Visualization of keystroke data and its interpretation

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Abstract: Keystroke data from keyboard input is time-series data and follows a fixed pattern. However, it is difficult to intuitively grasp the meaning of the data. In this study, we investigated visualization methods for keystroke data, which is a form of biometric information. We extracted feature indices from the keystroke timing between consonant-vowel letter pairs in Japanese text input and propose three visualization methods: two consonant-vowel doughnut methods, a consonant-vowel matrix method and a keyboard layout method. These patterns of visualization are expected to be useful in analyzing personal characteristics and authenticating users

Keywords: Visualization, Keystroke dynamics, Information security, Man-machine interface**.**

I. INTRODUCTION

Computers are essential in today's information society, and with the increased frequency of using keyboards, applications that utilize keystroke data are expected to lead to innovations in various fields. Keystroke data is regarded as a form of biometric information from which various personal characteristics can be extracted [1–3]. However, keystroke data is time-series data and difficult to understand intuitively. In this study, we aim to develop methods for visualizing keystroke data in order to extract various personal characteristics.

Prior research on the visualization of keystroke data is limited. Neumann et al. [4] have proposed a method for visualizing input data in order to make signatures and postcard-like art for e-mail and other forms of Internet communication.

In this study, we propose methods for visualizing keystroke data obtained from free typing of Japanese text in order to reveal personal characteristics.

II. Typing Data Collecting System

This section describes the keystroke data collection system[5]. In this study, we used a web-based system that is able to collect keystroke data from a large number of participants in a single experiment. The system uses typing support software that was familiar to the participants, thereby lowering effects related to unfamiliarity and tension. Figure 1 shows a screenshot of the software interface used in this study.

The document display screen allows participants who are skilled typists to input text while viewing the Japanese text displayed in the upper row. Less skilled typists can type while viewing the Latin alphabet text displayed in the middle row. Latin alphabet text is removed from the screen as it is typed, allowing confirmation of mistyped characters. The top row displays the number of keystrokes, the number of errors, and the amount of time remaining. Because this experiment focuses only on Latin alphabet input keystroke, by design Latin character input is not converted into Japanese kanji characters.

While participants are typing, browser-embedded JavaScript code records character input, key press times, and key release times. Times are recorded using UNIX times (millisecond precision). Recorded data was sent to a server using Ajax.

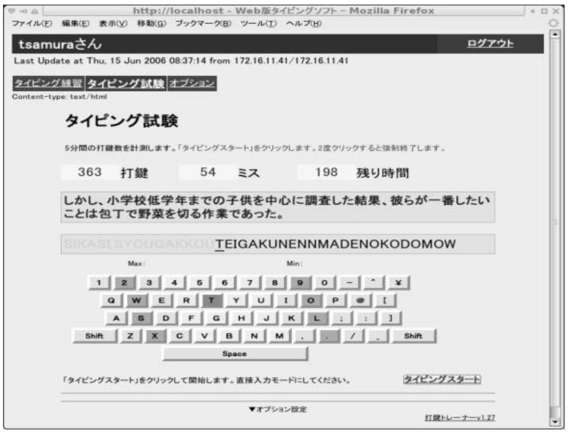

Fig. 1. Screenshot of interface of keystroke data collecting system.

III. CONSONANT-VOWEL DOUGHNUT METHODS

In this section, we propose two consonant-vowel doughnut methods: an absolute transition time method and a relative transition time method, the latter of which is based on the time variance from the average transition time of all participants.

3.1 ABSOLUTE TRANSITION TIME METHOD

The visualization procedure is as follows:

1. Define incoming alphabetic characters as nodes. Exclude the letters "l", "q", "v" and "x", which have a low frequency of occurrence.
2. Arrange the letters in a circular doughnut arrangement, with vowels on the inner circle and consonants on the outer circle. Indicate consonant-vowel letter pairs (hiragana) that appear three times or more using edges.
3. Display the color-coded edges, as indicated in Table 1, on the basis of the transition time T between pressing a key and the next key.

Table 1. Edge colors according to transition time T

Transition Time T [ms]	Color
$T < 70$	Red
$70 < T < 100$	Peach
$100 < T < 130$	Yellow
$130 < T < 160$	Green
$160 < T < 190$	Blue
$190 < T$	Not colored

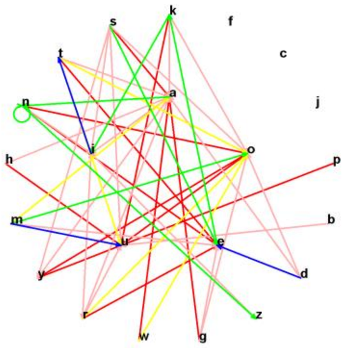

Fig. 2. Visualization pattern based on the absolute transition time method (fast typing)

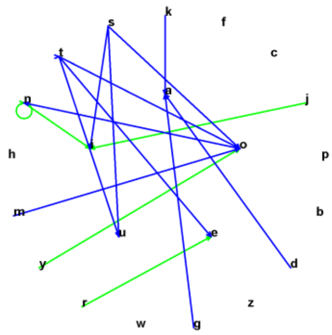

Fig. 3. Visualization pattern based on the absolute transition time method (slow typing)

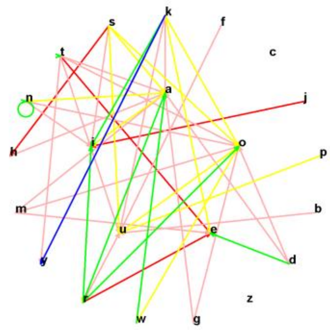

Fig. 4. Visualization pattern based on the absolute transition time method (Hepburn Romanization, "ji" typed quickly)

Figure 2 shows a visualization pattern for a participant who typed Japanese text. It can be seen that the typing speed of this participant was fast, as many edges are colored red and peach. On the other hand, Fig. 3 shows many blue edges, indicating that the typing speed of the participant was slow. In Fig. 4, the edge for "ji" indicates a fast typing speed for this pair, from which we can ascertain that the participant used the Hepburn system of Romanization.

3.2 RELATIVE TRANSITION TIME METHOD

Here, we focus the time variance ΔT (=T - $\bar{T}$) between targeted transition time T and the average transition time of all participants, $\bar{T}$. Edges from consonants to vowels are color-coded for only three conditions: fast, average and slow, based on the time variance ΔT. No color is shown for other conditions.

The visualization procedure is as follows:

1. Calculate the average transition time $\bar{T}$ of all participants.
2. Seek the time variance ΔT between transition time T of a participant and the average transition time of all participants, $\bar{T}$.
3. Draw color-coded edges from consonants to vowels according to Table 2.

Table 2. Edge colors according to time variance ΔT

Time Variance ΔT [ms]	Color
$\Delta T < -60$ (fast)	Green
$-5 < \Delta T < 5$ (average)	Black
$60 < \Delta T$ (slow)	Yellow
Other (5 ms < $\lvert\Delta T\rvert$ < 60 ms)	Not colored

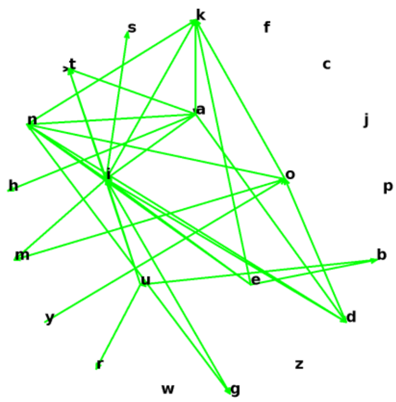

Fig. 5. Visualization pattern based on relative transition time method (fast typing)

Figures 5 and 6 show examples of visualization patterns created using this method. As all edges for the participant in Fig. 5 are colored green, it is indicated that the typing speed of the participant is faster the average. Meanwhile, in Fig. 6, many edges for the participant are colored yellow and black, indicating that the typing speed of the participant is slower than the average. However, only the edge from "y" to "u" is colored green, which shows that the participant has a habit such as typing "y" with the left index finger. In addition, only black edges or no edges at all are seen for typing of "n" to "n" by all participants, indicating that there is no difference in the input time of the transition time among any participants.

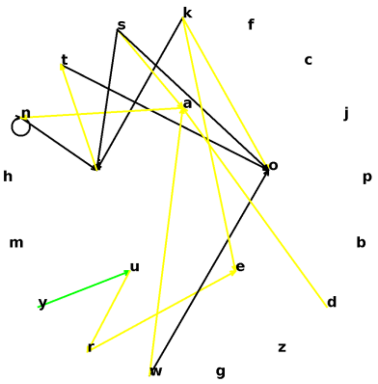

Fig. 6. Visualization pattern based on the relative transition time method (slow typing)

IV. CONSONANT-VOWEL MATRIX METHOD

The visualization procedure is as follows:

1. For hiragana input of consonant-vowel pairs, place consonants of the first letter in columns (vertical) and vowels of the second letter in rows (horizontal). Exclude "c", "f", "j", "l", "p", "q", "v" and "x" because of their low frequency of occurrence.
2. Prepare two keystroke data sets for input by a participant. Obtain variances in the transition time for each single letter. Consonant-vowel letter pairs (hiragana) that appear three times or more are targeted for both data sets. Letters with small time variance are colored dark red and letters with large time variance are colored light red. Thus, the figure is configured to be displayed entirely in dark red if files are input by the same participant, and displayed in white and light red when the files are input by different participants.

Figure 7 shows an image of when a participant typed three different texts. The participant's identity can be confirmed because most of the image is colored dark red. Meanwhile, Fig. 8 shows an image comparing text typed by a different participant. In most cases, typing differs between participants, and thus the image is generally displayed in light red.

Fig. 7. Visualization pattern based on the consonant-vowel matrix method for a certain participant.

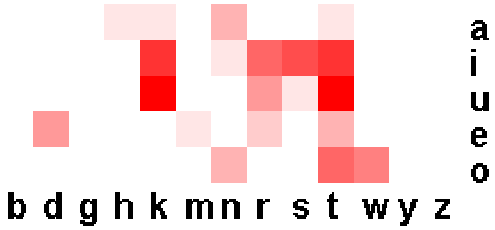

Fig. 8. Visualization pattern based on the consonant-vowel matrix method for different participants.

V. Keyboard layout method

The visualization procedure is as follows:

1. Place nodes in the same layout as the QWERTY keyboard.
2. The average time of pressing a letter is displayed as red circles on the nodes, and the transition time is displayed as light blue links. Shorter times are shown in darker colors.

Figure 9 shows a visualization pattern based on this method. For this method, it is verified that a similar network is created even if different texts are typed. In addition, Fig. 9 shows that movements are more active on the right side of the keyboard, which suggests the participant is right-handed.

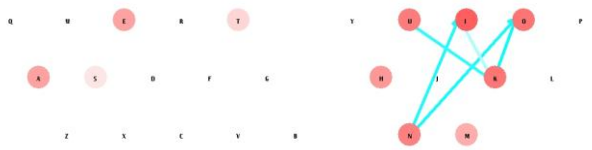

Fig. 9. Visualization pattern based on the keyboard layout method

VI. CONCLUSIONS

In this study, various methods for visualizing keystroke data were proposed, and the results showed that the methods were effective in revealing the characteristics of individuals.

In future work, we plan to study changes in visualization images the typing of English text, programming languages and other documents in addition to Japanese texts. We also plan to investigate typing by non-Japanese participants. In addition, we considered only transition time in this work, and therefore we would like to consider other keystroke times as well.

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