Line-Drawing Presentation Strategies with an Active-Wheel Mouse

Yoshihiko Nomura, Yoshiaki Kashino, Tokuhiro Sugiura
Graduate School of Engineering
Mie University
Tsu, Japan
e-mail: {nomura, y-kashino, sugiura}@mach.mie-u.ac.jp

***Abstract*— The objective of this study is to develop a presentation method of line-drawings by using a finger-tactile interface, i.e., an "*active-wheel mouse*," which can present slippages to users via the user's fingertip skin. The interface embodies an active wheel being rotatable in any direction, with any speed and for any duration of time. Through the slippage stimuli, the interface can present stroke motions with any direction, velocity and length to users. In this paper, we proposed two kinds of presentation strategies, called an "*after-recognition go strategy*" and a "*while-perceiving go strategy*" for some line-drawings being connected with several line-segments, and their perceptual performance was examined. The former employed an off-line, open loop scheme, and the latter does an on-line closed loop control scheme. By evaluating lengths and directions of subjects' reproduced line-segments, a feasibility of the interface and the presentation methods were confirmed.**

Keywords-fingerpad; tactile sensation; slippage; interface.

I. INTRODUCTION

Human beings get a large amount of information via vision from the surroundings. Therefore, once we lose our vision, we shall suffer inconveniences in daily life. Many assistive devices were developed as an alternative. Visually impaired persons utilize sensations other than the vision such as skin-sensations and proprioceptive sensations. For examples, some handy-and-portable devices were proposed for character presentation and walking route guidance [1]-[4]. They can present motion information by using tactors, and, yet, there are some tasks to be solved: ① the number of physical properties to be presented was restricted in such a way that only motion direction can be presented, ② the working area was also restricted to several millimeters.

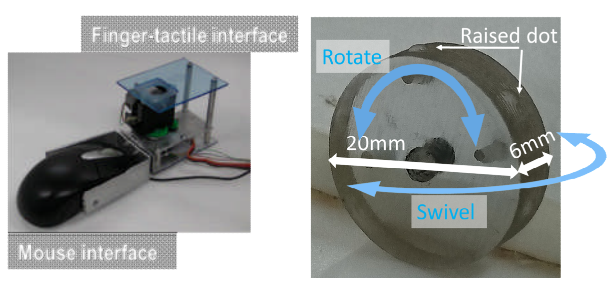
The objective of this study is to develop an operational strategy by utilizing our developed tactile-device, i.e., an Active-Wheel Mouse (AWM) [5][6]."

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 and III, respectively. That is, Section II outlines our developed AWM, and Section III introduces two line-drawing-stroke presenting strategies to be compared in this paper: one is an after-recognition go strategy (ARG-S), and the other a while-perceiving go strategy (WPG-S). Next, two stages of experiments follow the system descriptions. Practically, in Section IV, perceptual characteristics of simple patterns of 1-, 2-, and 3-strokes are presented as a basic study, and, in Section V, those for complicated patterns of 5-strokes are presented as an example of practical applications. The paper closes with a conclusion and remarks for further developments.

II. ACTIVE-WHEEL MOUSE, A FINGER-TACTILE INTERFACE

A. Apparatus

In our previous work [5][6], we have developed an AWM: a specific mouse interface, at the front of which a finger-tactile interface is attached as shown in Figure 1. The finger-tactile interface can rotate a wheel around the wheel central axis in any horizontal direction by two stepping motors (M15SP-2N and M25SP-6NK (Mitsumi Electric Co., LTD., Tokyo, Japan) (see Figure 1.). The former rotates the wheel, and the latter swivels the wheel rotating part. The rotation and the swivel result in slippage velocity and direction, respectively. Here, the velocity together with the time duration decide the slippage lengths. The diameter and thickness of the wheel are 20 mm and 6 mm, respectively (see Figure 1. (b)). Particularly, it is noted that raised dots are formed on the wheel peripheral surface to enhance slippage perceptual performance [7][8]: 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 decided as 10.5 mm so that the dots appear one by one on the fingerpad to make the slippage perception easier [5][6].



(a) Finger-tactile interface is attached to a mouse interface: it constitutes an active-wheel mouse.

(b) Raised dots formed on a wheel peripheral surface.

Figure 1. Active-wheel mouse.

While holding the mouse body, touching their finger-pad on the rotating wheel peripheral surface from above, users can accept slippage stimulus (see Figure 2.).

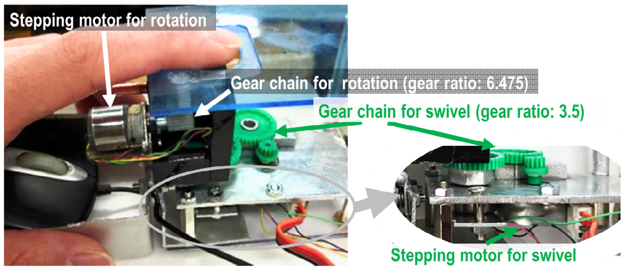


Figure 2. Side view of the finger-tactile interface.

Here, note that the circumference of the wheel is circular, and the shape of the slippage is physically not a straight line, but an arc. However, it is not easy for us to perceive the arc-shaped slippages. Therefore, users are instructed not to perceive the slippage as arc segment, but as straight line segments.

III. LINE-DRAWING-STROKE PRESENTING STRATEGIES

Two control schemes were applied: one control scheme is off-line and the other is on-line. In terms of the former, we introduced a line-drawing-stroke presenting strategy, i.e., “After-Recognition Go Strategy”, and, in terms of the latter, “While-Perceiving Go Strategy.” The strategies will be explained in the following.

A. *After-Recognition Go Strategy*

In this section, a presenting strategy for line-drawing-strokes, that is, the after-recognition go strategy, is explained. The strategy is carried out in the following procedure.

[Step 1] A subject holds the mouse in his right hand. Then, he touches his index-fingerpad on the wheel from above.
[Step 2] Finger-tactile interface swivels the rotating unit in a given direction. Next, it rotates the wheel with a given velocity and angle (see Figure 3. ①) .
[Step 3] While accepting the slippage stimulus, the subject recognize the stimulus as a straight line motion. (See Figure 3. ②.)
[Step 4] The subject drags AWM so as to reproduce his recognized motion (see Figure 3. ③).
[Step 5] The subject memorizes the drag motion as a stroke (see Figure 3. ④).
[Step 6] Just after memorizing stroke, the subject sends a signal by pressing a button in the left hand.
[Step 7] Return to [Step 2] till all the strokes are memorized.

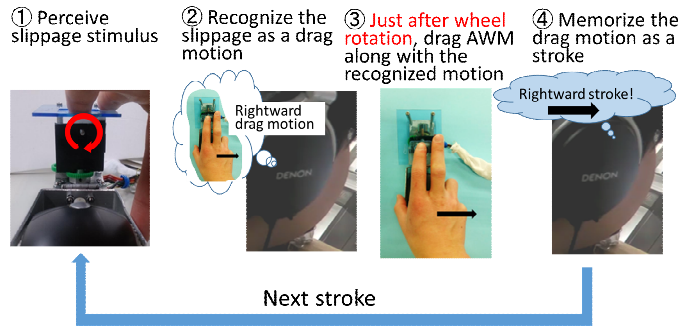


Figure 3. “*After-Recognition Go strategy*” for line-drawing-stroke teaching & learning.

B. *While-Perceiving Go Strategy*

In this section, the second presenting strategy for line-drawing-strokes, that is, the while-perceiving go strategy, is explained.

[Step 1] A subject holds the mouth in his right hand. Then, he touches his index-fingerpad on the wheel.
[Step 2] As shown in Figure 4. , the finger-tactile interface swivels in a specific direction. At a time, the wheel rotates with another specific velocity under a positional feedback control scheme: as shown in Figure 4. the direction is given by the positional difference vector between the present position and a sub-goal of a desired stroke. The velocity is given by the desired velocity at the proximal point on a desired trajectory.
[Step 3] While accepting the slippage stimulus, the subject recognizes the stimulus as a straight line motion, and drags AWM along with the recognized motion (see Figure 5. ① and ②).
[Step 4] The subject memorizes the drag motion as a stroke (see Figure 5. ③).
[Step 5] Just after memorizing stroke, the subject sends a signal by pressing a button in his left hand.
[Step 6] Return to [Step 2] till all the strokes are presented.

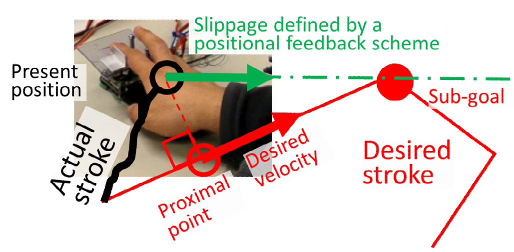


Figure 4. Explanation of a positional feedback scheme employed in “*While-Perceiving Go Strategy* “ as a stroke presentation method. The slippage velocity is given as the desired velocity at the proximal point on a desired trajectory.

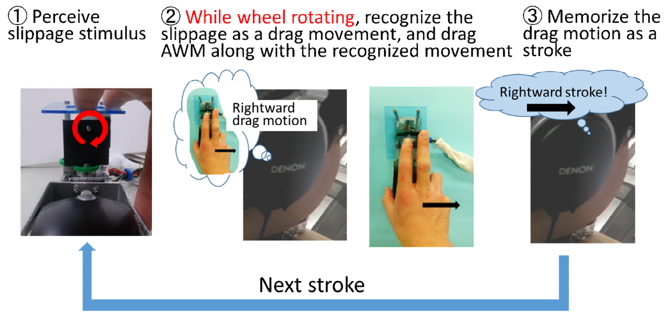


Figure 5. *"While-Perceiving Go Strategy"* for stroke presentation. The step ② in this figure can be regarded as an on-line integration of the steps ② and ③ in Figure 4, i.e., the *"After-Recognition Go Strategy."*

Here, note that the point of the strategy is in a position feedback control scheme as explained in [Step 2].

IV. BASIC EXPERIMENT

A. Experimental Method

1) Experimental Conditions: In order to confirm a potential of the "after-recognition go" method as a drawing presentation, a line-drawing-stroke presenting experiment was carried out.

Five healthy right handed males in their 20s (22~24, 22.6 (mean) ± 0.9 (SD)) participated in the experiment. The stroke drawings from single to three strokes were presented as shown in Figure 6. All the strokes were of the uniform motion, i.e., constant-velocity straight line motion. The factors and the factor levels are shown in TABLE I. In the experiment, the levels for each of the presentation-mode factor and the stroke-number factor were given by a pseudo-random order.

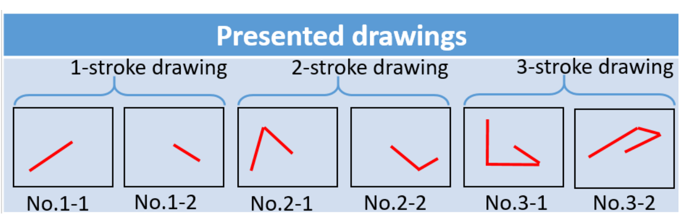


Figure 6. Presented drawings used for a stroke learning experiment.

TABLE I. FACTORS AND FACTOR LEVELS IN BASIC EXPERIMENT.

Factor	Level
Subject	5 males
Presentation strategy	While-perceiving go, After-recognition go
Presented stroke pattern	6 stroke patterns in total: 2 patterns for each of 1-stroke, 2-strokes, and 3-strokes
Length	Randomly chosen between 50 - 150 mm
Speed	Randomly chosen between 12 - 50 mm/s
Direction	Randomly chosen between 0 - 359 deg.

2) Procedures: The experiment was carried out by the following procedures (see Figure 7.).

[Step 1] For each of the presentation strategies, ARG-S or WPG-S as described in Section III, subjects repeat accepting slippages until they finish recognizing whole drawing trajectories.

[Step 2] They repeat accepting slippages until they finish recognizing the whole velocity variation.

[Step 3] They reproduce the memorized stroke trajectory by using AWM, while the system records the mouse movements.

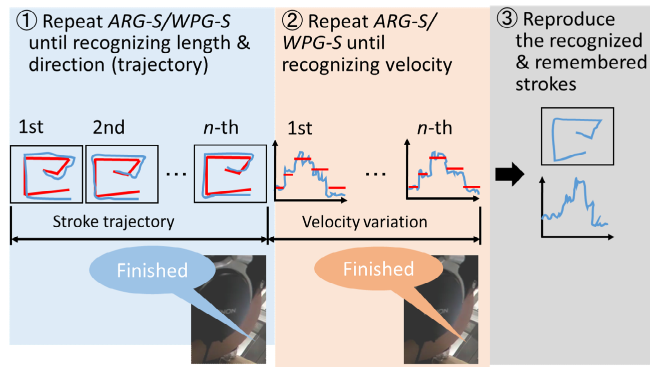


Figure 7. Experimental procedures.

3) Evaluation Values: We obtained secants from actual strokes where the word "secant" represents the line segment connected from start to end point. Next, we defined evaluation values by the differences of the lengths as well as the angles between the secants of the actual strokes and the desired strokes for each of the strokes (see Figure 8.). That is,

$$\Delta l = l_{secant} - l_{desired} \quad (1)$$

$$\Delta \theta = \theta_{secant} - \theta_{desired} \quad (2)$$

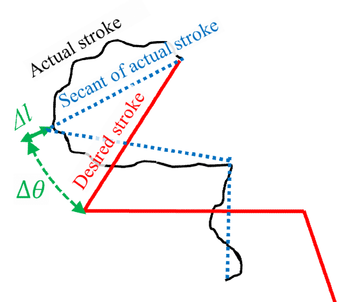


Figure 8. Evaluation values: the differences of lengths and angles between the secants of actual trajectory and the desired trajectory.

In addition to these, a velocity difference of v_{mean} from $v_{desired}$ was also employed as an evaluation value:

$$\Delta v = v_{mean} - v_{desired} \quad (3)$$

where v_{mean} is the mean velocity of the time-varying actual velocity, and $v_{desired}$ is the desired velocity.

B. Experimental Results

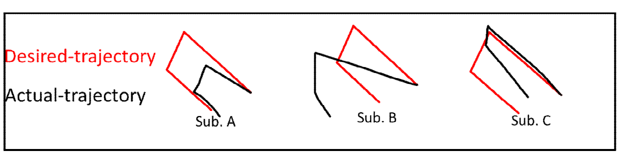
As with some three-stroke drawings, experimental results of the ARG-S are shown in Figure 9. Trajectories and velocities are shown in (a) and (b), respectively.

For the errors of the lengths and angles of the reproduced trajectories, as well as the velocities, means and standard deviations were calculated and shown in Figure 10. (a), (b), and (c), respectively. In addition to that, the means and standard deviations of the per-stroke time duration, i.e., the elapsed time, for the recognizing and memorizing steps, [Step 2] and [Step 3], in Section IV A 2) are shown in Figure 10. (d). Comparing the two presentation strategies, i.e., the ARG-S and WPG-S, we found the following results.

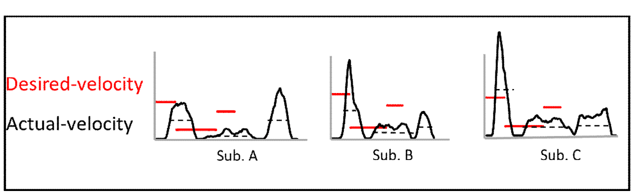
1) A result of t-test on population means of the errors: There was no significant difference between the ARG-S and the WPG-S with respect to the reproduced lengths, angles, and velocities (see Figure 10. (a), (b), and (c), respectively.) On the other hand, as shown in Figure 10. (d), the ARG-S was superior to the WPG-S by a significant level of 1 % with respect to the per-stroke time duration: a test statistic *t* of 2.70 > a critical value $T^{29,28}_{0.01}$ of 2.00 where $T^{29,28}_{0.01}$ represents $T^{DOF1,DOF2}_{significant\ level}$.

2) A result of F-test on variance ratios of the errors: the ARG-S was inferior to the WPG-S by a significant level of 0.1 % with respect to the reproduced lengths and angles: a test statistic *F* of 2.94 > a critical value $F^{59,58}_{0.001}$ of 2.40 with respect to the reproduced lengths; a test statistic *F* of 3.03 > a critical value $F^{59,58}_{0.001}$ of 2.40 with respect to the reproduced angles where $F^{59,58}_{0.001}$ represents $F^{DOF1,DOF2}_{significant\ level}$. Yet, there was no significant difference between them with respect to the reproduced velocities. On the other hand, the ARG-S was, vice versa, superior to the WPG-S by a significant level of 0.1 % with respect to the per-stroke time duration: a test statistic *F* of 5.57 > a critical value $F^{29,28}_{0.001}$ of 3.34.

3) Subjects' report: In addition, all the subjects reported that, especially near sub-goals, they felt much more exhausted in the WPG-S than in the APG-S. They suggest humans are not able to catch up with the closed-loop feedback-control scheme: for achieving the closed-loop feedback-control, it is necessary to respond in a short period of time, but humans cannot respond so.

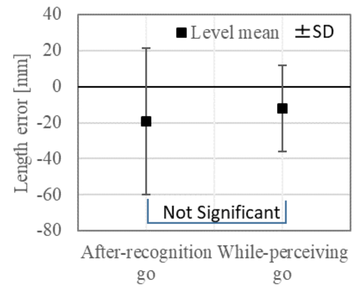


(a) Recognized trajectory.

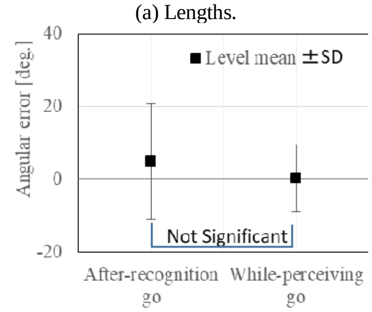


(b) Recognized velocity variation.

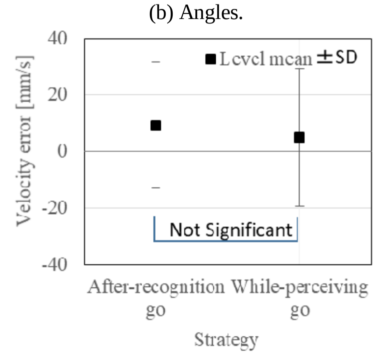
Figure 9. Some examples of the recognition with three-stroke drawings.



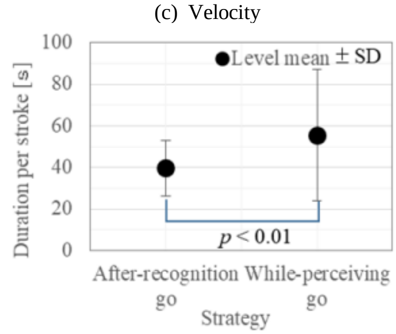
(a) Lengths.



(b) Angles.



(c) Velocity



(d) Time duration per stroke.

Figure 10. Root mean squared errors with respect to the recognized length, angles, and velocities for multi-stroke drawings.

The errors of the lengths, angles, and velocities showed little differences between the two strategies, but the time duration showed significant differences. Therefore, the time duration was considered to carry more significant weight than the errors of the lengths, angles, and velocities. As a result, the ARG-S, whose time duration had the advantages in terms of population means and variances, was recommended for further studies.

V. Practical Experiment

A. Experimental Method

1) Experimental Conditions and Procedures: We carried out a practical experiment in order to confirm the effectiveness of the above-selected stroke-presention strategy, i.e., the ARG-S. In the practical experiment, the number of strokes was increased to five. The experimental conditions are shown in TABLE II.

TABLE II. Factors and Factor Levels in Practical Experiment.

Factor	Level
Subject	3 males (around age 23)
Presentation strategy	After-recognition go strategy
Presented stroke pattern	2 patterns of 5-strokes
Length	Randomly chosen between 10 - 150 mm
Speed	Randomly chosen between 12.5 - 70 mm/s
Direction	Randomly chosen between 0 - 359 deg.

The procedures were almost the same as those in Section IV.A.2) except that each of the strokes was presented only once, and no repetition was allowed. In addition, the presented lengths were individually adjusted to each of the subjects to cancel the foreshortening effect of perceived lengths as shown in Figure 10.

B. Experimental Results

Experimental results are shown in Figure 11. In this figure, presented drawing patterns are shown in the leftmost cells, and the perceived drawing patters are in the other cells.

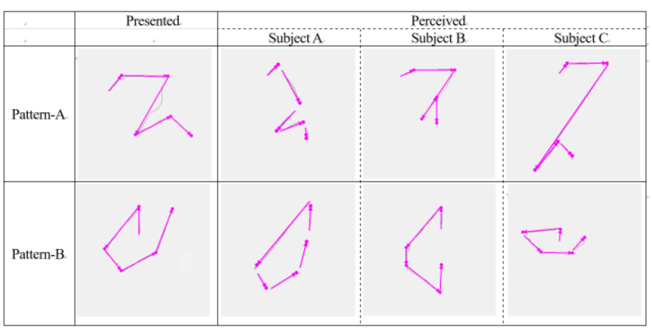


Figure 11. Experimental results of multi-stroke line drawing perception by using the active-wheel mouse.

Although it leaves much to be improved, the perceived drawing patterns capture the essential features of such complicated patterns. It shows a potential of the proposed finger tactile interface and the stroke presentation strategy.

VI. Conclusion and Future Work

Two multiple-stroke presenting strategies using a tactile interface, i.e., AWM were presented: one is an after-recognition go strategy, and the other is a while-perceiving go strategy. As a result of multiple-stroke recognition experiments, the following conclusions were confirmed.

Although the after-recognition go strategy was inferior to the while-perceiving go strategy in terms of the variance ratios of the errors with respect to the lengths and angles, the after-recognition go strategy was, vice versa, superior to the while-perceiving go strategy in terms of the time duration from the viewpoints of population means and variance ratios. In addition to that, all the subjects reported that they were much more exhausted in the while-perceiving go strategy than in the after-recognition go strategy. As a result, it can be said that the while-perceiving go strategy that does employ a closed-loop on-line positional feedback scheme does not work well, while the after-recognition go strategy that employs an open-loop control scheme does work better.

In the future, accuracy and efficiency need to be improved. Although it is difficult, further extension of applicable scope, such as curved strokes and accelerated strokes is expected.

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References

[1] N. Tsuda, N. Kato, and Y. Nomura, “Instruction of arm motion for calligraphy using vibrotactile stimulations,” 2011 IEEE/ASME International Conference in Advanced Intelligent Mechatronics (AIM), pp. 677-682, 2011.

[2] A. Causo, S. H. Yeo, and I. M. Chen, “Vibrotactile motors on stationary arm as directional feedback to correct arm posture,” 2012 IEEE/ASME International Conference in Advanced Intelligent Mechatronics (AIM), pp. 202-207, 2012.

[3] S. L. Norman, A. J. Doxon, B. T. Gleeson, and W. R. Provancher, “Planar hand motion guidance using fingertip skin-stretch feedback,” IEEE Transactions on Haptics, vol. 7, no. 2, pp. 121-130, 2014.

[4] A. Ion, E. J. Wang, and P. Baudisch, “Skin drag displays: dragging a physical tactor across the user's skin produces a stronger tactile stimulus than vibrotactile,” Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems, pp. 2501-2504, 2015.

[5] Y. Nomura and S. Oike, “Active-wheel mouse for human-computer interface: slippage-perception characteristics on fingerpad,” Proceedings of 10th International Conference, UAHCI 2016, Part of HCI International 2016, part II, pp. 54-61, 2016.

[6] Y. Nomura, Y. Kashino, and S. Oike, “Proposal of active-wheel-based finger-tactile interface and its slippage-presenting functions,” Transactions of the JSME, vol. 83, no. 852, pp. 1-17, 2017 (in Japanese)

[7] Y. Nomura and K. Iwabu, “Length perceptual characteristics on raised-dot slippages,” Human-Computer Interfaces and Interactivity: Emergent Research and Applications, IGI Global, pp. 286-308, 2014.

[8] Y. Nomura and H. Kato, “Raised-dot slippage perception on fingerpad using active wheel device,” Recent Advances on Using Virtual Reality Technologies for Rehabilitation, Nova Science Publishers, Inc. New York, pp. 165-172, 2015.

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