Head and eye movement as pointing modalities for eyewear computers

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***Abstract*—While the new generation of eyewear computers have increased expectations of a wearable computer, providing input to these devices is still challenging. Hand-held devices, voice commands, and hand gestures have already been explored to provide input to the wearable devices. In this paper, we examined using head and eye movements to point on a graphical user interface of a wearable computer. The performance of users in head and eye pointing has been compared with mouse pointing as a baseline method. The result of our experiment showed that the eye pointing is significantly faster than head or mouse pointing; however, our participants thought that the head pointing is more accurate and convenient.**

Keywords*—*Gaze tracking, Eye pointing, Head tracking, Head pointing, Head-mounted display, Wearable computing.

I. Introduction

Advances in hardware and software technologies has resulted in developing new generation of eyewear computers, such as Google Glass and Vuzix smart glass, and it seems feasible that eventually these unobtrusive eyewear devices play role in everyday tasks. However, design for wearable devices is associated with a lot of known and unknown challenges. An important design challenge of interactive wearable computers is the need for novel interaction techniques since the classical WIMP desktop metaphor do not support users mobility. That is the reason why other alternative interaction metaphors, such as Personal Assistant [1], has been introduced for interactive wearable computers.

Head-mounted display is one of the main components of an eyewear computer which means the wearers of these devices need to interact with graphical user interfaces. Interaction with standard graphical user interfaces involves pointing at the object of interest and selecting the object. Some suggested interaction techniques that use hand for pointing are often inconvenient for mobile settings and sometimes require external devices like smart phones, joysticks or hand-held point-and-click devices [2]. Hand gestures recognized by a front-view camera or other wearable sensors have also been used as a mechanism for interaction with wearable devices [3]. However, for a mobile user, hands-free interaction is a big advantage in many situations.

Head and gaze-based input mechanisms are two modalities that can be useful for situations that prohibit the use of the hands, such as when the users' hands are disabled or occupied with other task. These two techniques are among the less-explored hands-free pointing mechanisms for the eyewear computers.

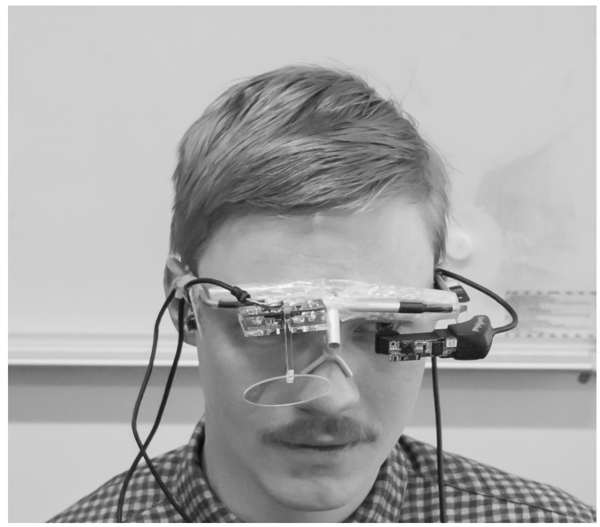

Fig. 1. A subject wearing the eyewear setup including the gaze tracker (tracking the right eye) and a HMD on the left eye. A head tracker sensor is mounted on the right side of the Glasses frame.

In this paper, we investigate the possibility of using head and gaze movements as a pointing mechanism for wearable computers through an experiment. In the experiment, participants were asked to point and select different targets on a head-mounted display by moving the head, gaze, or a mouse trackball.

II. Related Work

Using the eye gaze as a source of input has long been a topic of interest in HCI and it is due to the fact that humans naturally tend to direct the eyes toward the target of interest [4], [5], [6], [7]. In fact, gaze pointing is one of the possible ways of pointing, and the typical use of gaze as a pointing mechanism is to control the cursor position on the screen. Gaze pointing has also been used for interaction with head-mounted displays [8], [9].

Head movement is another possible way of controlling the cursor on the screen and can be measured through a camera [10], [11] or other wearable sensors [12], [13]. Moreover,

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Fig. 2. The hand-held finger mouse used in the experiment

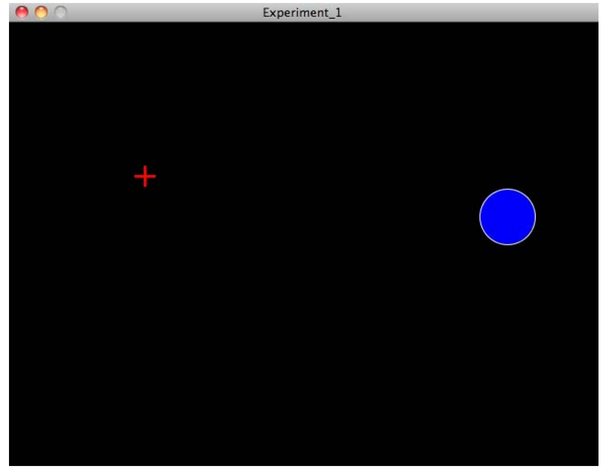

Fig. 3. A screen shot of the system: the blue circle is a 60 pixels width target, and the red cross is illustrating the pointer. By moving the pointer over the target the color of the target changes to red and the user clicks on the target.

head gesture has been used as an input modality in upcoming eyewear computers, such as Google Glass. But to the best of our knowledge, using head movement as a pointing modality is not investigated for wearable computers.

Bates and Istance [14] investigated the usability problems associated with eye and head-based pointing for direct manipulation on a standard graphical user interface. They compared the quality of interaction using these two input modalities during an interaction task.They found that an eye mouse is generally faster than head mouse and it could exceed the performance of a head mouse if target sizes were large and users sufficiently well practiced. While previous works have explored the eye and head pointing for stationary screens, the focus of our paper is to evaluate eye and head pointing for head-mounted displays (HMD).

III. Experiment Design

Given the known challenges of using WIMP desktop metaphor techniques for wearable computers, in this paper, we investigate whether gaze and head tracking methods can be used as a viable alternative to classical techniques such as mouse for pointing purpose. To answer this question we conducted an experiment to measure the user performance using a head-tracker, a gaze-tracker, and a mouse given the same pointing task.

IV. Method

A. Participants

8 participants (mean age = 32, no female) were recruited among local university students to participate in the experiment. Most of the participants were highly skilled computer users ($\bar{X} = 4.87$, $\sigma = .35$, where the range was 1 to 5), and all of them had perfect visual acuity. All participants were experienced hand mouse users; however, only two of them were used to use the finger hand-held mouse (see Fig. 2) . Also three participants had the experience of using gaze-tracker.

B. Apparatus

In order to examine head and gaze movement as an input modality for eyewear computers, we developed a wearable prototype including a gaze tracker, a head tracker, and a HMD connected to an ordinary MacBook laptop (see Fig. 1). The HMD was a MicroOptical SV-9 (640 $\times$ 480 pixels), and the head tracker sensor was a Sparkfun Razor (9DoF) including accelerometer, gyroscope, and magnetometer sensors. The size of the HMD was about $15 \times 10mm$ and the average distance between the eye and the HMD was about $35mm$. For tracking gaze, we used a custom-built hardware platform including a small infrared camera and a hot mirror reflecting the infrared light back to the camera to capture eye image. Gaze tracking is done by the open-source Heytham gaze tracker [15].

C. Procedure

The experiment started with a short introduction to the purpose of the experiment and the use of the apparatus. To keep the physical condition of the participants equal for all conditions, all of the participants were asked to wear the whole device during all conditions; however, they did not need to use all components in each condition. After participants were prepared for the experiment, they were asked to use the system until they felt comfortable. This usually took 2-3 minutes for each condition. Then each participant was asked to complete the task in three different conditions. The task was selecting the targets displayed on the HMD by using gaze-pointing, head-pointing, and mouse-pointing. The targets were blue circles with three different diameters of 60, 80, and 100 pixels displayed on a black background one after each other (see Fig. 3). The pointer was illustrated by a red plus which could be moved by moving head, eye, or trackball of the mouse. When the pointer was on the target the color of the target changed from blue to red and users had to click on the target. After the experiment, the users were asked to complete a short questionnaire with 5-point likert scale questions polling their experiences completing the task and using the system. The experimental setup was randomized to balance conditions and avoid the order effect. The conditions in which the task was completed were as follows:

1) Gaze pointing: Gaze tacker needed to be calibrated prior to the start of each trial. The calibration procedure required the user to look at 9 points shown in the HMD. After calibration, participants completed the task for 24 targets (8 instances of 3 different sizes) by moving the eye.

2) Head pointing: Before starting the task using head movements, the head tracker needed to be calibrated to set the starting position of the pointer in the center of the screen when the head of the user was in the neutral position (facing straight ahead). After a short warm-up trial, participants accomplished the task for the targets similar to the gaze pointing condition.

3) Pointing with the mouse: As a base-line condition, the participants were asked to complete the task using a hand-held finger mouse (Fig. 2) which is typically used for wearable computers.

D. Design

The experiment was an 8 × 3 within-subjects design, and each participant completed all above-mentioned conditions in one experimental session that lasted for approximately half an hour. Aside from training the amount of entry was: 8 participants × 3 conditions × 3 target size × 8 repetition = 576 trials.

V. Result

A. User performance

We recorded the task completion time and the number of wrong selections (errors) for each pointing and selecting task. The average speed of each pointing was calculated based on the distance between the departure point and the target divided by the task completion time.

In total, we had 192 samples for each condition. A one-way between subjects ANOVA was conducted to compare the pointing speed for each target size in different conditions. There was a significant difference at the $p < .05$ level for all 9 groups of trials (three conditions × three target widths) [F(8, 567) = 12.005, $p < .05$]. Also for each target group the user performance was significantly different in each condition: for the target size of 60 pixels [F(2, 189) = 4.87, p = .008], for the 80 pixels target [F(2, 189) = 3.70, p = .02], and for the 100 pixels target [F(2, 189) = 6.71, p = .001]. Post hoc comparisons using the t-test indicated that the pointing speed in gaze condition was significantly higher than head and mouse conditions for all targets (see Fig. 4). However, there was no significant difference between head pointing and using mouse.

As illustrated in the Fig. 5), the accuracy of the eye pointing was less than other conditions, but the statistical tests indicated no significant difference between error rates in the different conditions.

B. Questionnaire

From the questionnaire, 5 out 8 participants preferred using the head pointer over the eye-tracker and mouse since they found it easier to point with head ($\bar{X} = 4.12$, $\sigma = .99$) than eye pointing ($\bar{X} = 3.62$, $\sigma = .74$) and using mouse ($\bar{X} = 3.87$, $\sigma = 1.12$).

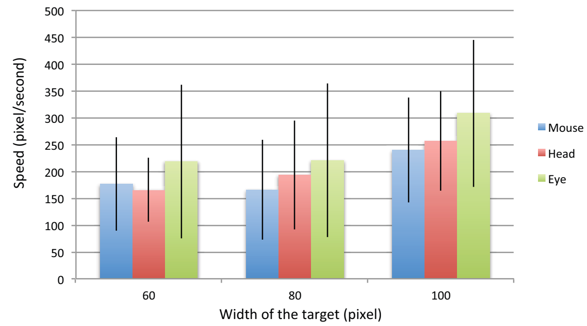

Fig. 4. The speed of completing the task for different sizes of the target.

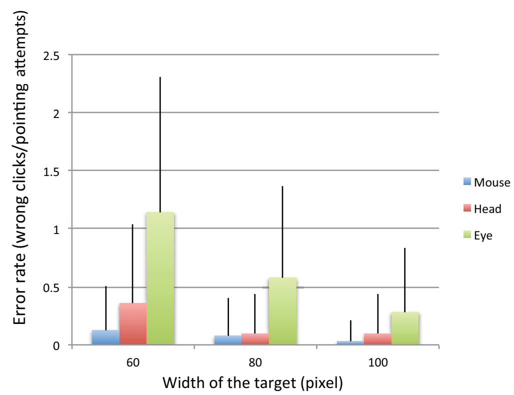

Fig. 5. The accuracy of completing the task for different sizes of the target.

VI. Discussion

In this paper we compared the performance of three different input modalities (mouse, gaze, and head) as a mechanism for pointing while interacting with a HMD. These three input mechanisms can be compared in terms of speed, accuracy and comfort. However, there are some differences between gaze pointing and head or mouse pointing that somehow makes it difficult to compare the gaze modality with the others. The main difference is the fact that the user can look at the target or the cursor while moving the cursor with either mouse or the head movements. This provides the user a visual feedback which is needed for the target acquisition. However, this is not the case with gaze pointing. With the gaze pointing the cursor always follows the user's gaze point and the user always sees the cursor at his/her fixation point. Therefore, the target acquisition can be very fast compared to the other pointing methods. Our experiment also showed the higher speed of the gaze pointing; however, we observed less accuracy in gaze pointing in comparison with head and mouse pointing. Since gaze tracking is inherently not a highly accurate pointing mechanism [16]. This means for eye-pointing to the small targets the user needs to keep looking at the target for a long time or correct the error by moving the eye which decreases the convenience of eye pointing method. The result of our questionnaire also indicated the lower user acceptance of the eye pointing compared to the other methods.

An important challenge of using camera-based gaze trackers for monocular head mounted displays is the fact that the pointer eye is mostly covered by the head mounted display, so that we need to track the other eye. In our experiment, the gaze-tracker was used in the right eye regardless of the dominant eye of the participants. This might also be another source of error for the gaze tracking approach.

Another critical issue with using gaze as an input modality for eyewear computers is that head-mounted eye trackers have the maximum accuracy of about 0.5 degrees and this limits how small the display can be and how small targets can be selected.

Regarding the low accuracy of the gaze trackers specially for small HMDs, one possibility to improve the user acceptance can be using the eye pointers for big targets on the graphical user interfaces.

Unlike the gaze tracking, the head pointing is a relatively stable approach for pointing (see fig. 5). That is probably why most of our users preferred the head pointing method to other approaches. Another advantage of using head movements as an input modality for eyewear computers is availability of the inertial sensors in most of the existing commercial products such as Google Glass and Vuzix smart glass while to track the eye we usually need additional hardware and software platforms. However, the mass of the head can reduce the speed of pointing, and it can be tiring for the neck muscles [14].

VII. Conclusion

In this paper, we compared two input modalities for eyewear computers: eye pointing and head pointing. Our experiment showed that the eye pointing is significantly faster than head pointing and pointing with hand-held mouse; however, head pointing is more accurate and convenient for users.

As a future work, we will repeat the experiment after improving the hardware platform. In the next wearable prototype, an eyewear computer (Vuzix smart glass) will be mounted in front of the dominant eye which is tracked by the gaze tracker. Furthermore, in the next step we will try to combine the gaze and the head tracking mechanisms so that the pointing can take advantage of both speed of the eye-based approach and the accuracy of the head tracking.

VIII. Acknowledgement

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