Introduction of New Features in Writer Verification Based on Finger-writing of a Simple Symbol

Takahiro Horiuchi
Graduate School of Sustainability Sciences
Tottori University
Tottori, Japan
m21j4053a@edu.tottori-u.ac.jp

Tomoyuki Inoue
School of Engineering
Tottori University
Tottori, Japan

Isao Nakanishi
Faculty of Engineering
Tottori University
Tottori, Japan
nakanishi@tottori-u.ac.jp

***Abstract*— In this study, a method of verifying an individual from their style of drawing simple symbols that everyone is familiar with and never forgets was studied. Individuals were asked to draw symbols using their fingertips on a digital device screen. Various features, such as the finger pressure, the touch area, and the touch direction, which were directly detected by a tablet device, were measured. In addition, the finger volume, force, and amount of work that were derived from the directly detected features were calculated. Subsequently, the verification performance of these features was evaluated.**

Keywords—writer verification, finger-writing, simple symbol, finger-pressure, finger-touching area

I. INTRODUCTION

Currently, almost all people around the world use a smartphone or a tablet terminal for acquiring information from websites and communicating with others. In most cases, such terminals contain important personal information. Therefore, security technologies are strongly required to prevent unauthorized access and illegal use by others. Currently, fingerprint and face authentication, as the methods of personal authentication, are used in smartphones. These are convenient and have a high authentication rate but their security is low because fingerprints and faces are exposed to the outside world and thus can be stolen by others unexpectedly. Biological information cannot be changed unlike passwords.

Accordingly, in this study, we have focused on written authentication. This authentication method is based on writing habits, which are difficult for others to know a priori and the risk of their theft or imitation is low. In particular, when using a smartphone or a tablet, online signature verification, in which a signature is written using a pen on a tablet screen, is suitable.

However, it takes time to write a signature, it is difficult to write on a small screen, such as a smartphone, and it is also cumbersome to use a dedicated pen. Therefore, we have proposed a system in which users write a simple symbol with their finger on a smartphone or tablet screen for authentication [1].

In this study, we have attempted to further improve the person verification performance using the finger volume feature, which is composed of the finger pressure and the finger-touch area. In addition, we have attempted to perform person identification using the features of force exerted by the finger and the amount of work, derived from the finger volume employing the finger-touch direction detected from the tablet device.

II. PERSON VERIFICATION BASED ON FINGER-WRITING OF A SIMPLE SYMBOL

In this work, a method of person verification based on their style of finger-writing of a simple symbol has been proposed [1]. In this method, the users wrote a symbol (e.g., a circle, a triangle, or a rectangle), which nobody forgets, on the touch-panel screen of a smartphone or tablet directly using a finger (i.e., without using a pen). Our conventional research extracted 41 features from the writing data (20 sets of three symbols from 19 subjects), as listed below.

- Average of the X and Y coordinates
- Maximum values of the X and Y coordinates
- Minimum values of the X and Y coordinates
- Difference between the X and Y coordinates
- Distance between the start and end points
- The drawing area
- The start- and end-point coordinates
- Average finger pressure and touch area
- Maximum values of finger pressure and touch area, and their coordinates
- Minimum values of finger pressure and touch area, and their coordinates
- Average speed and acceleration
- Maximum speed and acceleration, and their coordinates
- Minimum speed and acceleration, and their coordinates
- Velocity near the start and end points
- Start point and end point peripheral acceleration
- Start point and end point finger pressure
- Start point and end point finger-touch areas
- Writing time

From the evaluation of their verification performance conducted using the Euclidean distance matching method, the smallest equal error rate (EER) of 18.4 % was obtained using the end-point coordinates of the rectangle symbol.

III. NEW FEATURES DERIVED FROM THE FINGER PRESSURE AND THE FINGER-TOUCH AREA

To obtain an effective feature for verifying the individuals, we derived a new feature, called “volume”, by multiplying the finger pressure with the finger-touching area. In using the finger pressure as a measure for height, its multiplication with the finger-touching area was considered as the volume and could be expected to have some individuality.

In this study, we generated the features of the maximum, average, and minimum values of the volumes, and the features derived by multiplying the maximum, average, and minimum values of the finger pressure with those corresponding to the finger-touching area. All of these features are listed below:

978-1-6654-8559-3/22/$31.00 @2022 IEEE

- Average finger volume
- Maximum finger volume
- Minimum finger volume
- Multiplication of the average finger pressure and the maximum finger-touch area (hereinafter called “avg/max”)
- Multiplication of the average finger pressure and the minimum finger-touch area (hereinafter called “avg/mini”)
- Multiplication of the maximum finger pressure and the average finger-touch area (hereinafter called “max/avg”)
- Multiplication of the maximum finger pressure and the minimum finger-touch area (hereinafter called “max/mini”)
- Multiplication of the minimum finger pressure and the average finger-touch area (hereinafter called “mini/avg”)
- Multiplication of the minimum finger pressure and the maximum finger-touch area (hereinafter called “mini/max”)
- Start and end point finger volumes
- Multiplication of the start point of the finger pressure and the end point of the finger-touch area (hereinafter called “start/end”)
- Multiplication of the end point of finger pressure and the start point of the finger-touch area (hereinafter called “end/start”)
- Finger volume at maximum finger pressure
- Finger volume at minimum finger pressure
- Finger volume at maximum finger-touch area
- Finger volume at minimum finger-touch area

To evaluate the verification performance of these features, we created a new database of finger writings. The measurement conditions were the same as those described in Ref. [2]. The total number of participants was 30. They wrote three symbols 20 times. In total, 540 sets were included in the database.

The average EER values for the three symbols are shown in Table I. A few features are observed to improve the verification performance. In the case of the finger pressure as well as finger-touch area, the features using not the minimum but the maximum value decrease the EER. This could be because of the following reasons:

TABLE I. AVERAGE EER VALUES FOR THE THREE SYMBOLS WHEN USING THE FINGER VOLUME FEATURE

Feature Name	EER(%)
Average finger volume	30.7
Maximum finger volume	29.7
Minimum finger volume	41.4
avg/max	30.5
avg/mini	33.4
max/avg	29.6
max/mini	32.5
mini/avg	40.1
mini/max	39.9
Start point finger point	40.8
End point finger point	32.4
start/end	39.3
end/start	32.8
Finger volume at maximum finger pressure	30.5
Finger volume at minimum finger pressure	41.7
Finger volume at maximum finger touch area	30.6
Finger volume at minimum finger touch area	42.8

When the finger pressure is plotted along the horizontal axis and the finger-touch area along the vertical axis, their relation is observed to be an exponential curve [3]. Therefore, features with large values improve the verification performance. This is also the reason why features using not the start point but the end point decrease the EER. These phenomena suggest that large individualities are obtained when users write symbols with strong force.

IV. NEW FEATURES USING FINGER VOLUME FEATURES

Next, we proposed a new feature that uses volume features. Assuming that the finger volume is the “load,” the writing action is considered as pulling the load.

The pulling forces are expected to differ from each other. Thus, we proposed a new “force” feature provided by multiplying the finger volume by the acceleration used in the conventional study.

However, the force feature varied from moment to moment. Therefore, the maximum, average, and minimum values were treated as the features.

When assuming the finger volume as a load, the load multiplied by the distance was considered as a new feature, called the “amount of work (joule)”. Distance was also a feature obtained from the number of sampled data. In addition, the finger volume and force, when the acceleration is at a maximum or minimum, were considered as features.

The new features are as follows:

- Joule
- Finger volume at maximum acceleration
- Force at maximum acceleration
- Finger volume at minimum acceleration
- Force at minimum acceleration
- Drawing distance
- Force on the entire drawing (average acceleration multiplied by the average finger volume)

We evaluated the verification performance of these features using a finger-writing database. The average EER values for the three symbols are listed in Table II.

The proposed new features, force and joule, and the distance feature achieved an EER of approximately 29 %. Compared to the EERs listed in Table I, better verification performance was obtained using these features.

The distance, that is, the amount of sampled data, corresponds to the writing speed, and thus has large individualities. Because the joule feature consists of the distance and load features, it also has large individualities.

The coefficient of friction is related to the angle of the finger in contact with the plane [4]. Figure 1 shows a finger dragging on a plane at an angle θ. A larger finger angle leads

TABLE II. AVERAGE EER VALUES FOR THE THREE SYMBOLS CORRESPONDING TO THE NEW FEATURES

Feature name	EER (%)
Joule	29.3
Finger volume at maximum acceleration	35.7
Force at maximum acceleration	39.5
Finger volume at minimum acceleration	35.0
Force at minimum acceleration	39.4
Drawing distance	28.3
Force on the entire drawing	28.5

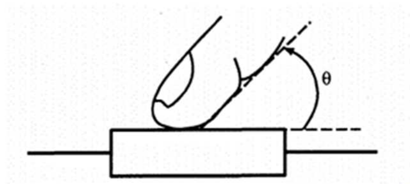

Fig. 1. Finger dragging on a plane at an angle *θ*.

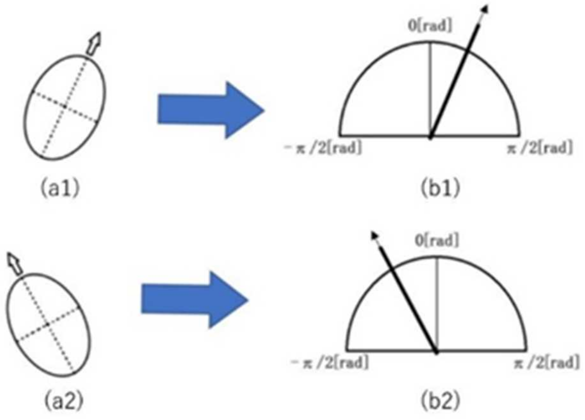

Fig. 2. Example of extracting the direction of the finger touch.

to a small coefficient of friction. Therefore, the acceleration changes according to the finger angle. Consequently, the force feature, including the acceleration, has large individualities and exhibits better performance.

V. Feature of the Direction of the Finger-Toucing Area

In this section, the feature of the direction of the finger-touching area has been examined. The direction of the finger-touching area is detected when a user touches a certain smartphone. In the experiments performed in our previous study [4] (development environment: Android Studio, smartphone ARROWS NX F-04G), it was confirmed that the detection was displayed on the screen with the major axis of the ellipse aligned with the direction of the finger-touching area, as shown in Fig. 2. The "getOrientation" method in Android Studio can be used to extract the orientation of the finger-touching area [5].

When the contact surface of the finger on the screen is represented as shown in Fig. 2 (a1,a2), the values are detected in the range of $-\pi/2$ to $\pi/2$ rad, with the upright direction of the smartphone screen at 0 rad, as shown in Fig. 2 (b1, b2). In this study, the average values of the finger contact direction from the beginning till the end of writing, the finger contact direction at the beginning and the end of writing, and the direction of the finger-touching area near the start/end point were extracted. Because the values at the beginning and the end of writing are affected by the way the smartphone is held, we considered that this could lead to the extraction of individual's characteristics of the way they hold a smartphone. In addition to the direction of the finger-touching area, the finger pressure and finger-touch area could also be extracted simultaneously. The direction of the finger-touching area corresponding to the maximum/minimum finger-touching area was also considered to represent the individual's characteristics. The following are the created features.

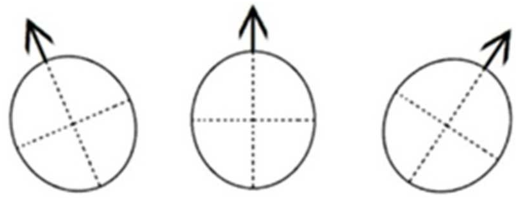

Fig. 3. Variation of the direction of the touching area.

TABLE III. Average EER values of the new features obtained from the feature of the direction of the finger-touching area

Feature name	EER(%)		
	○	△	□
Average finger touch direction	24.7	35.8	39.3
Start point finger touch direction	31.2	42.6	45.2
End point finger touch direction	29.5	46.5	43.2
Near start point finger touch direction	27.8	42.8	42.0
Near end point finger touch direction	32.0	41.7	39.9
Finger touch direction at maximum finger pressure	40.4	51.5	42.6
Finger touch direction at minimum finger pressure	37.5	43.8	46.0
Finger touch direction at maximum finger touch area	35.4	51.4	40.4
Finger touch direction at minimum finger touch area	36.6	41.8	41.8

- Average finger-touch direction
- Start and end point finger-touch directions
- Near-start point and near-end point finger-touch directions
- Finger-touch direction at maximum finger pressure
- Finger-touch direction at minimum finger pressure
- Finger-touch direction at maximum finger touch area
- Finger-touch direction at minimum finger touch area

Finger-writing data were generated from 10 experimental subjects who wrote three symbols 10 times under the same experimental conditions as in the previous study [1]. The average EER values for each symbol are listed in Table III.

When using the feature of the direction of the finger-touching area, the smallest EER of 24.7 % was obtained in these experiments for the circle symbol. The smallest EER was also obtained for the triangular and square symbols. It was confirmed that the average value of the finger-touching area is effective for verifying individuals. However, compared to the EERs in Refs. [1,2], the verification performance was not high. This could be due to the following reasons:

The "getOrientation" method in Android Studio approximates the finger-touching area on an ellipse by calculating the orientation of the ellipse and regards (outputs) it as the orientation of the finger-touching area. However, when the finger-touching area is close to a circle, its orientation fluctuates significantly, as shown in Fig. 3, and thus its performance degrades.

The detection range of the finger-touching area used in this experiment is the upper half of the circle, as shown on the right-hand side in Fig. 4. When an orientation is located slightly diagonally upward to the left, as shown in the upper half of the figure, it is detected to be less than $-\pi/2$. However, if the orientation is tilted slightly diagonally downward to the

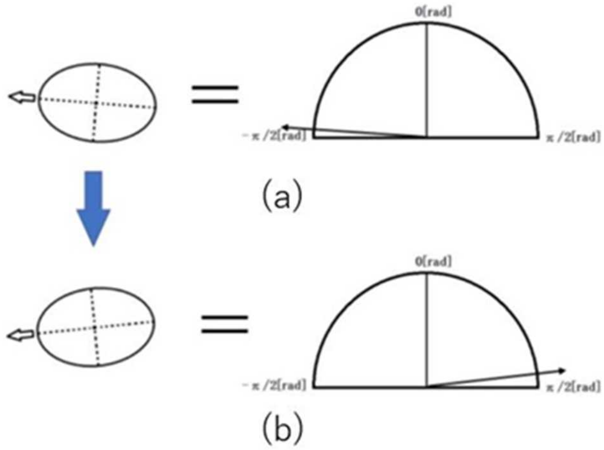

Fig. 4. A change in the direction of the touching area.

left, as shown in the lower half of the figure, it is detected to be more than $\pi/2$. Even though the fluctuation in the orientation is small, as shown on the left-hand side of the figure, the difference between the detected values becomes large (approximately π). This might degrade the verification performance.

From the comparison of the EERs of each symbol, it was observed that those corresponding to the triangle and square symbols were worse than those corresponding to the circular symbol. The triangle and square symbols have angles and cause large changes in the finger movement when writing the symbols. This might lead to the fluctuation of feature values, which results in the degradation of the verification performance.

VI. CONCLUSIONS

In this study, the finger volume, force, and amount of work were proposed as features, which were derived from the finger pressure and the finger-touching area. The verification performance of the proposed features was evaluated and it was confirmed that the features of force and amount of work were effective for verifying individuals. An evaluation of the verification performance of the features derived from the orientation of the finger-touching area was also done. The smallest EER of 24.7 % was obtained compared to those in the conventional studies and those of all the proposed features.

In future studies, we will improve the verification performance by fusing the features discussed in this work. We will also increase the number of experimental participants to improve the reliability of the results obtained in this study.

REFERENCES

[1] I. Nakanishi, and A. Takahashi, "A study on writer verification based on finger-writing of a simple symbol on a tablet," Proc. of 2018 IEEE Region 10 Conference (TENCON 2018), pp. 28-31, October 2018.

[2] S. Kawai, H. Kobayashi, and H. Nakamura, "Contact-surface-area changes in relation to finger force (in Japanese)", Journal of Tezukayama College. Cultural and Social Sciences & Natural Sciences, no. 31, pp. 202-213, March 1994.

[3] A. Shimada, H. Han, and S. Kawamura, "Analysis of friction characteristics on human fingers (in Japanese)" Proc. of the Society for Automatic Control of Metrology, vol. 32, no. 12, pp. 1581-1587, December 1996.

[4] A. Takahashi, and I. Nakanishi, "Authentication based on finger-writing of a simple symbol on a smartphone," Proc. of International Conference on Intelligent Signal Processing and Communications (ISPACS2018), pp. 411-414, November 2018.

[5] Y. Nakamura, and M. Kidode, "Online writer verification using feature parameters based on the document examiners' knowledge", ISCIE, vol. 22, no. 1, pp. 37-47, 2009.