A Study on Writer Verification Based on Finger-Writing of a Simple Symbol on a Tablet

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***Abstract*—A novel writer verification method based on finger-writing of a simple symbol on a tablet is proposed. The symbol is well known, unmistakable to write, and never forgotten, for example, a circle, triangle, or square. In this paper, a development environment for finger-writing the symbols on an Android tablet is constructed and finger-written data are captured from twenty experimental subjects. Using simple on-line and off-line individual features extracted from finger-writing data, the verification performance is examined and as a result, it is hopefully confirmed that the proposed method is feasible especially when relative individual features are used.**

***Index Terms*—biometrics; writer verification; simple symbol; finger writing; tablet**

I. Introduction

Biometrics as a method for verifying individuals is actively researched [1]. Such researches are divided into two main categories, one is to use static features and the other uses dynamic features. In general, the biometrics using the static features achieves higher verification performance. Many of the static features are on the body surface; therefore, their data can be easily captured by others. It makes easier to impersonate genuine users by using artifacts that are produced by stolen biometric data. On the other hand, it is not easy for the biometrics using the dynamic features to achieve high verification performance. However, some of the dynamic features are not surfaced on the body, therefore, it is not easy to capture biometric data They have resistance to the spoofing.

The purpose of our study is to verify whether genuine users or not by using features extracted from the writing. It is called writer verification [2], [3].

The writer verification is categorized by two dimensions, one is whether writing objects are dependent on users and the other is whether the writing objects are dependent on verification systems.

The signature verification is well-known and to verify users by writing of users' own signatures [4]–[6]. The signatures are dependent on the users and independent of verification systems. Users never forget their own signatures; therefore, the usability of signature verification is high. However, signatures can be known by analogy with users' name, so that the security of signature verification is not high. Comparing with login authentication using passwords, signature verification seems to use the same password every authentication.

The free-writing verification is to allow users to write anything. However, free-writing is not convenience for users since the users must change descriptive contents every time they write in order to prevent others from knowing the contents. On the other hand, for the reason, the security of free-writing verification is very high. In addition, descriptive contents in writing are not familiar with users, so that the usability of free-writing becomes the worst. The descriptive contents in writing are independent of users and also independent of verification systems. Comparing with login authentication using passwords, free-writing verification seems to use different passwords every authenticating and so be very inconvenient.

In signature verification, verification methods based on pattern matching can be applied, while it is impossible in free-writing verification since users change patterns, that is, descriptive contents in writing every time the users write. Some kind of "Habit" in writing must be extracted from written data and/or writing process in free-writing verification. Any established method for extracting the habits is not available yet, so that the free-writing verification has not been realized.

The text-indicated verification is also proposed [7], [8]. In Ref. [7], a verification system requires users to write characters in which users' habits (features) can be easily extracted. Descriptive contents in wiring depend on systems and depend on users. The degree of freedom in writing becomes lower than that of the free-writing verification; therefore, the security becomes lower than the free-writing verification. The descriptive contents are not familiar with users, so that the usability becomes lower than the free-writing verification.

In Ref. [8], all users write the same three alphabetical letters correspond to initial characters of users' university name. Therefore, this method is classified to the system dependent. On the other hand, the descriptive contents have a little relationship with the users and so this method is categorized to the user dependent. The descriptive contents are the same every time the users write; therefore, the security is lower and the usability is higher than the method in Ref. [7].

The above verification methods using the writing are sum-

TABLE I
CLASSIFICATION OF VERIFICATION METHODS USING THE WRITING.

	System Dependent	System Independent
User Dependent	Text-Indicated	Signature
User Independent	?	Free-Writing

marized in Table I from the viewpoint of "user dependent/independent" and "system dependent/independent". From this categorization, we can find a new category, which is independent of users and dependent on verification systems. It is indicated as "?" in the figure. The descriptive contents are specified by the systems and have no relationship with the users. The authors call this category "text-indicated free-writing" in convenience.

In the free-writing verification, the descriptive contents are specified by users while by systems in this category. Therefore, the security of this category has comparable with that of the free-writing verification. On the other hand, the descriptive contents must be different every time users write them but they are specified by systems in this category, so that the usability is higher than that of the free-writing verification. However, verification methods based on any pattern matching cannot be applied in this category as well as the free-writing verification. Some kind of "Habit" in writing must be extracted from written data and/or writing process.

Straightforward realization of text-indicated free-writing develops a verification system that requires users to write something that has no relationship with the users and be different every time the users write it. Some methods based on this realization approach might have been already proposed but the authors are unfortunately unaware of them. This system puts a high priority on security than usability.

On the other hand, putting a high priority on usability than security in this category creates a completely different verification system. Users write a symbol that is simple, well-known, and never forgotten and mistaken, for example, a circle, a cross, a triangle, and a square. In a verification stage, to write a simple symbol makes usability the highest. There is no relationship with the descriptive content and users; therefore, this system is user-independent. The descriptive content is specified by the system and it results in being system-dependent.

Table II shows comparison of the above mentioned methods on security and usability, where the order corresponding to $\bigcirc$, $\triangle$, $\bigtriangledown$, and $\times$ shows that of the superiority of the methods. However, these evaluation are relative. Please be aware that the $\times$ never shows that the methods with such an evaluation does not have security or usability.

The proposed writer verification method is defined by the highest usability comparing with conventional methods. The descriptive content of the proposed method is well known to everyone and simple, so that to adopt some verification method based on pattern matching makes it very easy to imitate what users write. The security level becomes extremely

TABLE II
COMPARISON OF WRITER VERIFICATION METHODS ON SECURITY AND USABILITY

	Secutiry	Usability
Free-Writing	$\bigcirc$	$\times$
Text-Indicated Free-Writing	$\bigcirc$	$\bigtriangledown$
Text-Indicated [7]	$\triangle$	$\times$
Text-Indicated [8]	$\bigtriangledown$	$\triangle$
Signature	$\bigtriangledown$	$\triangle$
Proposed	$\times$	$\bigcirc$

low. However, if verification using extracted "Habits" from written data and/or writing process is applied to the proposed method, a certain level of security is guaranteed.

II. FINGER-WRITING OF A SIMPLE SYMBOL

In order to further increase the usability of the proposed method, the authors to propose to write a simple symbol by not using a pen but directly a finger on a display of a tablet or a smartphone. We call this "finger-writing" for discriminating from the writing using a pen.

A. *Supposed Applied Scene*

The proposed verification method based on finger-writing of a simple symbol put a high priority on usability; therefore, it is not suitable for person authentication with high security. Login authentication for personal information equipment, for example, a smartphone or a tablet is suitable for the proposed method. In general, password authentication or pattern-lock authentication is adopted as the login authentication in smartphones or tablets. However, their usability is low because the passwords and the patterns require users to remember them. In the proposed verification method, it is assumed that all users have already known to write a simple and unforgettable symbol like a circle, cross, triangle, or square; therefore, to remember the symbol is not required.

Recently, there are smartphones equipping authentication using the fingerprint, face, and iris, which are of static biometrics. However, such static biometrics have vulnerability as described below. It is easy to capture the static biometric data since they are stable and detectable by using easily available digital equipment, for example, a scanner or a digital camera. By using the secretly captured data from genuine users, fake fingerprint, face, and iris can be easily produced

Therefore, the static biometrics have the vulnerability that the spoofing can be performed by using the secretly captured data. On the other hand, the proposed method is categorized to the dynamic biometrics. Furthermore, "Habits" in writing is invisible, so that it is difficult for forgers to imitate the writing of genuine users.

B. *Simple Symbols*

As descriptive content, characters are not suitable for the proposed method because they depend on languages. On the other hand, symbols are independent of languages. However, complicated symbols are not adequate since users write them by not a pen but a finger on a tablet display. In addition, from the viewpoint that all people around the world know the symbol, never forget it, and never mistake to write it, we focus on ◯, △ and □ in this paper. These are unicursal.

C. Individual Features

In the proposed method, it is impossible to compare written data based on their shapes, that is, pattern matching. It is necessary to extract the writing-habits from written data and/or writing process.

As the start, the authors evaluated the following features in this paper.

- On-Line features
  - Maximum speed of writing
  - Maximum acceleration of writing
  - Writing interval
- Off-Line Features
  - Distance between the beginning and the end points of a written symbol
  - Maximum values of X and Y of a written symbol
  - Minimum values of X and Y of a written symbol
  - Averaged values of X and Y of a written symbol
  - Difference between the maximum and the minimum values in X and Y of a written symbol

Assuming that the sampling period is constant, the sampling period is defined as one, so that the writing speed is substituted by the distance between successive two sampled points. In addition, the acceleration is obtained by the difference of speed (distance).

III. Experiments for Evaluation

The authors constructed an experimental environment for obtaining finger-writing data using a tablet and then measured finger-writing data from experimental subjects and evaluated their verification performance using the above mentioned features.

A. Experimental Environment

The tablet used in this experiment was Hi8 PRO 8 inch tablet produced by CHUWI Inc.. Its specifications are summarized in Table III. As the developing environment, Android Studio was used.

TABLE III
SPECIFICATIONS OF THE USED TABLET.

OS	Android 4.4
CPU	Intel Atom Z3736F
RAM	2 GB
Storage	32 GB
Display	8 inch IPS (1920×1200)
Size	207.4×122.1×7.9 mm
Weight	310 g

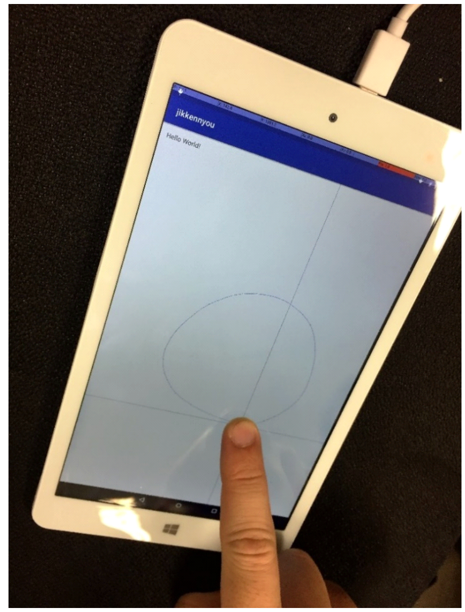

Fig. 1. An experimental scene.

B. Experimental Conditions

The number of the experimental subjects was twenty and they all were male from 22 to 24 years old. Prior to the experiment, they are briefly explained the purpose of the experiment, the descriptive contents, and the experimental procedure. The subjects sit a chair in a well-lit place. Figure 1 shows the experimental scene. Evaluated symbols were ◯, △ and □ as mentioned the above. To write these three symbols was regarded as one set. The interval between their writings was about thirty seconds. To avoid the influence of successive writings on evaluation, the interval between sets was more than six hours. Each subject performed the set for twenty times.

C. Evaluation Results

Euclidian Distance matching was used as a verification method. The number of dimensions of all features was one. The first ten data were used for making a template and the rest ten data was used for evaluation. The evaluation value was an equal error rate (EER).

EERs of all features in three symbols are summarized in Table IV and V.

TABLE IV
EER (%) OF ON-LINE FEATURES IN THREE SYMBOLS.

Maximum Speed	◯	31.0
	△	30.5
	□	28.8
Maximum Accelerator	◯	35.3
	△	32.4
	□	33.8
Writing Interval	◯	29.0
	△	27.0
	□	26.0

TABLE V
EER (%) OF OFF-LINE FEATURES IN THREE SYMBOLS.

Distance between Beginning and End points	○	42.8
	△	43.5
	□	44.4
Averaged values of X	○	39.8
	△	41.4
	□	39.8
Averaged values of Y	○	33.5
	△	36.0
	□	30.5
Maximum values of X	○	32.9
	△	32.5
	□	35.0
Maximum values of Y	○	33.4
	△	35.5
	□	36.5
Minimum values of X	○	30.5
	△	32.8
	□	31.9
Minimum values of Y	○	38.5
	△	33.9
	□	32.5
Difference between Max. and Min. values in X	○	27.0
	△	28.0
	□	28.0
Difference between Max. and Min. values in Y	○	30.0
	△	31.3
	□	29.3

D. Discussions

As the simple features were used in this evaluation, EERs were not so low. However, the EERs in the case of using the writing interval and the difference between the maximum and the minimum values in X were lower than 30 %; therefore, using more effective features, it is expected to realize the writer verification based on finger-writing of a simple symbol on a tablet display.

The smallest (best) EER of 26 % was obtained when the writing interval of □ was used as an individual feature. Comparing with EERs of other on-line features, those of the writing interval are relatively low. The writing interval is a relative amount, that is, a time difference between the beginning and the end points in writing.

In the case of off-line features, EERs of the difference between the maximum and the minimum values in X were relatively low regardless of symbol. The differences between the maximum and the minimum values of not only X but also Y are relative amounts while other off-line features, that is, averaged, the maximum, and the minimum values of X and Y are absolute amounts. In this experiment, there was no guide for subjects to the writing place; therefore, they freely wrote the symbols on the tablet display. Therefore, the degree of freedom to the writing place was higher than that of the conventional writer verification.

It is concluded that to use relative amounts as individual features is more effective in the proposed method.

On the other hand, the worst EERs were obtained regardless of symbol when the distance between the beginning and the end points that was also a relative amount was used. The three symbols regularly have closed shape but in finger-writing the beginning and the end points never be the same as shown in Fig. 2. The authors had an idea that such a difference became an individual feature. However, the intra-individual variation might be larger than the inter-individual variation, so that the verification performance was not good.

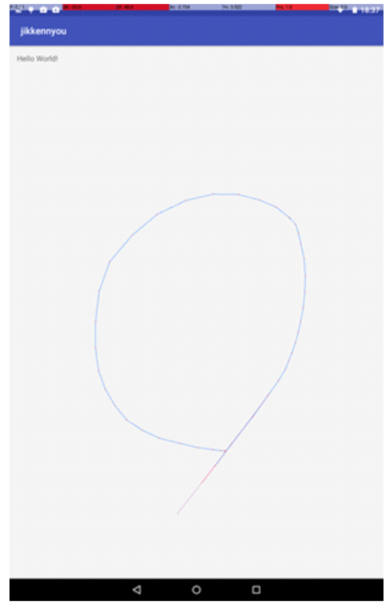

Fig. 2. An example of written symbol.

IV. Conclusions

As one of writer verification methods, the authors proposed to write a simple symbol by a finger on a tablet display. Everyone knows the simple symbol, and never forget and mistake to write it. This proposed method performs the highest usability comparing with conventional methods.

In this paper, the authors constructed a finger-writing environment using Android tablet and measured two-dimensional coordinate data of the finger position on the tablet from twenty experimental subjects who wrote a ○, △, and □. At the start of the evaluation, the authors examined verification performance using simple on-line and off-line features extracted from writing data of those symbols. As a result, it could be confirmed feasible to realize the writer verification based on finger-writing of a simple symbol on a tablet display when relative individual features are used.

The authors are now constructing another finger-writing environment to detect not only finger position data but also the data of contact-pressure and contact-area that are detectable in recent smartphones and tablets. The contact pressure and area data are invisible; therefore, they are harder to imitate by forgers. In addition, to use time-series data of finger-position, contact-pressure and contact-area, and to fuse them in feature extraction and verification are problems to be solved. The authors will report the evaluation results in near future.

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