Efficient on-line signature verification system

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***Abstract*-In this paper, a robust automatic on-line signature verification system is proposed. The effectiveness of any on-line signature verification system depends mainly on the robustness of the dynamic features use in the system. Inability to extract highly discriminative dynamic features from signature has been contributing to higher verification error-rates. On-line signature verification experiments are conducted on seven dynamic signature features extracted from signature trajectories. Three features are found to be highly discriminative in comparison with others. The proposed system incorporates these three features for signature verification. Verification is based on the average of all the distances obtain from the cross-alignment of the features. The proposed system is tested with quality signature samples and it has 0.5% error in rejecting skilled forgeries while rejecting only 0.25% of genuine signatures. These results are better in comparison with the results obtained from previous systems.**

Keywords -Dynamic features, Dynamic Time Warping, Skilled forgeries, On-line Signatures Verification,

1. INTRODUCTION

Signature verification involves authentication of a person claimed signature in order to determine whether the claimed signature belong to the claimer or not. The signature verification can be done manually or automatically. Automatic signature verification can be classified into two categories: on-line and off-line. In off-line technique, signature is obtained on a piece of paper and scanned to a computer system while in on-line technique signature is obtained on a digitizer connected to a computer system. On-line signature verification involves comparison of two parameter vectors, that is, a template signatures stored in the system database and a test signature. The verification process is based on dynamic features captured during the process of writing the signature with a special pen on a digitizing tablet.

Jain et al[1] developed an on-line signature system that uses nine local features which includes the x and y coordinate differences between two consecutive points (Δx, Δy), curvature β, gray values in 9x9 neighborhoods, the sine and cosine of the angle with the x-axis, absolute and relative speeds. Alisher Kholmatov et al [3] proposed an on-line signature verification system that uses local features of the points on the signature trajectory: x-y coordinates relative to the first point of signature trajectory, the x and y coordinate differences between two consecutive points and the curvature differences between two consecutive points. Also Ohishi et al [4] presented a PPI (pen-Position, pen-Pressure, and pen-Inclination) algorithm for on-line pen input verification. Julian Fierrez et al [5] developed a function-based approach for on-line signature verification. The system uses a set of time sequences and Hidden Markov Model (HMM). And Tong Qu et al [6] proposed a novel stroke-based feature for Dynamic System Verification (DSV).

The verification error-rates of the above mentioned systems are not too encouraging particularly for skilled forgeries. Therefore in this paper, experiments are carried out to search for more discriminative features since this will go a long way to improve the effectiveness of the proposed system. And three features are found to be highly discriminative in comparison with other extracted features; these features are used to build the proposed system.

Also in previous systems, classification decisions are based on minimum, maximum distance of a test signature from the reference signatures and template distance [1], [2]. But in the proposed system, we developed a better method in which the threshold value is obtained based on the average of all the distances obtained from the cross-alignment of all reference signatures.

The rest of the paper is organized as follows: Section II describes the system component and data acquisition method is presented in section III, section IV introduces the feature extraction method, and section V describes the training process and threshold selection, section VI presents the classification algorithm. The experimental results are shown in section VII. Finally, conclusion is presented in section VIII.

II. SYSTEM DESCRIPTION

The proposed on-line signature verification block diagram is shown in fig.1. It consists of a data acquisition, feature extraction, training, and classification stage. The training and classification stages use Dynamic Time Warping (DTW) algorithm to establish a correspondence between feature sequences of signature samples.

A. Data Acquisition Device

The proposed system used a graphics tablet from wacom as capturing device. The tablet is as shown in fig. 2. It is intuos3 A6 model with USB interface. This tablet provides 100 samples per second contain values for pressure, x and y co-ordinate points for every sample at very fine resolution of 0.005cm. The system is able to capture signature samples both at pressure and non-pressure sample points [7]. The raw signature data available from the tablet consists of three dimensional series data as represented by equation (1), where (x(t), y(t)) is the pen position at time (t) and $p(t) \in \{0,1,\ldots,1024\}$ represents the pen pressure.

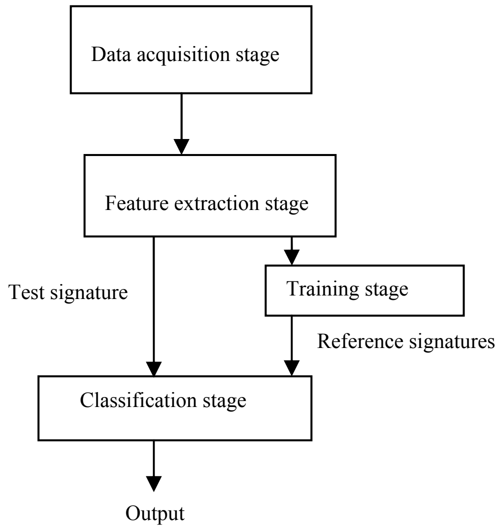

Fig.1. Proposed on-line signature verification system block diagram.

III. ON-LINE DATA ACQUISITION

On-line signature samples are collected from 200 users, each user signed ten genuine signatures on the digitizer. Total on-line genuine signature samples collected amounted to 2000. These signatures are collected over a period of three months. At the same time, 100 forgers made 400 skilled forgeries after study the shape and dynamic movement and manner in which the genuine users signed. An example of genuine signatures and corresponding pressure graph of one particular user is shown in fig.3, also the skilled forgeries version is shown in fig.4.

$$S(t) = [x(t), y(t), p(t)]^T \; t = 0,1,2,.........., n \quad (1)$$

A. *Dynamic Signature Preprocessing*

In this paper, signatures preprocessing is not carried out on the dynamics signatures in order to preserve the timing characteristics of the user's signatures. Actually preprocessing stage is an important stage in automatic signature verification systems particularly when acquired signatures have been corrupted but in many cases unique properties of the user's signature are lost during preprocessing. In [1], preprocessing was done; they uniformly re-sampled the signatures at equal interval points along the signature curve. Also in [4], [8] preprocessing was carried out, they re-sampled signature curve in such a way as to retain the critical points while in [9] tangent angle sequence was re-sampled to equidistant points. In [2], [3], [5], [10] they didn't perform any preprocessing also we didn't preprocess the data because the same equipment with good resolutions is used throughout the period of data collection.

Fig. 2. On-line signature graphics tablet.

VI. NEW ON-LINE SIGNATURE FEATURES

Seven on-line signature features are extracted at each sampling point from the raw data. The features are Δx, Δy, Δp, Δy/Δx, Δp/Δx, Δp/Δy and v. Δx corresponds to change of x between two successive sampling points, Δy corresponds to change of y between two successive sampling points, Δp corresponds to change of p between two successive sampling points, Δy/Δx corresponds to ratio of Δy to Δx, Δp/Δy corresponds to ratio of Δp to Δy, Δp/Δx corresponds to ratio of Δp to Δx and v which corresponds to change of speed between two successive sampling points. These features are obtained using equation (2, 3 - - - 8).

$$\Delta x = x(t) - x(t-1) \quad (2)$$

$$\Delta y = y(t) - y(t-1) \quad (3)$$

$$\Delta p = p(t) - p(t-1) \quad (4)$$

$$\frac{\Delta y}{\Delta x} = \frac{y(t) - y(t-1)}{x(t) - x(t-1)} \quad (5)$$

$$v = \sqrt{(\Delta x)^2} + (\Delta y)^2 \quad (6)$$

$$\frac{\Delta p}{\Delta y} = \frac{p(t) - p(t-1)}{y(t) - y(t-1)} \quad (7)$$

$$\frac{\Delta p}{\Delta x} = \frac{p(t) - p(t-1)}{x(t) - x(t-1)} \quad (8)$$

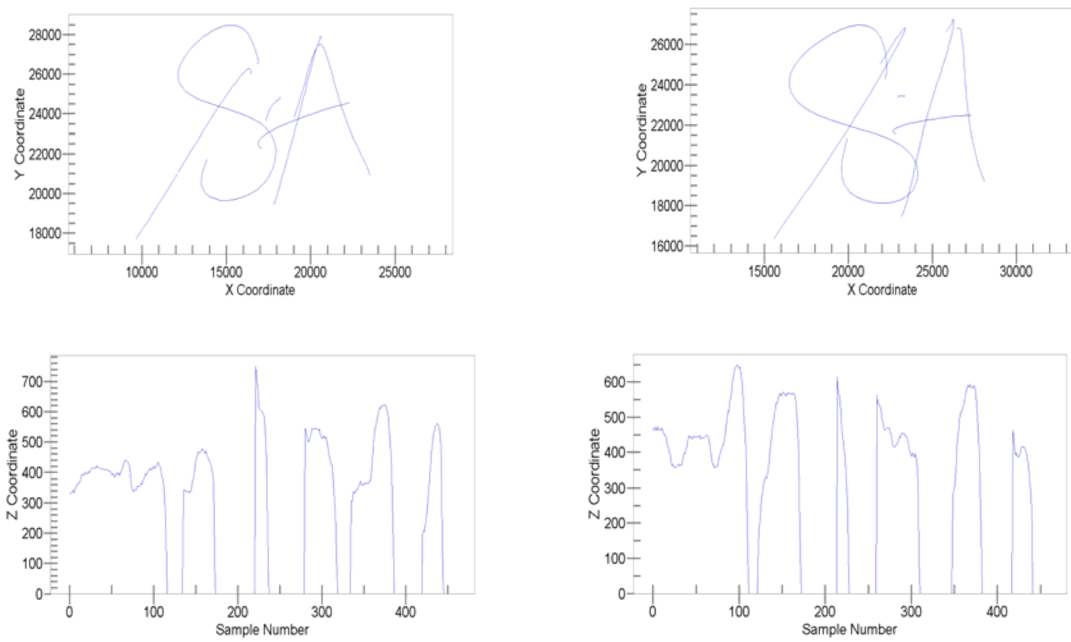

Figure 3: Genuine on-line signatures and the corresponding pressure graph

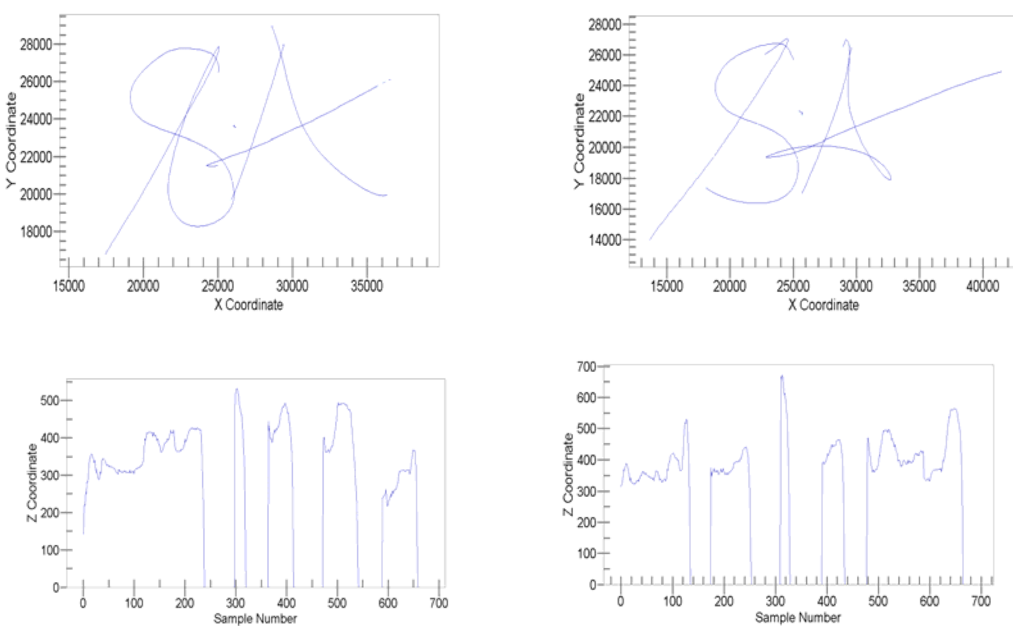

Figure 4. Skilled forgeries and the corresponding pressure graph

V. TRAINING AND THRESHOLD SETTING

Each registered user submitted 10 genuine signatures to the system, out of which six signatures are used to generate 15 distance values by, cross-aligned the signature features to the same length using Dynamic Time Warping (DTW). These distance values are used to measure the variation within each user's signatures, so as to set user-specific thresholds for accepting or rejecting a test signature. Given six reference signature samples S1, S2, S3, S4, S5 and S6, these signatures are cross aligned to obtain 15 distance values as shown in fig. 5. The mean (m_k) and standard deviation (σ_k) of the distance d_{12}, d_{13}, d_{14}, d_{15}, d_{16}, d_{23}, d_{24}, d_{25}, d_{26}, d_{34}, d_{35}, d_{36}, d_{45}, d_{46} and d_{56} are calculated and used to set the threshold (t_k) for each user based on each feature as given in equation (9).

$$0 \geq t_k \leq m_k + \sigma_k \tag{9}$$

VI. CLASSIFICATION

Whenever a test signature comes into the system, the feature vector of the test signature is pair wise aligned with each of the six reference signatures using DTW. Six distance values are obtained as shown in fig.6. The distance (d_t) of test signature (ST) from the six reference signatures S1, S2, S3, S4, S5 and S6 is calculated using equation (10).

$$d_t = \frac{d_{T1} + d_{T2} + d_{T3} + d_{T4} + d_{T5} + d_{T6}}{6} \tag{10}$$

If d_t is within the assigned threshold then the test signature is assigned a pass mark otherwise it has no pass mark. Finally a decision by the system in accepting or rejecting a test signature is based on total pass mark it obtained based on the three features.

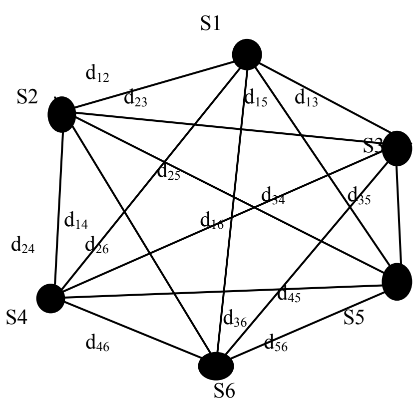

Fig. 5. Cross-alignment of reference signatures

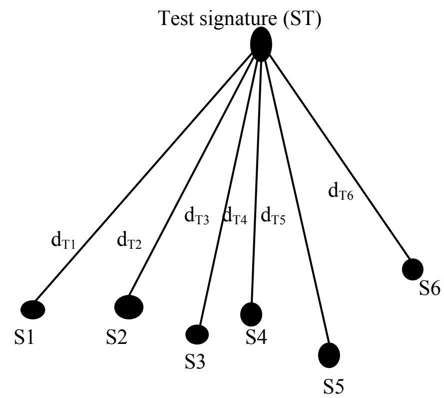

Fig. 6. Distance between reference signatures and test signature

VII. EXPERIMENT RESULTS.

We performed experiments on seven features (Δx, Δy, Δp, Δy/Δx, Δp/Δx, Δp/Δy and v) in order to determine the information content in each feature based on maximum, minimum and average distance threshold. The result in table 1 shows the verification results for each feature, it is discovered that features (Δy/Δx, Δp/Δx and v) have low verification error rate in comparison with others using average distance threshold. The proposed on-line signature verification system is tested using 800 genuine signatures from 200 users, 400 skilled forgeries from 200 forgers and 400 random signatures. The combination of features (Δy/Δx, Δp/Δx and v) and average distance threshold are used in the proposed system. Table 2 shows the on-line signature verification results for the proposed system. Actually [1], [2] and [3] used related features with minimum or template distance for signature verification but the FAR and FRR results obtained from the proposed system are better in comparison with the results obtained from the previous systems.

VIII. CONCLUSION

Efficient on-line signature verification system is needed in order to increase security in access control and financial transaction. The proposed system is robust enough to improve the current situation. The excellent verification results obtained from the system can be traced to the combined robust features and good threshold setting adopted. The system is better in comparison with previous systems in its ability to give low error-rates against forgeries.

TABLE 1 RESULT OBTAINED FROM SEVEN EXTRACTED FEATURES.

Features	Maximum distance		Average distance		Minimum distance	
	FAR	FRR	FAR	FRR	FAR	FRR
Δx	0.30	0.15	0.05	0.10	0.10	0.10
Δy	0.125	0.125	0.01	0.10	0.125	0.10
Δy/Δx	0.10	0.10	0.025	0.025	0.05	0.025
Δp	0.150	0.250	0.010	0.075	0.125	0.150
Δp/Δy	0.125	0.150	0.075	0.10	0.05	0.075
Δp/Δx	0.100	0.150	0.05	0.025	0.05	0.075
v	0.075	0.10	0.05	0.05	0.15	0.10

TABLE 2 VERIFICATION RESULT

Types of Signature	Signatures tested	Signatures accepted	Signatures rejected	FRR	FAR
Genuine signatures	800	798	2	0.25	
Skilled forgeries	400	2	398		0.50
Random forgeries	400	0	400		0.00

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