Setting That Mouse for Tracking Tasks

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Abstract. A pointing device plays an important role in human-computer interaction. The computer mouse is a convenient device for both pointing and steering. The literature related to the effect of mouse gain on steering tasks is scarce. An experiment was conducted with 10 participants and each participant was asked to traverse a constrained path using a computer mouse. There were three levels of gain approximately equal to 2.3, 10, and 15. The experiment had 11 levels of difficulty (D/P) based on path width (P) and path length (D) and three trials for each combination of D and P. Performance was evaluated using movement time taken to traverse the path. The results showed that movement time is minimized, in feedback-controlled steering tasks, at a gain of around nine.

Keywords: Pointing devices, Mouse, Gain, Drury's Law, Steering Law.

1 Introduction

1.1 Mouse as an Input Device

The computer mouse [1, 2] is a popular pointing device even today for different types of human-computer interaction tasks. Without a pointing device such as a mouse, the computer would have not been a device that would have been easy to use. The major functionality of the mouse is mapping human hand movements on a 2D plane to a computer screen. In modern graphical user interfaces, the more common mouse related tasks are pointing the cursor or moving the cursor through a constrained path. Human performance in pointing tasks has been studied by Fitts [3] and his results have been applied in many human-computer interaction related settings [4, 5].

1.2 Movements in Constrained Paths

The model (equation 1) for movements in constrained paths was proposed by Drury [6] and it has been widely known as the steering law [7-10].

$$\text{Movement Time} = a \times (\text{Index of Difficulty}) + \text{b} \quad (1)$$

V.G. Duffy (Ed.): DHM/HCII 2013, Part II, LNCS 8026, pp. 276–281, 2013.

where a and b are constants and the Index of Difficulty is defined with respect to path length (D) and path width (P),

$$\text{Index of Difficulty (ID)} = \frac{\mathrm{D}}{\mathrm{P}} \quad (2)$$

Equation (1) only holds for large ID values where visually controlled hand movement is required [11]. If the path width is relatively large, then the task can be completed in an open-loop manner where smooth pursuit eye movements are not required. Thibbotuwawa et al. [8, 9] showed that movements are ballistic when the ID is less than 8 to 10. Furthermore, for ballistic tasks, the model of movement time changes to that given in equation (3).

$$\text{Movement Time} = a' \times \sqrt{\mathrm{D}} + \mathrm{b}' \quad (3)$$

where a' and b' are constants.

1.3 Mouse Gain

Gibbs [12] determined that the gain (G) of a joystick, defined as the ratio between displacement of display pointer to movement affects movement time as follows:

$$\text{Movement Time} = 0.91 - 0.02 \times \frac{1}{G} \quad (4)$$

However, Buck [13] and Arnaut et al. [14] showed that device gain does not have any effect on movement time. Jellinek and Card [15] observed a U-shaped variation for movement time with mouse gain in pointing tasks. However, they claimed that movement time should not have any effect on input device gain explaining that mouse resolution and the small space available contributed to the U-shaped curve. In 2001 Accot and Zhai [16] reported that Index of Performance (IP) given by equation (5) has an inverted U-shape curve with gain, and IP is a maximum when gain is between two to four.

$$\text{Index of Performance (IP)} = \frac{1}{\text{Gradient of equation (1)}} \quad (5)$$

However, they have used a graphics tablet and therefore the optimum gain value may not be applicable for an optical mouse. This experiment is an attempt to determine the gain for a mouse that minimizes movement time in steering tasks.

2 Method

2.1 Participants

Five right-handed males and five right-handed females were participants in the experiment. They were undergraduate and graduate students of the Hong Kong University of Science and Technology. On average, participants used a computer mouse 4.1 hours per day. They did not have any disabilities or defects in their hands or vision that might affect performance. Participants were paid HKD 50 for their time.

2.2 Equipment

The task was to move the mouse cursor through a constrained path. The tracking software was developed using C++. The software also recorded all mouse clicking events and cursor positions with a software timer. A Logitech G9X high precision optical mouse on a gaming mouse pad and an Acer T232HL LED display with a screen resolution of 1920×1080 was used. The display was positioned at a 60^0 upward angle from the horizontal plane.

2.3 Experimental Design

The experiment was a within-subject design with mouse Gain and ID as independent variables. The experiment was run for eleven IDs, four of which were ballistic tasks, and the other seven were visually controlled tasks based on the Thibbotuwawa et al. [8, 9] classification. Each Index of Difficulty had two combinations of Path Length (D) and Path Width (P) ratios. Therefore, there were twenty-two experimental conditions. Each participant completed a practice trial of forty-eight conditions followed by three experimental trials with each trial having twenty-two random conditions. These conditions were performed for mouse gains of 2.3, 10, 15 in a random order for each participant.

2.4 Procedure

Prior to the experiment, participants were asked to adjust the monitor brightness and chair position to a comfortable level. A rectangular path with a black circle on the left-hand side was presented to the participant (Fig. 1) and he/she was instructed to click on the black circle to initiate and steer through the path towards the end as fast as possible. If the cursor touched the border of the path, it was considered as an error and that condition was repeated at the end of the twenty-two conditions. The participant had no time pressure in any condition. Participants were given a 10-minute break when changing from one mouse gain to another.

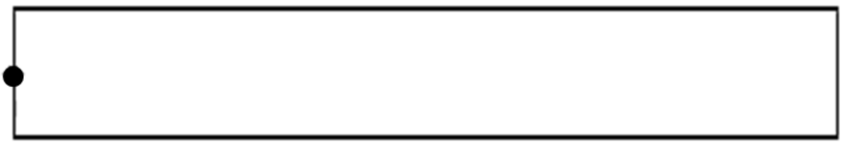

Fig. 1. A sample path

3 Results and Analysis

A repeated measure ANOVA was performed, separately, for the ballistic and visual control task. For visually controlled tasks, Gain and (D/P) were significant (Greenhouse-Geisser probability, $F(1.586, 14.277) = 11.505$, $p < 0.005$; $F(1.110, 9.9987) = 40.041$, $p < 0.001$). For Ballistic tasks, Gain and $\sqrt{D}$ were significant (Greenhouse-Geisser probability, $F(1.273, 11.456) = 14.697$, $p < 0.005$; $F(1.088, 9.791) = 36.187$, $p < 0.001$).

The data for ballistic tasks and visually controlled tasks were regressed separately (Fig. 2 and Fig. 3).

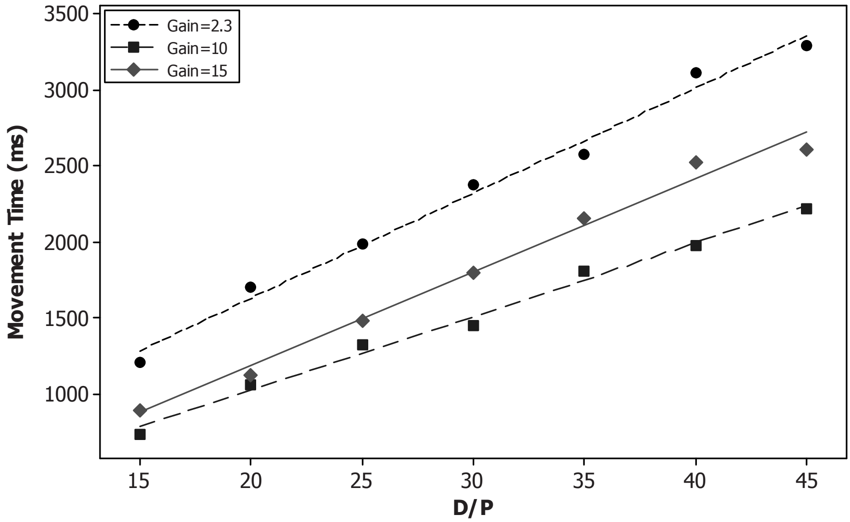

Fig. 2. MT vs (D/P) relationship for visual control tasks

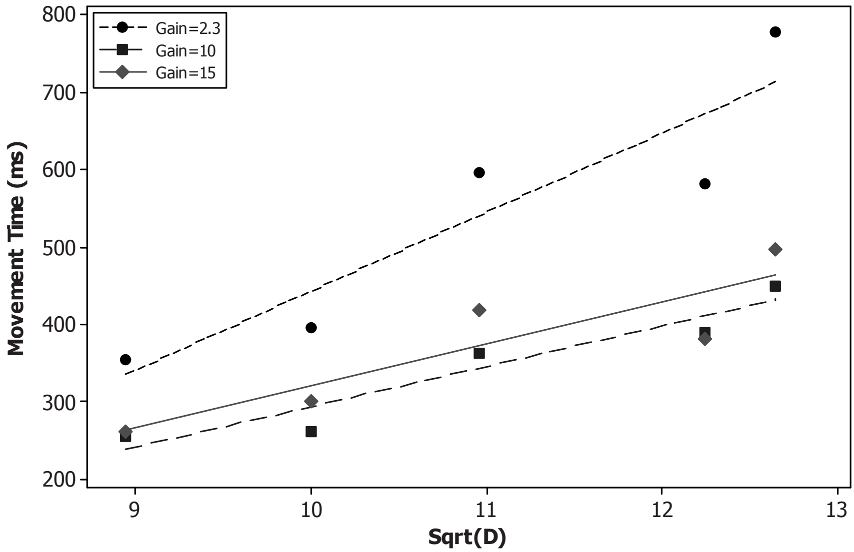

Fig. 3. MT vs $\sqrt{D}$ relationship for visual control tasks

The Gradient of each line in the visually controlled tasks was plotted against mouse gain as shown in Fig. 4. The fitted quadratic curve is given in equation (6). The minimum of the curve was calculated, and it is at a gain of 9.4.

$$\text{Gradient} = 0.416 \times (\text{Gain})^2 - 7.788 \times (\text{Gain}) + 84.623 \quad (6)$$

4 Discussion and Conclusions

It was found that movement time for all levels of Index of Difficulty varies depending on the mouse gain (equation 7). The minimum movement time is at a gain of around 10.

$$(\text{MT})_{\text{Gain}=2.3} \geq (\text{MT})_{\text{Gain}=15} \geq (\text{MT})_{\text{Gain}=10} \quad (7)$$

The results support the idea of a U-shaped curve for steering tasks. Further, it can be concluded that the Index of Performance is maximum when the mouse gain is around 9.4. This particular level of gain of a mouse that minimizes movement time in steering tasks appears to be different from that found for a graphics tablet [16].

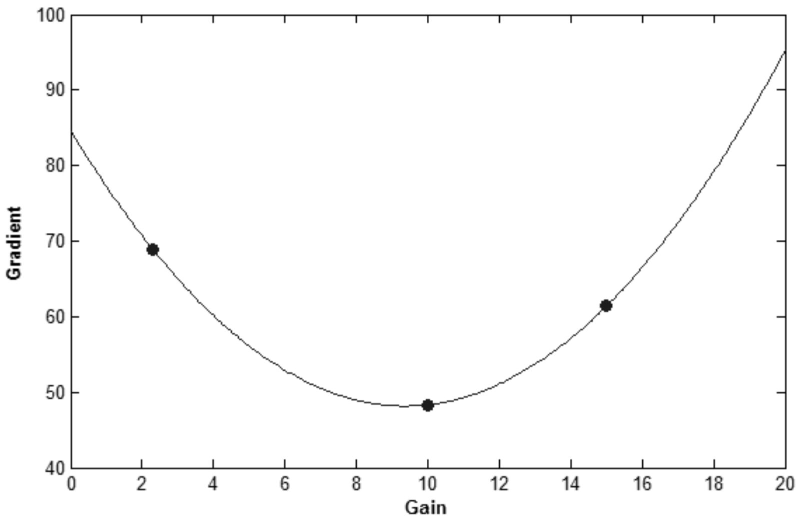

Fig. 4.

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