Calculation of Effective Target Width and Its Effects on Pointing Tasks

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Technical Note

Calculation of Effective Target Width and Its Effects on Pointing Tasks

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Using effective target width (W_e) in Fitts' law has been widely used for evaluating one directional pointing tasks. However, concrete methods of calculating W_e have not been officially unified. This paper concentrates on resolving this problem. A specially designed and controlled experiment is described. The results reveal that the method of mapping all the abscissa data into one unified relative coordinate system to do calculation is better for modeling human computer interfaces than dividing data into two groups according to corresponding target sides and mapping them into two separate coordinate systems.

1. Introduction

Fitts' law[3] is a well known model for evaluating one directional pointing tasks in human-computer interactions (HCIs). The relationship between movement time (MT) and the index of difficulty (ID_e) described in Eq. (1) is a widely used form to model Fitts' law[1),6),7)].

$$MT = a + bID_e \tag{1}$$

$$ID_e = \log_2\left(\frac{A}{W_e} + 1\right) \tag{2}$$

A is the amplitude between the centers of two rectangular targets, and W_e is called the effective target width, which indicates the range of actual input hits around the target based on participants' behaviors. The Fitts' law model expressed by Eq. (1) has been accepted by ISO standards 9241-9[4].

Although the Fitts' law model has been used widely in HCI and advocated by many researchers[6], it is still under suspicion[10]. One problem is that the calculation of W_e has not been unified.

In Eq. (2), $W_e = 4.133SD$. SD is the standard deviation for the distribution of hits. Some researchers, such as Douglas, Kirkpatrick, and Mackenzie[2], have used one unified coordinate system to calculate the average x-coordinates to obtain SD. We have called this method the Combined-Coordinate-system (CC) in this paper. Some researchers have used two sets of coordinate systems to calculate the average x-coordinates to obtain SD, as Isokoski and Raisamo did in their study[5]. In this way the average x-coordinates need to be calculated separately for a left or right coordinate system. This method is referred to as the Separate-Coordinate-system (SC) in this paper.

However, there have been no comparisons of concrete methods to calculate W_e to date even in ISO standards 9241-9[4]. Moreover, no research has been reported on preferable methods of calculating W_e for application to the Fitts' law model, either. We therefore compared two methods to see which was better for calculating W_e. This knowledge should be of great help for further applications of Fitts' law to the HCI field.

2. Experiment

To analyze and compare the two methods of calculating W_e accurately, we developed an experiment that could produce a set of time measurements when participants fully complied with given target widths to an extent that was almost ideal (W_e matches W within 7% margin).

2.1 Subjects

Ten volunteers, five males and five females (average 28.8 years old), participated in this experiment.

2.2 Apparatus

A desktop PC with a color LCD monitor produced by Eizo FlexScan L567 (338 mm (W) × 270 mm (H)) was used in this experiment. The resolution was 1,024 × 768 pixels. One pixel equaled 0.264 mm. The input device was the Microsoft Wheel Mouse Optical 1.1 A.

2.3 Design

Similar to Fitts' paradigm experiment[3], our participants reciprocally pointed with a mouse to a pair of vertical strips with a fixed distance A of 400 pixels. W (appointed target width) was set at 10, 14, 20, 28, and 40 pixels. If the region outside the target was tapped, the task would not be abandoned. Instead an auditory

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signal would be played as a warning signal. The start position for the cursor was the center of the screen.

We used a method of enforcing target width inspired by Zhai, et al.'s verbal feedback [8),9)] to obtain data when subjects fully complied with the target width. By observing the ideal input hits distribution, we could see whether the Fitts' law model could accurately model the pointing task by using either method to calculate W_e.

If participants during the experiment took too many risks and created a large SD and hence a big W_e, the program would remind them to slow down. In contrast, if W_e was very small, the program would remind them to hurry up. If their current endpoints dispersion corresponded to an ideal ($W = W_e$ within 7% margin) [9)], the participants could maintain their current pace.

2.4 Procedure

We used the following variations on the two methods to calculate SD and control the programs for CC and SC.

The program for the CC calculated the SD based on one coordinate system (see **Fig. 1** (b)). This meant that the standard deviation (SD) could be calculated by:

$$SD = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} \qquad (3)$$

In Eq. (3), x_i was the ith of the participant's selection point's x-coordinates (they were mapped into one unified coordinate system), $\bar{x}$ was the mean of x-coordinates, and n was the number of trials.

The situation for SC was more complex. The program calculated SD based on two sets of coordinate systems (see Fig. 1 (c)). The steps were: first, compute the average for the left and right x-coordinates for the past 14 trials (or less than this before the 15th trial). Second, obtain the x_i-$x_{average}$, ($i = 1, 2 \cdots n, n \leq 14$). Here, x_i is the ith hit's x-coordinate and $x_{average}$ represents the average values for x_i. Then, there should be 14 numbers for x_i-$x_{average}$ ☆. The next step was to obtain the SD for the 14 (x_i-$x_{average}$)s, if x'_i=x_i-$x_{average}$, then

☆ One notable point here is that for the left and right side hits, the values of $x_{average}$ were different. Therefore, x_i-$x_{average}$ should be written as $x_{i_{left}}$-$x_{average_{left}}$ for left side hits, and x_i-$x_{average}$ should be written as $x_{i_{right}}$-$x_{average_{right}}$ for right side hits. Here, we used x_i-$x_{average}$ for convenience.

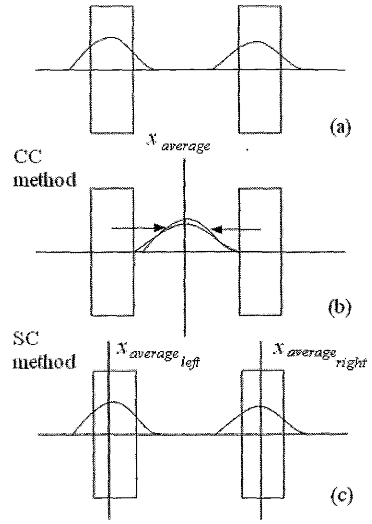

Fig. 1 Two methods for effectively calculating target width. ((a) indicates distribution of hits for left and right targets. (b) indicates using CC to map all dots into one combined coordinate system to calculate average SD and W_e. (c) indicates using SC to calculate average SD and W_e with two separate coordinate systems.)

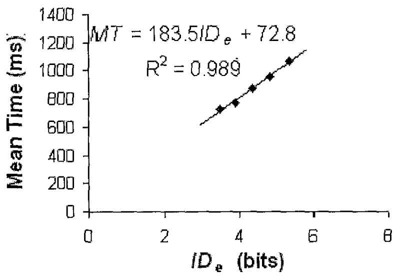

Fig. 2 Regression between mean time and ID_e using CC.

$$SD' = \sqrt{\frac{\sum_{i=1}^{n}(x'_i - \bar{x}')^2}{n-1}} \qquad (4)$$

2.5 Results and Discussion

We collected data and made the Fitts' law regression lines in **Figs. 2** and **3**.

The R^2 in the regression line for CC is nearly 1 (0.989), which means using this method makes the regression in Fitts' law ideal and strong. The regression in Fitts' law line in Fig. 3 is still large (0.909), but not as great as indicated by Fig. 2. This means that SC is not as good as CC.

Since the system in the experiment gave immediate responses to subjects in all trials, performance was almost ideally controlled. Therefore, the regression between mean time and ID_e

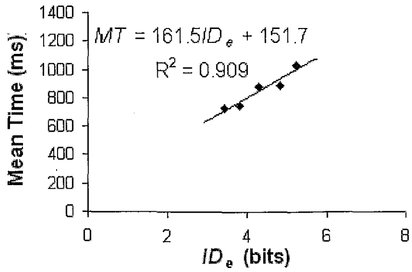

Fig. 3 Regression between mean time and ID_e using SC.

should be rather strong. From this point of view, however, the regression in Fitts' law line in Fig. 3 (related to SC) is not strong enough.

3. Conclusion

We studied and compared two methods of calculating W_e. The results revealed that CC was better than SC, i.e., it was a better way to map all the abscissa data into one unified relative coordinate system to do calculation, and did not divide data into two separate groups according to corresponding target sides.

Moreover, calculation with CC is also much easier and more convenient than with SC.

The data presented in this paper enable a detailed and reliable comparison of the two methods for calculating W_e based on knowledge about input hits with different target sizes. This study should help to develop a standard for application to effective target width.

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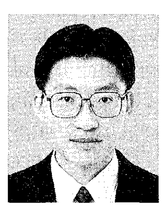

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