The Movement Time and Optimal Control-Display Ratio of Foot-Controlled Isotonic Mouse

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Abstract
This paper experimentally derived the optimal control-display ratio and the expected movement time of the foot-controlled isotonic mouse that positioning was controlled by a right pedal and clicking was performed by a left pedal. The results showed that both the index of difficulty and the control-display ratio varied the total movement time in a target acquisition task on the monitor. The optimal control-display ratio 0 was 3.76 in the index of difficulty below 3.0. The results could be used in design of a foot-controlled isotonic mouse for the arm-impaired users.

Keywords: Foot-controlled mouse, Control-display ratio, Isotonic device

1. Introduction
Although mouse is one of the fastest positioning devices [1, 2, 3, 4, 6, 7], it is not available for the arm-impaired computer users.

Interesting foot-controlled interfaces are following. By adding a momentary foot switch, Mohamed and Fels [8] introduced the Look Ma No Keyboard user interface, an intuitive method for music sequencing control software from a piano controller. Stanton et al. designed tangible interfaces to the KidPad collaborative drawing tool in order to support the reenactment of stories to audiences. The interface, called magic carpet, used pressure mats and video-tracked and bar-coded physical props to navigate a story in KidPad. Yin and Pai[11] presented an intuitive animation interface, called FootSee, that used a foot pressure sensor pad to interactively control avatars for video games and animation.

Although the previous studies suggested useful foot-operated interfaces, they did not investigate the optimal control-display(CD) ratio of the foot-controlled mouse. CD ratio is the ratio of control displacement divided by cursor displacement.

This paper suggested the foot-controlled isotonic mouse that positioning was controlled by a right pedal and clicking was performed by a left pedal and experimentally derived the optimal CD ratio over the index of difficulty (IOD) below 3.0. The results could be used in designing a foot-controlled isotonic mouse for the arm-impaired users.

2. Experimental apparatus
The foot-controlled isotonic mouse in this experiment consists of two parts (Figure 1), a left pedal (260mm long × 120mm wide) and a right pedal (260mm long × 110mm wide). The right pedal controls positioning. An ordinary optical mouse was embedded beneath the right pedal. Subject can move cursor by moving his or her right pedal on the floor. For easy movement, four casters were attached at the four corners of the right pedal respectively. The sliding friction coefficient of the right pedal was 0.09. A belt was employed and tightened to prevent the possible slip between the right foot and the right pedal.

The left pedal carries out the clicking. This paper employed a foot pedal made by Digital Hunter™. Pressing toe of the left pedal is identical to pressing the left button of the ordinary hand mouse. Unlike fingers, it is difficult to use toes individually. So, it can be said that it is a useful alternative to employ the left pedal as a click switch[9, 10].

The monitor size is 370 mm × 280 mm with the resolution of 1280 pixels × 1024 pixels. The distance between subjects and the monitor is about 500 mm.

3. Experiment
Ten subjects who had used computers for more than 3 years participated in the experiment (6 male and 4 female, aged 20-30). For the adaptation to the foot-controlled mouse, each subject had 60-minute practice session per one day and continued these practices for 7 days. The learning curves was stabilized after 5 days for all subjects.

The independent factors were control-display ratio and index-of-difficulty. The levels of control-display ratio were 0.67, 1, 2, 2.5, 3.3, and 5. Pre-test showed a strong possibility that the optimal control-display ratio
could lay in this region.

Figure 1. Foot-controlled isotonic mouse (left pedal for clicking, right pedal for positioning)

280 mm

90 mm

The levels of IOD were set to 0.1, 1.7, 2.3, and 3.0. The size (height or width) of most icons or pull-down menus is greater than 7 mm. So, IOD from Fitts’s equation seldom exceeds 3.0 if movement distance is below 270 mm. Therefore, it could be said that most IOD of icon-selecting task is below 3.0.

Experimental procedure was as follows. A subject sat in front of the monitor and put his or her feet on the two pedals respectively. Figure 2 shows the monitor screen with a rectangular experimental area of 280 mm × 280 mm. Home of 10 mm diameter was located in the center of experimental area. First, using right pedal, subject was instructed to position the cursor (cross hair) on the home position. A target appears on the experimental area as soon as the subject clicks the toe of the left pedal. The subject then moves the cursor to the target and clicks the toe of the left pedal as quickly and accurately as possible. If the cursor is located within the target and click is occurred, the movement time is measured with the accuracy of 1/100 second. Movement time is from the time a target appears to the time the target is selected.

Then the subject moves the cursor to the home position and proceeds to the next trial. If the cursor is located outside the target when click is occurred, a beep sounds and an error is recorded.

The IOD of a target is randomly generated out of 1.0, 1.7, 2.3, and 3.0 by the software. This IOD determines the diameter of the target and the distance between home and the center of target. The target appears at an angle of 0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315° from the center of home.

All subjects participated in all 28 combinations of CD ratio (6 levels) × IOD (4 levels). There were 48 replications at each combination. So, the total number of trials were 11,520 (10 subjects × 6 CD ratios × 4 IODs × 48 replications). The experimental procedure was completely within subjects design.

Movement time consists of travel time (fast movement from home to vicinity of target) and adjustment time (microscopic movement that hits the target). Small CD ratio shows small travel time and large adjustment time, and large CD ratio shows large travel time and small adjustment time. The optimal CD ratio is the CD ratio that has a minimal movement time.

Experiment software was coded Visual Basic™. The software automatically recorded the subject’s identification number, IOD, CD ratio, and movement time for each trial.

4. Results

The data was analyzed on the subject means. As expected, ANOVA showed significant effects on movement time of CD ratio, F=13.9, p<0.001, and IOD, F=381.5, p<0.001. The interaction between CD ratio and IOD was not statistically significant, F=1.89, p>0.05.

For clarity of visual inspection and interpretation, the figure connects data point with lines, even though the categories are discrete. Figure 3 presents mean movement time across seven CD ratios for each of four IODs. It shows that mean movement time increases as the IOD increases.

In Figure 3, the optimal CD ratio stayed around CD ratio of 3.3 for each of four IODs. So, it can be said that the optimal CD ratio is not sensitive over IODs.

When people perform an acquisition task on the monitor, it can be said that the IOD is not chosen by people, but given by the characteristics of the task. Therefore it is desirable to suggest one optimal CD ratio over IODs.

Table 1 shows the mean movement time as a function of CD ratio of 2 to 10 only. CD ratio smaller than 0.5 was far from optimum and was not included. The mean movement time was regressed onto the CD ratio. The 2nd order regression model fitted Table 2 best (Equation 1). Equation 1 explains 98.14% of variance in the average movement time. (i.e., r²=0.9814)

The CD ratio that minimizes the Equation 1 is around 3.76. Therefore, the optimal CD ratio of the foot-
controlled isotonic mouse is 3.76 in target acquisition task with IOD below 3.0

Movement time (msec) = 1868.3 - 495.36 × (CD ratio) + 65.581 × (CD ratio)^2

where R² = 0.9814  <Equation 1>

Figure 3. Movement time of the foot-controlled isotonic mouse

Table 1. Mean movement time of the foot-controlled isotonic mouse for CD ratios

| CD ratio | 0.67 | 1.0 | 2.0 | 2.5 | 3.3 | 5.0 |
|----------|------|-----|-----|-----|-----|-----|
| movement time | 1602 | 1384 | 1150 | 1072 | 924 | 1034 |

5. Conclusion and Discussion

This paper suggested a foot-controlled isotonic mouse of which the cursor was controlled by the right pedal and the clicking was performed by the left pedal. Both IOD and CD ratio significantly varied the movement time in a target acquisition task on the monitor. The optimal CD ratio was not sensitive over IODs. Therefore, this paper proposes 3.75 as an optimal CD ratio for the menu or icon-based software of which IOD falls below 3.0.

The foot-controlled isotonic mouse is similar to the slide mole[9] in that the right foot controls the cursor in Cartesian coordinate and the left foot clicks the button. Pearson and Weiser[10] showed that the mean movement time of the slide mole was 5.1 seconds for 6.0 IOD(The IOD was calculated by the present author from their experimental condition since they only referred target size and distance between home to target). Comparing the study with the present study, Pearson and Weiser investigated the optimal CD ratio for IOD of 6.0 and the present author derived optimal CD ratio for IODs below 3.0, which is more frequent in menu or icon-based target acquisition task.

This paper also showed that mean movement time of the foot-controlled mouse was 0.92 seconds at the optimal CD ratio of 3.75 for IOD below 3.0(Equation 1).

These results could be used in designing a foot-controlled isotonic mouse for the arm-impaired users. Further study would include the frequently used technique such as ‘double clicking’ and ‘drag & drop’ task.

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