Line Drawing Perceptual Characteristics for the Number of Strokes Using an Active-Wheel Mouse

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***Abstract*—This paper reports perceptual characteristics for multiple line-drawings using an "*active-wheel mouse*" and employing an "*After-Recognition Go*" presentation strategy. The active-wheel mouse is a mouse interface to which a finger-tactile interface is attached. The finger-tactile interface embodies an active wheel being rotatable in any directions, with any speeds and with any time durations, and the rotation provides slippages to users on their fingertip skin. Users are instructed to accept the slippage stimuli as straight-line stroke motions with specific directions, velocities and lengths. A perceptual experiment was conducted: up to seven, straight-line strokes were presented to subjects, i.e., participants by the active-wheel mouse, and the strokes were drawings reproduced by the subjects. Next, the reproduced strokes were evaluated from the viewpoints of lengths, directions, velocities, and time durations. As a result, it made clear that the active-wheel mouse worked well for line drawing presentation.**

Keywords— Fingerpad; tactile; interface; stroke; perception

I. INTRODUCTION

Visually impaired persons utilize sensations other than the vision such as skin and proprioceptive sensations. For example, some handy-and-portable devices were proposed. For instructing arm motions, Tsuda et al. [1] and Causo et al. [2] proposed vibrotactile device. Norman et al. [3] proposed skin-stretch device. Gwilliam et al. [4] proposed a skin stretch-based tactile display in conjunction of a joystick-based force feedback, and Koslover et al. [5] combined a skin stretch-based tactile display with vibrotactile and voice guidance. Ion et al. [6] proposed a tactile display to drag a physical tactor across the skin for instructing geometrical shapes. Tsagarakis et al. [7] proposed a slippage display to rotate two cones for instructing 2D directions. Moscatelli et al. [8] proposed other slippage display to rotate a ball for instructing 2D slippages.

They provided motion information with tactors. However, they could not solve following problems: ① the number of physical properties to be presented was restricted in such the way that motion direction can be presented alone, ② the operating range was restricted in several millimeters. As a solution for the problems, the authors have presented an "Active-Wheel Mouse (AWM) [9]" and an "After-Recognition Go (ARG)" presentation strategy [11].

Towards a practical application of the AWM, we should know better the line-drawing perceptual characteristics. The perceptual characteristics can be evaluated by the outcome, that is, the reproduced strokes resulted from a series of processes from the stimulus perception, stroke recognition, and memory-retention. In this study, the perceptual characteristics were examined for multiple-stroke line-drawings up to seven strokes through a psychophysical experiment. The remainder of the paper is structured as follows. The hardware and software of the system employed in this work are explained in Sections II, i.e., the authors' developed AWM, a line-drawing-stroke presenting strategy. Next, a stroke perception experiment follows the system descriptions. Practically, in Section III, perceptual characteristics of simple patterns of 1-, 3-, 5-, and 7-strokes are presented. The paper closes with a conclusion and remarks for further developments.

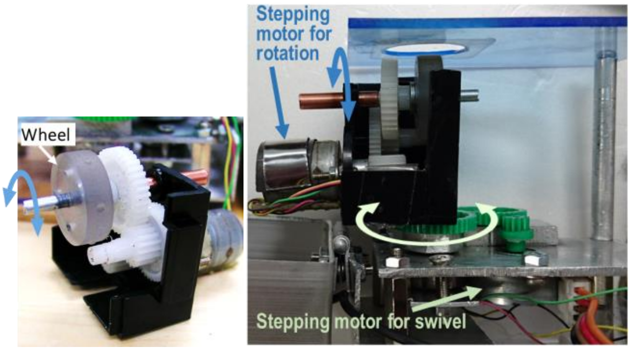
II. METHOD

This section describes a hardware and software, i.e., a mouse interface and a line-drawing stroke presenting strategy.

A. Active-Wheel Mouse

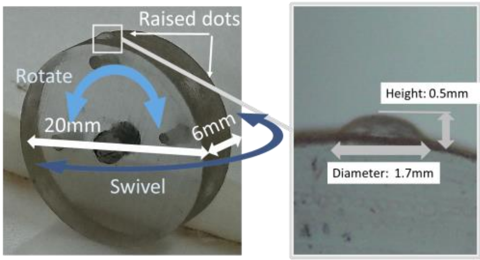
An "Active-Wheel Mouse (AWM) is a renovated mouse interface: at the front of a mouse interface, a Finger-Tactile Interface (FTI) is attached as shown in Figure 1. In the FTI, a wheel is swiveled and rotated by two stepping motors (M15SP-2N and M25SP-6NK by Mitsumi Electric Co., LTD., Tokyo, Japan) as shown in Figure 2. The rotation and swivel provide a slippage on the user's fingerpad with a velocity and time-duration: the velocity together with the time duration results in a slippage length. The wheel has a diameter of 20 mm and a thickness of 6 mm (see Figure 3). On the wheel peripheral surface, raised dots are formed to enable slippage perception [9]-[11]: as for the raised dots, the height is 0.5 mm, and the diameter of the bottom circle is 1.7 mm. The dot interval was about 10.5 mm so that dots appear one by one on the fingerpad, which makes the slippage perceived [12][13].

Figure 1. Active wheel mouse (AWM): the finger-tactile interface (FTI) is attached at the front



(a) Rotation mechanism (b) Finger-tactile interface in total

Figure 2. Finger-tactile interface: reduction gear ratio for rotation: 6.5, that for swivel: 3.5



(a) Wheel (b) Raised dot:

Figure 3. Wheel configuration: raised dots were designed, based on the Japanese Industrial Standard (JIS) for tactile graphics

B. *After-Recognition Go Stroke-Presenting Strategy*

Multiple strokes were learned through two recognition stages as shown in Figure 4: (1) the first stage is for whole line segment patterns (i.e., motion loci), and (2) the second stage is for velocity variations (i.e., motion trajectories), in particular, the velocities were changed stepwise. In either case of the first or second recognition stage, the "After-Recognition Go stroke-presenting Strategy (ARG-S)" [14] was employed in presenting each of the strokes as in the following.

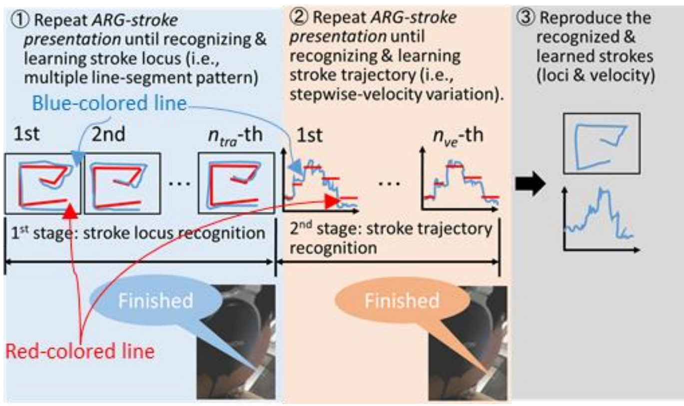


Figure 4. Two recognition stages for learning multiple-stroke loci and velocities.

[Step 1] Subjects hold the mouse in their right hand. Then, they touch the wheel upper peripheral surface from above with their index-fingerpad.

[Step 2] Finger-tactile interface swivels the rotating unit to a given direction and rotates the wheel with a given velocity and time duration: the velocity and the time duration determine a rotation angle. (See Figure 5 ①)

[Step 3] While accepting the slippage stimulus, the subjects recognize the stimulus as a line segment in the 1st stage and as a constant velocity movement in the 2nd stage. (See Figure 5 ②)

[Step 4] The subjects drag the AWM so as to reproduce subjects' recognized motion. (See Figure 5 ③)

[Step 5] The subjects memorize the drag motion as a stroke. (See Figure 5 ④)

[Step 6] Just after memorizing stroke, the subjects send a signal by pressing a button by their left finger.

[Step 7] Return to [Step 2] till all the strokes are presented and memorized.

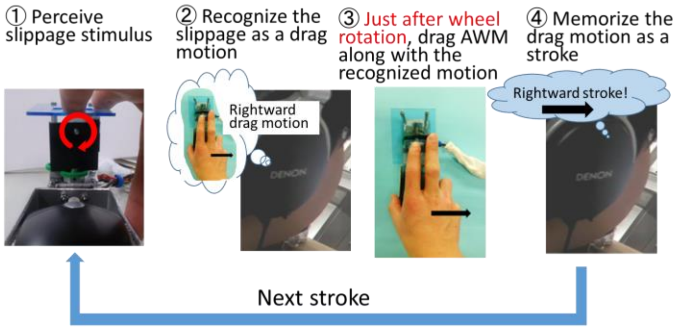


Figure 5. After-Recognition Go stroke-presenting Strategy (ARG-S).

III. Stroke Perception Experiment

This section describes a stroke perception experiment and presents line-drawing perceptual characteristics in relation to the number of strokes.

A. *Experimental Conditions*

Ten healthy right-handed males in their 20s (22~24; mean=22.6; SD=0.9) participated. The line drawings presented were from single to seven straight-line strokes (See Figure 6.). All the strokes were made by constant-velocity straight-line motion. The factors, i.e., the length, speed, direction and stroke-number and the factor-levels are shown in TABLE I. For each of the runs, the factor levels were randomly chosen, provided that corner angles are more than 30 deg.

TABLE I. Factors and Factor Levels Used for Experiment

Factor	Factor level
Subject	10 males
Presentation strategy	After-recognition go
Presented stroke drawing	8 drawings in total: 2 patterns for each of 1-, 3-, 5-, and 7-stroke drawings
Length	50, 66, 83, 100 mm
Speed	12, 25, 37, 50 mm/s
Direction	0, 22.5, 45, ・・・, 337.5 deg

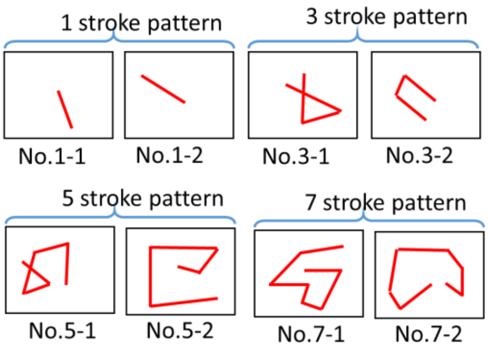


Figure 6. Presented drawings: each stroke is presented as an uniform motion.

B. Evaluation Values

By connecting the start and end point, a secant was obtained for each of the actually reproduced strokes. Then, the length- and angle-differences between the secants and the desired strokes were used as evaluation values (see Figure 7):

$$\Delta l = l_{secant} - l_{desired}$$

$$\Delta \theta = \theta_{secant} - \theta_{desired}$$

In addition to these, the velocity difference of the mean velocity from the desired one is also employed as the third evaluation value:

$$\Delta v = v_{mean} - v_{desired}$$

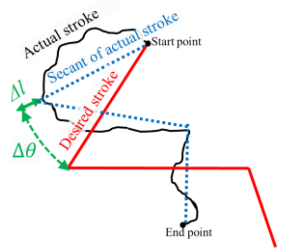


Figure 7. Evaluation values: the differences of lengths and angles between the secants of actual trajectory and the desired trajectory

C. Experimental Result

Some reproduced line-drawings for the drawing No. 7-1 are shown in Figure 8. Even though much improvement is expected, they show a potential for rough sketches. For each of the 1, 3, 5, and 7 stroke drawings and for each of the 10 subjects, the Mean Absolute Errors (MAEs) per stroke for the lengths, angles, and velocities of the reproduced strokes are shown in Figure 9. As the number of strokes increases, the elapsed times and their variances seem to increase. On the other hand, the errors of the length, angle, and velocity per stroke seem to be no difference in this experiment. That is, for the length MAEs (Figure 9 (a)), the angle MAEs (Figure 9 (b)), and the velocity MAEs (Figure 9 (c)), the sample means were calculated for the 1, 3, 5, and 7 stroke drawings, and they are shown by ▭, △, □, and ○, respectively. Then, we applied a statistcal test, ANOVA, to all the residuals (the differences of the perceived values from the actual value). It was confirmed that there were no significant differences between the population means of the 1, 3, 5, and 7 stroke drawings: lengths, $F(3, 309) = 0.73$, $p = 0.54$; angles, $F(3, 309) = 0.47$, $p = 0.70$; mean-velocities, $F(3, 309) = 1.01$, $p = 0.54$.

On the other hand, the sample means of the elapsed times and the number of iterations were plotted by ● and ■, respectively in Figure 10. It is interesting to note that there are linear characteristics of the elapsed time per iteration and the number of iterations. It means that the elapsed times per stroke would not increase as the number of stroke increases (see ○ in Figure 10). Even so, it is also noted that, since there must be some limits for human beings on the amount of information that can be memorized at a time, the elapsed time per stroke may increase in the much more strokes.

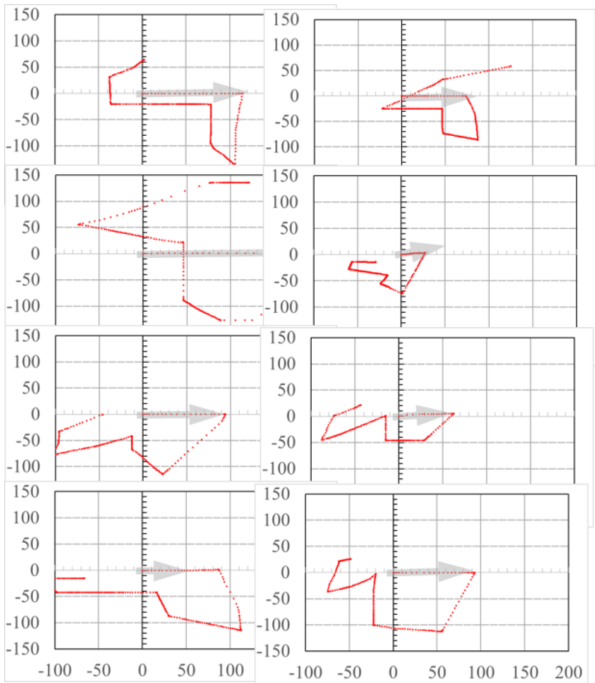
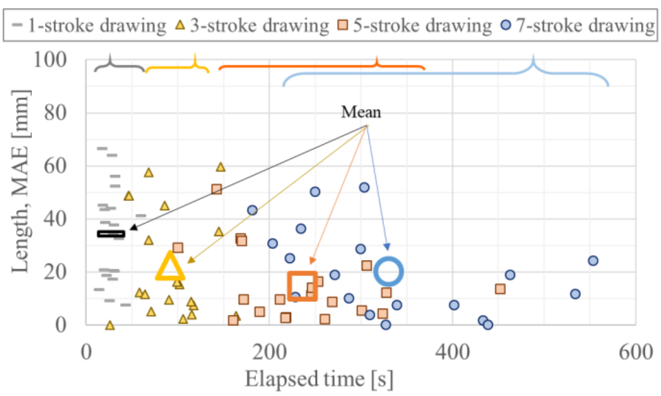
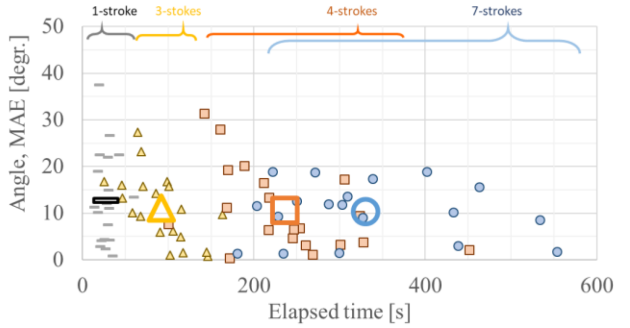


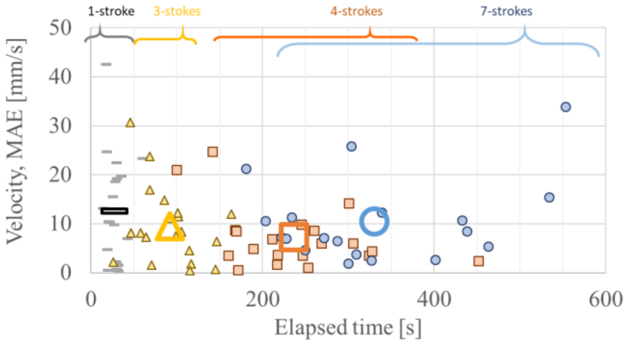
Figure 8. Examples of the reproduced line-drawings: drawing No. 7-1.



(a) Lengths



(b) Angles



(c) Velocities

Figure 9. Mean absolute errors with respect to the reproduced lengths, angles, and velocities for multi-stroke drawings

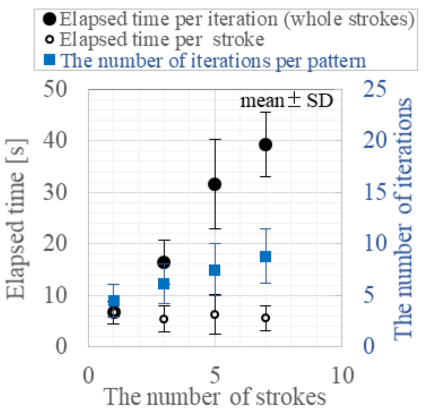


Figure 10. Elapsed times in relationship to the number of strokes

IV. CONCLUSION

This paper presented multiple-stroke recognition characteristics using a tactile interface, i.e., an active-wheel mouse, and with an after-recognition go strategy. As a result of multiple-stroke recognition experiments using 1- to 7-stroke drawings with less than 100 mm of strokes, the followings were confirmed.

(1) The residuals (the differences of the perceived values from the actual value) of lengths, angles, velocities and elapsed times per stroke did not show significant difference between the 1- to 7-stroke drawings. The means of them were about 20 mm, 10 deg, and 10 mm/s, and 6 sec, respectively.

(2) Elapsed times were proportional to the number of strokes of the presented drawings. It means per-stroke elapsed-times were almost remained unchanged even though the number of stokes increased.

In the future, accuracy and efficiency are to be furthermore improved. Further extension of applicable scope is expected for curved strokes and accelerated strokes.

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