Person Identification System using Static-dyamic Signatures Fusion

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***Abstract*—Off-line signature verification systems rely on static image of signature for person identification. Imposter can easily imitate the static image of signature of the genuine user due to lack of dynamic features. This paper proposes person identity verification system using fused static-dynamic signature features. Computational efficient technique is developed to extract and fuse static and dynamic features extracted from offline and online signatures of the same person. The training stage used the fused features to generate couple reference data and classification stage compared the couple test signatures with the reference data based on the set threshold values. The system performance is encouraging against imposter attacker in comparison with previous single sensor offline signature identification systems.**

Keywords- fused static-dynamic signature; feature extraction; forgeries

I. INTRODUCTION

Person identity verification is a problem of authenticating individual using physiological or behavioral characteristics like face, iris, fingerprint, signature, speech and gait. Person identification problem can be solved manually or automatically. Biometric systems automatically use biometric trait generated from one or two sensors to validate the authenticity of a person. Automatic person identity verification based on handwritten signature can be classified into two categories: on-line and off-line, differentiated by the way signature data is acquired from the input sensor. In off-line technique, signature is obtained on a piece of paper and later scanned to a computer system while in on-line technique, signature is obtained on a digitizer thus making dynamic information like speed, pressure available while in offline only the shape of the signature image is available [1] [2].

In this paper, combination of offline and online signatures are used for person identification. The process involves verification of a signature signed on both paper and electronic digitizer concurrently. Therefore the physical present of the signer is required during the period of registration and verification. This type of system is useful particular in the bank while the physical present of the holders of saving current are required before money can be withdrawn. In Nigeria many banks manually identify holder of saving current using face and static signature, in the process genuine users are rejected as imposters because of high intra-class variation in signatures. Frauds as result of signature forgeries must be prevented particular among closely resemble people. Fusion of dynamic and static signature will strengthen the identification of people physically in paper documentation environment.

A detailed review of on-line signature verification including summary of off-line work until the mid 1990's was reported in [1] [2]. Alessandro et al. [3] proposed a hybrid on/off line handwritten signature verification system. The system is divided into two modules. The acquisition and training module use online-offline signatures, while the verification module deals with offline signatures. Soltane et al [4] presented a soft decision level fusion approach for a combined behavioral speech-signature biometrics verification system. And Rubesh et al [5] presented online multi-parameter 3D signature and cryptographic algorithm for person identification. Ross et al [6] presented hand-face multimodal fusion for biometric person authentication while Kiskus et al [7] fused biometrics data using classifiers.

From the approaches mentioned above, some of the authors used online signature data to strengthen the system performance either at registration or training stage, while others combined online signature data with other biometric modalities data like speech, face as means of person identification. The system proposes in this novel frame work is based on fusion of static and dynamic signature data at feature level for person identification. The universal acceptance of signature, compatibility of offline and online signature features make the proposed system more robust, accurate and friendly in comparison with other previous multi biometric modalities systems or single sensor offline system for person identification.

Section 2 provides the description of the system, the signature preprocessing and feature extraction and fusion technique. Also in section 2, the signature training, threshold selection and classification are presented. Section 3 shows the experimental results and finally, conclusions are drawn in section 4.

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II. PROPOSED SYSTEM

The system block diagram is shown in Fig. 1. The offline and online data are collected at the same time from the same user during registration/training and verification exercises. Also the offline signature are preprocessed to remove unwanted noise introduced during scanning process whereas, the online signatures are not preprocess in order to preserve the timing characteristics of the signature. Discriminative static and dynamic features are extracted separately from offline and online signature respectively. At the feature level the two signatures are fused together to obtain a robust static-dynamic features. These features are used to generate couple reference data during training and for signatures classification.

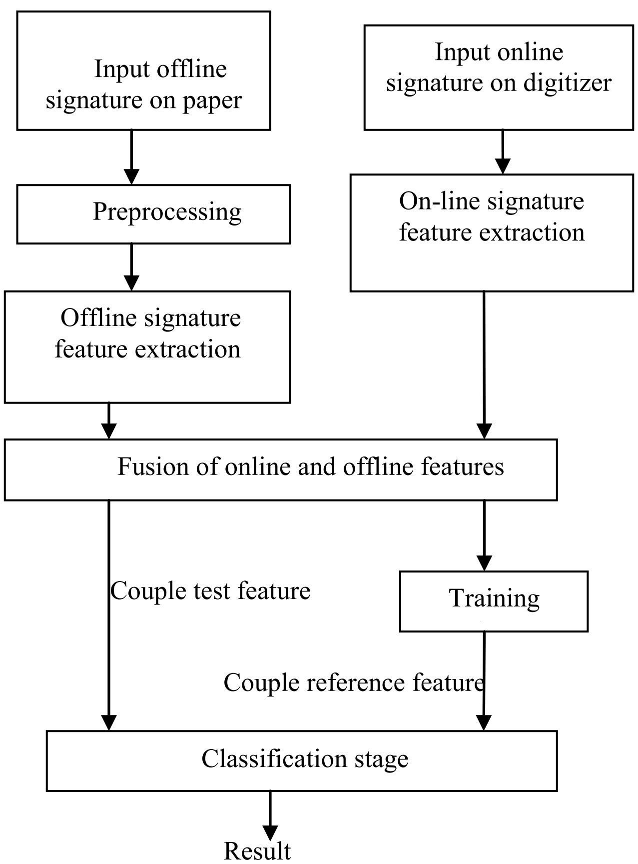

Figure1: System block diagram

A. *Data Acquisition*

The signature database consists of a total number of 300 offline and 300 online handwritten genuine signature images and 100 forged signatures. The genuine signatures are collected from 50 people. Each of the users contributed 6 offline and 6 online signature samples. The 100 skilled forgeries consist offline and online signatures, they are collected from 25 forgers and each of the forgers contributed 4 samples. The raw signature data available from our digitizer consists of three dimensional series data as represented by (1).

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

where $(x(t), y(t))$ is the pen position at time t , and $p(t) \in \{0,1,\ldots,1024\}$ represents the pen pressure.

B. *Offline Signature Preprocessing*

The scanned offline signature images may contain noise caused by document scanning and it has to be removed to avoid errors in further processing steps. The gray-level image is convolved with a Gaussian smoothing filter to obtain a smoothed image. The smoothed gray image is converted into binary image and then thinned to one pixel wide.

C. *Offline Feature Extraction*

The feature extraction algorithm for the static signature is stated as follows:

(1) Locate signature image bounding box.

(i) Scan the binary image from top to bottom to obtain the signature image height.

(ii) Scan the binary image from left to right to obtain the signature image width.

(2) Centralization of the signature image.

(i) Calculate centre of gravity of the signature image using (2).

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x(i),$$

$$\bar{y} = \frac{1}{N}\sum_{j=1}^{N} y(j). \qquad (2)$$

(ii)Then move the signature image centre to coincide with centre of the predefined image space.

(3) The image is partitioned into four sub-image parts.

(i) Through point $\bar{x}$ make a horizontal splitting across the signature image.

(ii) Through point $\bar{y}$ make a vertical splitting across the signature image.

(4) Partition each of the sub-image parts into four rectangular parts.

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(i) Locate the centre of each of the sub-image parts using (2).

(ii) Repeat step 3(i) and 3(ii) for each of the sub-image parts in order to obtain a set of 16 sub-image parts.

(5) Partition each of the16 sub-image parts into four signature cells

(i) Locate the centre of each of the sub-image parts using (2).

(ii) Repeat step 3(i) and 3(ii) for each of the sub-image parts in order to obtain a set of 64 sub-image cells.

(6) Calculate the angle of inclination of each sub-image centre in each cell to the lower right corner of the cell.

(i) Locate the centre of each of the 64 sub-image cells using (2)

(ii) Calculate the angle that each centre point makes with the lower right corner of the cell.

The feature extracted at this stage constitutes the offline feature vector, which is represented as: F = f_1, f_2, f_3, f_4……..f_{64}. The details and diagrams of the feature extraction are given in [8].

D. Online Signature Extraction

Three on-line signature features are extracted at each sampling point from the raw data. The features are 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, Δp/Δy corresponds to ratio of Δp to Δy, Δp/Δx corresponds to ratio of Δp to Δx and v corresponds to change of speed between two successive sampling points [9]. These features are obtained using (3), (4) and (5).

$$v = \sqrt{(\Delta x)^2} + (\Delta y)^2 \tag{3}$$

$$\frac{\Delta p}{\Delta y} = \frac{p(t) - p(t-1)}{y(t) - y(t-1)} \tag{4}$$

$$\frac{\Delta p}{\Delta x} = \frac{p(t) - p(t-1)}{x(t) - x(t-1)} \tag{5}$$

E. Fusion of Offline and Online features

This technique is designed to compute fused feature vector, which contains information from both the offline and online signatures and used this feature vector for subsequence processing. Information from two input sensors can be combined at data acquisition stage, feature extraction stage or at decision level stage. The accuracy of the system also depends on the level of fusion and the discriminative ability of fused data. In [4] the fusion of voice and signature data was done at decision level. While in [6] fusion of hand and face was done at feature level. In this work offline feature is combined with online feature at feature level. The compatibility of the signature data from the same person, from different sensors made the fusion possible without any lost of information. The steps involve are stated as follows: given that extracted static feature is F = f_1, f_2, f_3 , f_4……….f_{64}. The mean and variance of the feature vector are calculated using (6) and (7) respectively

$$\overline{\mu_{off}} = \frac{1}{N}\sum_{i=1}^{N} f_i \tag{6}$$

$$\sigma_{off}^2 = \frac{1}{N}\sum_{i=1}^{N}(f_i - \overline{\mu_{off}}) \tag{7}$$

The fused features are obtained by normalized each of the extracted online features $(v, \frac{\Delta p}{\Delta y}, \frac{\Delta p}{\Delta x})$ using the variance of the offline feature (σ_{off}^2) . The three fused features (SF1, SF2 and SF3) become: $\frac{v}{\sigma_{off}^2}, \frac{\Delta p}{\Delta y \sigma_{off}^2}, \frac{\Delta p}{\Delta x \sigma_{off}^2}$.

F. Training and Threshold Setting

Each of the registered users submitted 12 genuine signatures to the system, out of which 8 signatures are fused together to generate 4 couple reference features. These features are used to generate 6 distance values by cross-aligned the couple reference features to the same length using Dynamic Time Warping (DTW). These distance values are used to measure the variation within each of the user's signatures, so as to set user-specific threshold for accepting or rejecting a couple test signatures. Given four couple reference signature samples R1, R2, R3 and R4, these features are cross aligned to obtain 6 distance values as shown in Fig.2. The mean (m_k) and standard deviation (σ_k) of the distances: d_{12}, d_{13}, d_{14}, d_{23}, d_{24} and d_{34} are calculated and used to set the threshold (t_k) for each of the users based on each of the fused features as given in (8).

$$0 \geq t_k \leq m_k + \sigma_k \tag{8}$$

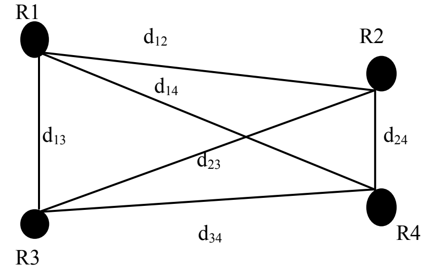

Figure2. Cross-alignment of Couple reference features

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G. *Classification of Couple Signature Features*

Whenever a couple test signatures (offline and online) come into the system, the fused feature vector of the couple test signatures is pair-wise aligned with each of the four couple reference features using DTW. Four distance values are obtained as shown in Fig.3. The distance (d_t) of the couple test feature (FT) from the four couple reference features R1, R2, R3 and R4 is calculated using (9).

$$dt = \frac{f_{T1} + f_{T2} + f_{T3} + f_{T4}}{4} \quad (9)$$

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

III. EXPERIMENTAL RESULTS

Experiments have been conducted to evaluate the discriminative ability of each of the fused features against forgers attack. Also the proposed system is tested based on the three new fused features. Total number of 150 fused signatures made up of 100 genuine signature features and 50 skilled forgery features are collected from 75 people are tested. The performance evaluation is based on False Acceptance Rate (FAR) and False Rejection Rate (FRR). Table 1 shows the results of the performance of these fused features in comparison with previous single offline features. Table 2 shows the proposed system FAR for skilled forgeries and the FRR for genuine signatures.

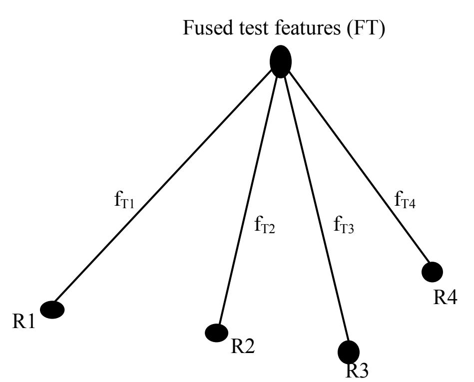

Figure 3. Distance between couple reference features and couple test feature

TABLE1: OFFLINE FEATURES IN COMPARISON WITH THE PROPOSED FUSED FEATURES.

Type	Feature	FRR	FAR
Some previous related offline features in [8][10]	Pixels normalized angle relative to the cell lower right corner	1.250	2.500
	Image centre angle relative to the cell lower right corner	2.500	2.500
	Vertical centre points	7.500	8.750
	Horizontal centre points	6.250	7.500
Proposed fused offline-online features	SF1	0.150	0.120
	SF2	0.120	0.052
	SF3	0.100	0.080

TABLE2: FAR AND FRR RESULTS OF THE PROPOSED SYSTEM

Type	Total	Accepted	Rejected	FAR	FRR
Individual genuine fused features	100	95	5	_	0.05
Individual skilled fused forgeries	50	1	49	0.02	_

IV. CONCLUSION

This paper has proposed a person identification system using fused signature features from two biometric sensors. Fused signature feature is used to strengthen verification system in paper documentation environment like banks where the present of the account holders are required for transaction. Signature is universally accepted, this make the proposed system more friendly and acceptable in comparison with

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others biometric traits combination. The experimental results have shown that fused signature identification method is more accurate in comparison with previous single sensor offline signature identification techniques.

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