Values of Time-series Data defined in 19794-7 for Signature Verification

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Abstract. The signature/sign time-series data format 19794-7:2007 was standardized in ISO/IEC JTC1 SC37 WG3. The format handles various data such as pen tip position (x,y,z), pen tip velocity (vx,vy), pen tip acceleration (ax,ay), pen tip force (f), pen azimuth (a), pen elevation (e) and so on. It is valuable that this data format enables different types of input devices to be used in signature/sign verification. However, there is no comparison of verification performance by these data, and no idea in mixing multiple data for improving verification performance. In this paper, nine kinds of time series data (x, y, vx, vy, ax, ay, f, a, e) calculated from the data acquired by WACOM tablet are used to signature verification for comparing their values by false rejection rate (FRR) and false acceptance rate (FAR) with changing decision threshold. In the verification, non-linear matching is used in making a template and calculating the distance between two signatures. The relationship between FRR and FAR with and without forgery is also given by experimental results of 11 Japanese signatures.

1 Introduction

In 2000, we have proposed the signature verification method which uses three features such as pen position, pen pressure and pen inclination [HYH00]. In the paper, we have shown that the pen inclination is robust to forgery signatures after non-linear matching. By some investigations regarding intersession variability of signature time series data, we have pointed out that periodical template updating is effective to keep the error rate of signature verification system to low[YKH01][KHH02]. Since 2003, our group has contributed to the standardization of 19794-7:2007 and its revised version which is signature/sign time-series data format and the format is now the way to be standardized. The format handles various data such as pen tip position (x,y,z), pen tip velocity (vx,vy), pen tip acceleration (ax,ay), pen tip force (f), pen azimuth (a), pen elevation (e) and so on[ISO11]. It is, of course, valuable that this data format enables different types of input device to be used and is flexible with any signature verification algorithm. As seen in signature verification competition SVC2004

[YCH04], the best EER against skilled forgeries was 2.84% using (x,y) and 2.89% using (x,y,f,a,e) respectively. In BMEC2007 [TEL07], the best EER against skilled forgeries was 13.43% using (x,y,f,a,e). Obviously, we are not satisfied with these error rates because the error of fingerprint verification is very low. In order to solve this problem, global features which use multiple data up to 100 were proposed [GFF07][TBa05].

In this paper, individuality included in nine kinds of time series data (x, y, vx, vy, ax, ay, f, a, e) calculated from the data acquired by WACOM tablet and the categorized data set such as pen tip position, pen tip force, pen inclination, pen tip velocity and pen tip acceleration are examined. The robustness against forgery signatures is also investigated based on FRR and FAR using two types of forgery, i.e., simulation and tracing.

2 Writing Data Acquired by Tablet and Errors to be used in Verification process

Fig. 1 shows acquired five writing data, i.e., pen tip position x(n) and y(n), pen tip force f(n), pen azimuth a(n), and pen elevation e(n) from a tablet with the specification given in Table 1.

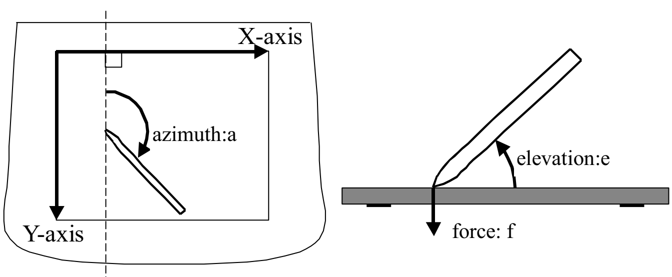


Fig. 1. Acquired five writing data.

Table 1 Specification of tablet and pen

Tablet	GD-0405-R:product of WACOM
Dimensions	127 x 99 mm
Force levels	1024
x-y Resolution	0.01mm
Max. data rate	200 pps
Azimuth range	0 - 359 degree
Elevation range	27 - 90 degrees
Tilt Resolution	1.0 degree

Velocity and acceleration are calculated by the following equations,

$$vx(n) = x(n) - x(n-1)$$
$$vy(n) = y(n) - y(n-1) \quad (1)$$

$$ax(n) = vx(n) - vx(n-1)$$
$$ay(n) = vy(n) - vy(n-1) \quad (2)$$

Fig. 2 shows an example of 5 kinds of time series data obtained by tablet.

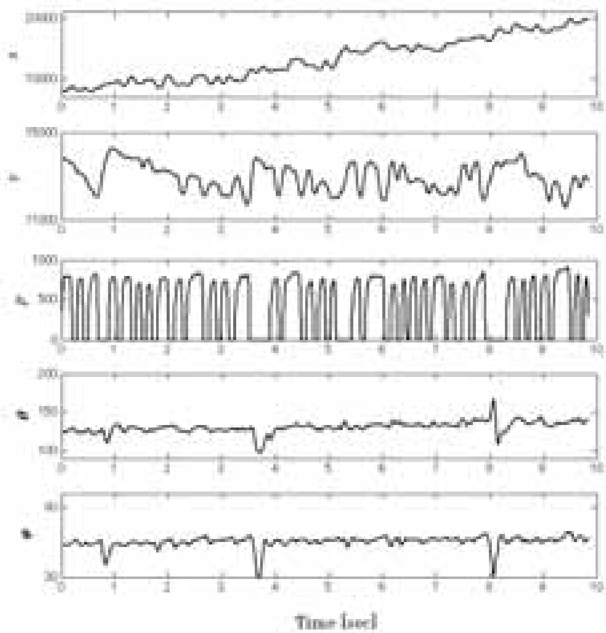


Fig.2 An example of acquired data by tablet

Respective errors in matching the *i*-th test signature S_i ={x_i, y_i, f_i, a_i, e_i, vx_i,vy_i,ax_i, ay_i} to the template signature S_T ={x_T, y_T, f_T, a_T, e_T, vx_T, vy_T, ax_T, ay_T} are calculated by the following equations,

$$\begin{aligned} &e_x(n) = \left|x_i(n) - x_T(n)\right|, \quad e_y(n) = \left|y_i(n) - y_T(n)\right|, \\ &e_f(n) = \left|f_i(n) - f_T(n)\right|, \quad e_a(n) = \left|a_i(n) - a_T(n)\right| \\ &e_e(n) = \left|e_i(n) - e_T(n)\right|, \quad e_{vx}(n) = \left|vx_i(n) - vx_T(n)\right|, \\ &e_{vy}(n) = \left|vy_i(n) - vy_T(n)\right|, \quad e_{ax}(n) = \left|ax_i(n) - ax_T(n)\right|, \\ &e_{ay}(n) = \left|ay_i(n) - ay_T(n)\right|. \end{aligned} \quad (3.1)$$

The categorized errors, i.e., pen position error $e_P(n)$, pen force error $e_F(n)$, pen inclination error $e_I(n)$, pen velocity error $e_V(n)$, and pen acceleration error $e_A(n)$ are calculated by the following equations,

$$e_P(n) = \sqrt{\{x_i(n) - x_T(n)\}^2 + \{y_i(n) - y_T(n)\}^2} \quad (3.2)$$

$$e_F(n) = \left|f_i(n) - f_T(n)\right| \quad (3.3)$$

$$e_I(n) = \cos^{-1}\left(\frac{\vec{V}_i(n)\cdot\vec{V}_T(n)}{\left|\vec{V}_i(n)\right|\left|\vec{V}_T(n)\right|}\right) \quad (3.4)$$

$$e_V(n)=\sqrt{\{vx_i(n)-vx_T(n)\}^2+\{vy_i(n)-vy_T(n)\}^2} \tag{3.5}$$

$$e_A(n)=\sqrt{\{ax_i(n)-ax_T(n)\}^2+\{ay_i(n)-ay_T(n)\}^2} \tag{3.6}$$

,where $\vec{V}(n)$ is a 3D vector, which gives the feature of pen inclination as follows,

$$\vec{V}(n)=\begin{bmatrix}\sin a(n)\cos e(n)\\ -\cos a(n)\cos e(n)\\ \sin e(n)\end{bmatrix} \tag{3.7}$$

.

In making template and/or verifying signature, we use the individual accumulated errors and the categorized accumulated errors as shown in following equations,

$$E_x=\sum_{n=0}^{N-1}e_x(n)\quad,\quad E_y=\sum_{n=0}^{N-1}e_y(n),\quad E_f=\sum_{n=0}^{N-1}e_f(n),\quad E_a=\sum_{n=0}^{N-1}e_a(n),\quad E_e=\sum_{n=0}^{N-1}e_e(n),$$

$$E_{vx}=\sum_{n=0}^{N-1}e_{vx}(n),\ E_{vy}=\sum_{n=0}^{N-1}e_{vy}(n),\ E_{ax}=\sum_{n=0}^{N-1}e_{ax}(n),\ E_{ay}=\sum_{n=0}^{N-1}e_{ay}(n),$$

$$E_P=\sum_{n=0}^{N-1}e_P(n),\ E_F=\sum_{n=0}^{N-1}e_F(n),\ E_I=\sum_{n=0}^{N-1}e_I(n),\ E_V=\sum_{n=0}^{N-1}e_V(n),\ E_A=\sum_{n=0}^{N-1}e_A(n) \tag{4}$$

3 Experimental Results

3.1 Experimental Method

Fig. 3 shows the schematic diagram for testing features in signature verification system.

The number of writers is 11, and each writer is requested to make genuine signature 10 times. Four of genuine signatures are used to make the template by the following process.

1) Inspect matching part in signatures for registration, and define the data that has the longest writing time as 'parent' data. Others are defined as 'child' data.
2) Compress or expand the time axis of child data to fit the time axis of parent data by Dynamic Programming (DP)

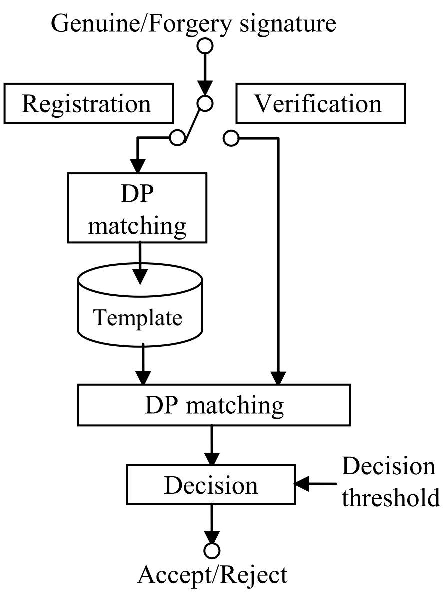


Fig. 3 signature verification system for feature testing.

matching. In DP matching, the path which relates corresponding samples of parent data with those of child data is determined with minimizing pen position error given by Eq.(3.2).

3) After DP matching, make the template data set by averaging in each time slot.

Six genuine signatures are matched to the template, and matching error is used for deriving the relationship between decision threshold and false rejection rate (FRR).

11 Japanese writers are also requested to make two kinds of forgery signature of 10 another writers. One is simulated forgery signature, and the other is traced forgery signature. The former is made by simulating signature with looking another genuine signature, and the later is made by tracing another genuine signature written on a paper. These signatures are matched to the template, and the matching error is used for deriving the relationship between decision threshold and false acceptance rate (FAR).

FRR and FAR characteristics are used to present the performance of features in the signature verification system, and equal error rate (EER) which is the error rate at that point where FRR and FAR characteristic curves intersect is also a measure of performance.

In the following sections, FRR, FAR and EER in two kinds of verification system using individual accumulated error or categorized error are compared.

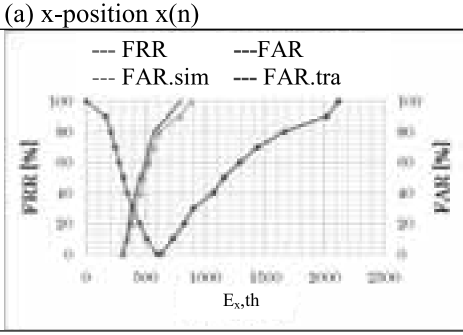
3.2 Error Rate using individual accumulated error

Fig. 4 (a)-(i) shows the relationship between FRR and FAR by changing decision threshold for the error defined by nine equations in Eq.(4) with and without forgery.

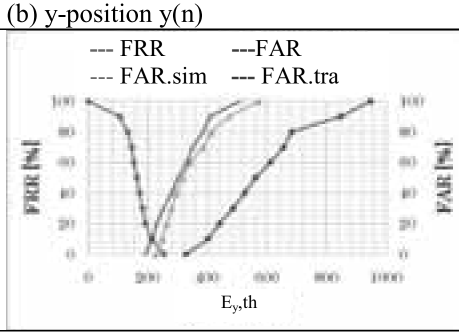
From these figures, three kinds of data, i.e., y-position, force, and velocity y, have a margin in the threshold for EER=0 in case of no forgery. On the other hand, each of elevation, acceleration-x and acceleration-y shows 20% or more EER, even if no forgery exists.

Forgery affects FAR of x-position and y-position. But azimuth and velocity-y is robust to forgery.

(a) x-position x(n)



(b) y-position y(n)



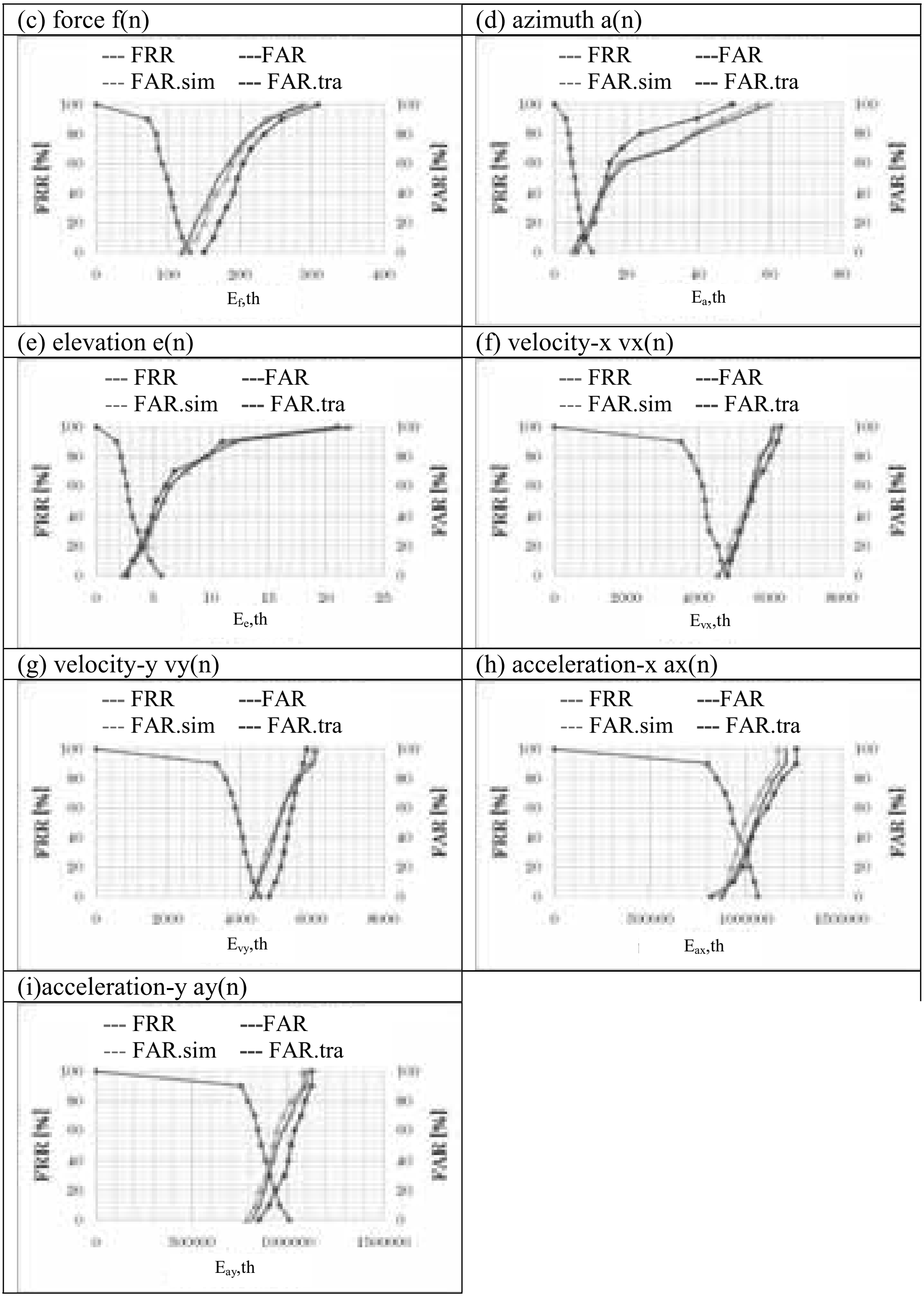


Fig.4 Relationship between FRR and FAR with and without forgery

3.2 Error Rate using categorized accumulated error

Fig. 5 (a)-(e) shows the relationship between FRR and FAR using the error defined by five equations in Eq.(4) with and without forgery. From the figure, it is shown that force and velocity are good features for verifying signature including forgery.

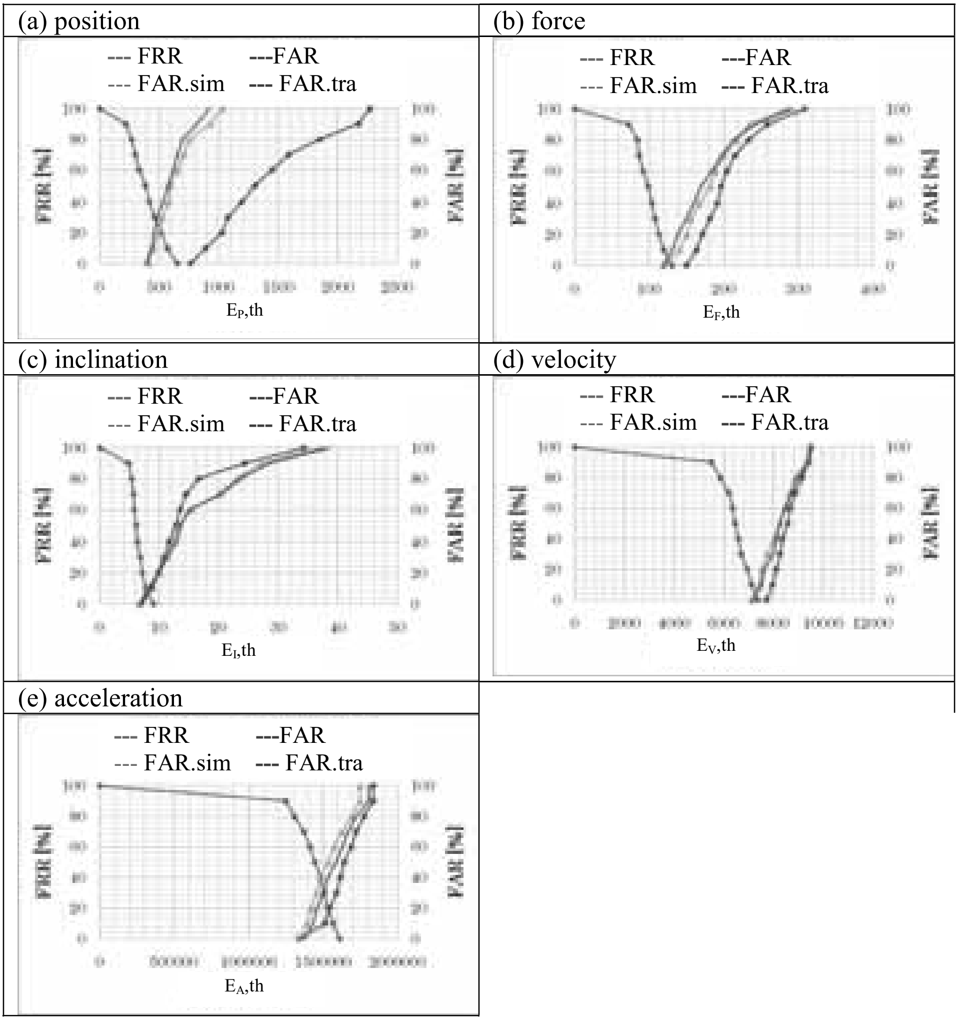


Fig.5 Relationship between FRR and FAR with and without forgery

3.3 EER based evaluation

Table 2 shows the summary of EER for 9 individual data which is involved in the ISO/IEC 19794-7 format and 5 categorized data with and without forgery.

From the table, x channel data, y channel data, f channel data, vx channel data and vy channel data are valuable for Japanese signature verification if there is no forgery.

This tendency is also found in remaking data set based on five categories such as position, force, inclination, velocity and acceleration. Although these results are obtained by DP matching algorithm and very limited samples, it is found that acceleration is bad features for verification if no post process is applied.

Table 2 Summary of EER of each data

	Forgery		
	Non	simulated	tracing
E_x	0	30	40
E_y	0	10	10
E_f	0	10	10
E_a	10	20	20
E_e	30	20	20
E_{vx}	0	10	10
E_{vy}	0	10	10
E_{ax}	30	40	40
E_{ay}	20	40	40

	Forgery		
	Non	simulated	tracing
E_P	0	30	30
E_F	0	10	10
E_I	10	10	10
E_V	0	10	10
E_A	20	50	40

unit: in %

4 Conclusion

In this paper, we have shown the robustness of signature verification system using nine kinds of data and five categorized data which are involved in ISO/IEC 19794-7:2007 data format against forgery. Although the number of signature is not sufficient, it has been found that pen tip acceleration and pen elevation angle are bad features for verification, and further research on pen tip force, pen tip velocity and pen inclination which showed good results might be focused on those to confirm the results on a larger test base. Increasing data size for reliable results and inter operability using different tablets are subjects in future works.

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