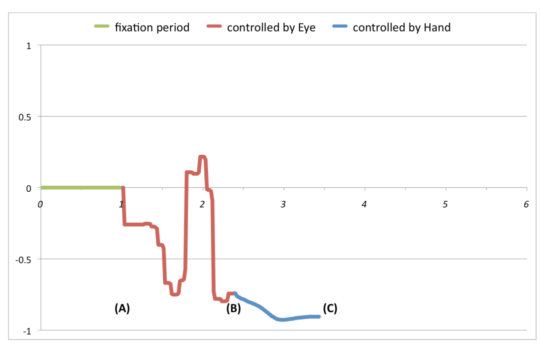

Figure 6. Eye and Hand control over Time as a function of Distance.

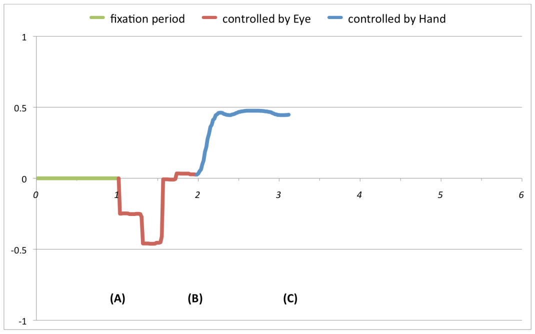

Figure 7. Eye control and Hand control shown over Time as a function of Distance.

V. CONCLUSION & FUTURE WORK

We show support for MAGIC by stating with confidence that in at least in one condition, the Eye-with-Hand condition, the performance was faster. An explanation for this could be that this system had a more optimized transfer function for the movements. Another factor contributing to this could be the more optimized parameters in the gaze system's filter. In addition, we used a more recent eye-tracker as compared with those used in previous work and is therefore expected to be more accurate.

Eye-gaze control is a novelty for users. Users' lack of experience with eye-gaze can introduce delays in the control action. It is expected that with the dissemination of eye-tracker these delays can diminish. However, controlling the cursor with Eye-gaze can give the user a sense of speed.

The results help to further understand how people progress to master controlling cursor using the combination of the eye-gaze and mouse.

We foresee that having a relatively short constant time for hand control will decrease the time taken to reach the target. More distance will be traveled during the fastest control, which is the control by the eye. We foresee that both, eye and hand control conditions are governed by Fitt's Law. We intend to perform more experiments in order to confirm this.

Some users considered having the cursor in the gaze position distracting. While in MAGIC's conservative approach the cursor stays in the boundaries of the target, this can still be a distraction. One potential solution for this problem might be to decrease the cursor's opacity.

In a pointing task, having the cursor in the eye-gaze might not be so distracting. In a selecting task this distraction can be higher. However, it is during reading that we expect to find the cursor in the eye-gaze to be most distracting. In future work, we intend to perform further experiments in order to confirm these hypotheses.

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