Off-line Signature Verification Based on Angular Features

Prashanth C. R. and K. B. Raja

***Abstract*—Signature is widely used as a means of personal verification which emphasizes the need for a signature verification system. In this paper, Off-line Signature Verification based on Angular Features (OSVAF) is proposed. The scanned signature image is skeletonized and exact signature area is obtained by preprocessing. In the first phase, the signature is divided into 128 blocks using the center of signature by counting the number of black pixels and the angular feature in each block is determined to generate 128 angular features. In the second phase the signature is divided into 40 blocks from each of the four corners of the signature to generate 40 angular features. Totally 168 angular features are considered from phase one and two to verify the signature. The difference between the angular features of the genuine and test signatures is computed and compared with the threshold value to authenticate the signature. It is observed that the proposed algorithm has better FAR, FRR and EER compared to the existing algorithms.**

***Index Terms*—Angular features, biometrics, centre of signature, image splitting, off-line signature verification.**

I. Introduction

The signature verification is used as a popular, cost effective authentication method and preferred among various biometrics as it is the widely accepted way to identify an individual. It is used in many areas of society related to automated banking transaction, electronic fund transfers, and document analysis and access control through out the world. The advantage of signature verification for identity authentication purpose is that most of the modern portable computers and personal digital assistants use handwritten inputs.

There are two categories in signature verification based on the acquisition of the signature viz., on-line and off-line verification systems. The on-line signature verification uses pen and an E-pad to generate information about velocity, stroke order, acceleration, pen pressure etc., The off-line signature verification uses a static image of the signature collected from individuals on white paper. The off-line signature verification problem is more challenging than the on-line signature verification, because the features are extracted from the static 2D image of the signature.

The difficulties in processing off-line signature are (i) the highly stylish and unconventional writing, (ii) the nature and variety of the writing pen (iii) the non-repetitive nature of variation of the signatures, because of age, illness, mood, stress levels, geographic location and perhaps to some extent the emotional state of the person. Considering these factors and to detect forgeries effectively, an efficient signature verification system has to be designed. The system should have an acceptable trade-off between a low False Acceptance Rate (FAR) and a low False Rejection Rate (FRR).

Contribution: In this paper, off-line signature verification based on Angular Features is proposed. The scanned signature image is skeletonized and exact signature area is considered. The angular features are extracted with respect to centre of the signature in two phases. The difference in angular features between database and test signatures is compared with a threshold for matching.

Organization of the paper: The rest of the paper is organized as follows. In section II, we discuss about related work. In section III, we discuss about signature verification model. In section IV, the performance analysis is presented and concluded in section V.

II. Literature Survey

Ramachandra *et al.*, [1] proposed robust off-line signature verification based on global features for skilled and random forgeries. The model extracts the features which are preprocessed by normalization, binarization and thinning. The feature extraction technique consists of global features such as aspect ration, maximum horizontal histogram and maximum vertical histogram, horizontal and vertical centre of signature and signature area.

Luiz S Oliveira *et al.*, [2] proposed a writer independent model which reduces the pattern recognition problem to a 2-class problem. Receiver operating characteristic curves are used to improve the performance of the system. The impacts of fusion strategies to combine the partial decisions are classified by SVM.

Ghandali and moghaddam [3] proposed a model based on image registration, discrete wavelet transform and image fusion. Training signatures of each person are registered to overcome shift and scale problems. The several registered instances of each signature are fused together to generate reference pattern of signatures. In the classification phase euclidean distance is used.

Debasish Jena *et al.*, [4] proposed a off-line signature verification system which is based on selecting 60 feature points. The classification of the feature points uses statistical parameters like mean and variance to identify skilled and unskilled forgeries.

Vu Nguyen *et al.*, [5] proposed a signature verification using global features, which are derived from total energy a writer uses to create signature. The global features are vertical and horizontal projection of a signature, distance between keystrokes in an image and aspect ratio of

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signature. Support vector machine is used for classification of extracted features.

Prakash and Guru [6] proposed relative orientations of geometric centroids off-line signature verification (ROGCOSV). The signature image is split into blocks to determine the centroids to form an interval valued symbolic features. The set of slopes representing the test signature are compared with corresponding slopes of the symbolic features stored in the database.

Prashanth *et al.*, [7] presented a standard scores correlation based off-line signature verification (sscosv) system in which pixel density and geometric features points are extracted from a signature and compared using the concept of correlation. Jesus F Vargas et al., [8] proposed an off-line verification of static image of handwritten signature. The histogram is calculated using pseudo-cepstral coefficients. The unique minimum phase sequence is estimated and is used as feature vector for signature verification.

Hai Rong Lv *et al.*, [9] proposed hidden markov model approach for off-line signature verification system. The images are represented as a set of turning points, isolated points, trifurcate points, intersection points and termination points. Bharadi and kekre [10] explained off-line signature recognition systems using normalization, noise removal and thinning of the signature. The features extracted include global features, walsh coefficient of pixel distribution, codeword histogram based on clustering technique, grid features and successive geometric centers.

III. OSVAF System

Figure 1 gives the block diagram of off-line signature verification based on angular features (OSVAF) system, which verifies the authenticity of given signature of a person. The signature images for study are collected from the different subjects to create the database. The discrete wavelet transform (DWT) is used for improving the spatial domain features of the signatures and to reduce the noise. The Angular features are extracted with respect to centre of the signature by vertical and horizontal splitting.

A. Image Aquition

Signatures are obtained from persons on a blank white paper at different timings depending upon the mood and stress levels and are scanned to get images of 96 dpi resolution in bmp format to create the database. The genuine signature is forged after sufficient training. A sample of genuine signature image is as shown in Fig. 2.

B. Preprocessing

The signature is transformed to enhance image quality. It includes discrete wavelet transformation (DWT), resizing, skeletonization by morphological operations and considering the exact signature area.

Wavelet Transform: A filtering function is used for removal of the noise in the image. The DWT applied on signature images to preserve the pixel density in the signature image as compared to size normalization. *The images are resized to 150* $\times$450 instead of having signatures of different dimensions. Algorithm needs all the signatures to be of same size so that fair comparison is made among the signatures to produce better results.

1) *Skeletonization:* The skeletonization is done by removing the pixels on the boundary of the signature image without allowing the signature image to break apart. The process is achieved by morphological operations on signature image. The Figure 3 shows the signature after skeletonization.

2) *Exact signature area:* The signature image might not be present on the entire frame. So, the exact signature area is considered in the skeletonized image for further analysis. This reduces verification time and is cost effective. The signature image is scanned horizontally from top to get the first black pixel row a1 of the image and is the value of the row variable i corresponding to first black pixel. The signature image is scanned from the bottom to get he last black pixel row a2 of signature and is the value of the row variable i corresponding to last black pixel. The horizontal scanning for finding the top row and bottom row of the exact signature area is given by the Equations 1 and 2.

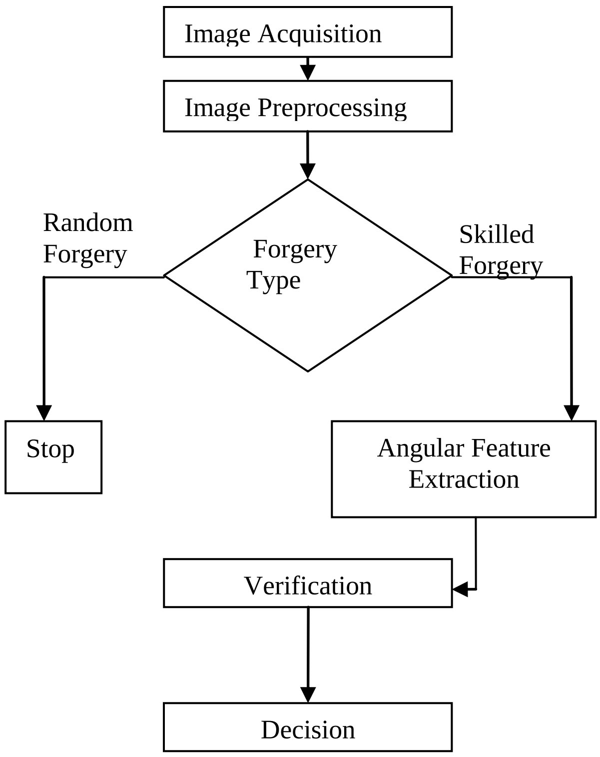

Fig. 1. Block diagram of OSVAF system

Fig. 2. Genuine signature

Fig 3. Signature after skeletonization

$$\sum_{i=1}^{M}\sum_{j=1}^{N} I_s(i, j) = 0 \tag{1}$$

$$\sum_{i=1}^{N}\sum_{j=1}^{M} I_s(N + (1 - i), j) = 0 \tag{2}$$

The signature image is scanned vertically from left to get the first black pixel column *a3* of the image and is the value of the column variable *j* corresponding to first black pixel. The signature image is scanned vertically from right to get the last black pixel column *a4* of the signature and is the value of the column variable *j* corresponding to last black pixel. The vertical scanning for finding exact signature area is given by the Equations (3) and (4). The Fig. 4 shows the image with exact signature area.

$$\sum_{j=1}^{M}\sum_{i=1}^{N} I_s(i, j) = 0 \tag{3}$$

$$\sum_{j=1}^{M}\sum_{i=1}^{N} I_s(i, M + (1 - j)) = 0 \tag{4}$$

where $I_s(x.y)$ is the skeletonized signature image.

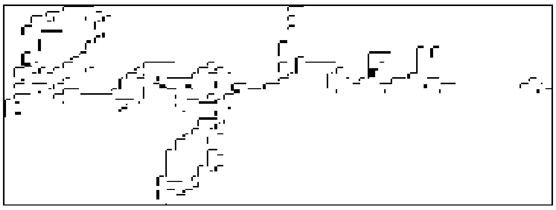

Fig. 4. Exact signature area

C. Random Forgery Detection

To detect random forgery at the early stage, the number of rows r_i and columns c_i are obtained for all the ten genuine signatures using the Equations (5) and (6). The average number of rows R_{avg} and columns C_{avg} are obtained using the Equations (7) and (8).

$$r_i = a_{1i} - a_{2i} \tag{5}$$

$$c_i = a_{3i} - a_{4i} \tag{6}$$

$$R_{avg} = \frac{\sum_{i=1}^{N_{GS}} r_i}{N_{GS}} \tag{7}$$

where r_i is the number of rows representing the i^{th} signature and N_{GS} is the total number of genuine signatures.

$$C_{avg} = \frac{\sum_{j=1}^{N_{GS}} c_j}{N_{GS}} \tag{8}$$

where C_j is the number of columns representing the j^{th} signature and N_{GS} is the total number of genuine signatures.

The number of rows and columns of test signature are calculated and compared with R_{avg} and C_{avg} respectively. If the absolute value of the difference between R_{avg} and number of rows R_{Ti} representing the test signature is less than or equal to predefined threshold value and if the absolute value of the difference between C_{avg} and number of columns C_{Ti} representing the test signature is less than or equal to predefined threshold, then the angular feature extraction and verification are carried out on the test signature else random forgery is detected and verification process is aborted.

D. Feature Extraction

The angular features are extracted in two phases. In first phase, the preprocessed signature image is made to undergo vertical splitting and horizontal splitting. The skeleton of the signature image is scanned from left to right and top to bottom to calculate the total number of black pixels. The image is divided into two halves with respect to the number of black pixels by two lines, vertically and horizontally which intersects at a point called the centre of signature or geometric centre.

The signature image is split with horizontal line passing through geometric centre of image to get top and bottom parts of image. The coordinates of the boundary of each part or block is stored. The geometric centre for each block is obtained by locating a point where number of black pixels is half of the total number of black pixels in the block. Geometric centre is found for top and bottom blocks respectively. The top block is split with a vertical line to find the geometric centre for left and right parts of top block. Again the coordinates of the boundary of each block is obtained. Similarly, the bottom block is split with a vertical line to find the geometric centre for left and right parts of bottom block. Then, each part is again split through their geometric centre to obtain angular feature points as shown in Fig. 5.

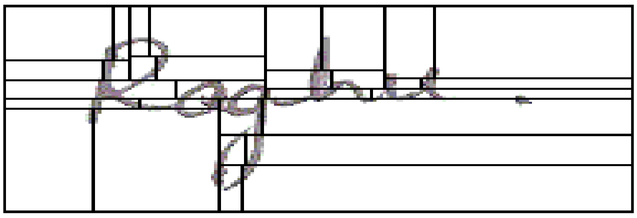

Fig. 5. Horizontal and Vertical splitting of Signature

The process of vertical and horizontal splitting of signature leads to 128 blocks. The top left corner of the image is considered as the reference point. The distance between reference point and the centre of signature is obtained by the Equation (9).

$$\text{Distance} = \sqrt{(i_2 - i_1)^2 + (j_2 - j_1)^2} \tag{9}$$

where, (i_2, j_2) and (i_1, j_1) are the coordinates of two points.

Consider the reference point, $A(1,1)$ and the centre $C(i, j)$ of signature as shown in the Fig. 6. The angle θ is computed using the Equation (10).

$$\theta_i = \cos^{-1}\left(\frac{AB}{AC}\right) \qquad (10)$$

where $i = 1,2,3,4........128$, adjacent side AB and hypotenuse AC are given by Equations (11) and (12) respectively.

$$AC = \sqrt{(i-1)^2 + (j-1)^2} \qquad (11)$$

$$AB = j - 1 \qquad (12)$$

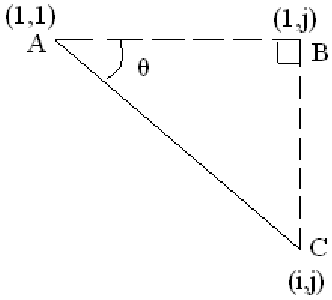

Fig. 6. Right angled triangle

The procedure is carried out for all the 128 blocks and the corresponding angular features are obtained. The number of blocks can be increased further but there may be the case where the angle computed would be infinity. As the pixel appears on the top left corner of the block, hypotenuse becomes zero. So the numbers of blocks are limited to 128.

The second phase consists of division of an image into dimensions which are predefined. The image is divided into ten square blocks containing 1, 4, 9, 16, 25, 36, 49, 64, 81 and 100 pixels as shown in the Figure 7. The Figures 7a, 7b, 7c and 7d correspond to division of the signature image from top left, top right, bottom left and bottom right respectively. Each division produces 10 blocks. The procedure is repeated for the remaining 3 parts to get 30 more blocks. This leads to totally 40 blocks. The angular features for these 40 blocks are determined. The 168 angular features obtained from first and second phase are used to verify the signatures.

Fig. 7. Division of signature image

E. Verification

The comparison between the genuine signature and test signature is made by computing the difference between the angles in radians obtained for both the signatures. A threshold is set which decides the authenticity of the signature. The threshold value of 0.26 radians is considered for verification purpose. The absolute difference between i th angle θ_{Gi} of the genuine signature and i th angle θ_{Ti} of the test signature is compared with the threshold as given in the Equation 13.

$$\left|(\theta_{Gi} - \theta_{Ti})\right| \le 0.26 \qquad (13)$$

where $i = 1,2,3,4........168$.

If the number of angles having difference less than or equal to 0.26 radians, is greater than or equal to 133 then it is considered genuine otherwise forged signature.

IV. Performance Analysis

For the performance analysis, we have not used the existing database; instead we created the database consisting of 80 signature samples of 4 subjects. Among them, 40 samples are genuine and 40 samples are forged. The Matlab version 7.0.1 is used for implementation of the proposed algorithm.

For each subject, 1 out of 10 genuine signature samples is taken as reference and it is compared with 9 other genuine samples. This process is continued until all signature samples are compared. The same process is repeated for the signature samples of other 3 subjects also to calculate False Reject Rate (FRR). One sample of each subject is considered as the reference signature and is compared with the 10 forged samples for the same subject. This process is repeated for all the genuine signature samples to calculate False Accept Rate (FAR).

Table I shows the comparison of the proposed OSVAF technique with the existing Relative Orientations of Geometric Centroids Off-line Signature Verification (ROGCOSV) [6] and Standard Scores Correlation based Off-line Signature Verification (SSCOSV) [7] techniques. FAR and FRR obtained by the proposed algorithm are better in comparison with existing algorithms.

TABLE I: Comparative Analysis of FAR and FRR

Error rates	**ROGCOSV [6]**	**SSCOSV [7]**	**OSVAF**
FAR	25.11	8.88	**4.995**
FRR	14.66	7.76	**8.500**

Table II shows the variation of FAR and FRR depending on the threshold parameter to decide the genuineness of a signature image. As the threshold increases, the FAR increases and FRR decreases.

TABLE II: Variation of FAR and FRR with Threshold

Sl. No.	**Threshold**	**%FRR**	**%FAR**
1	0.10	100	0
2	0.15	85.5	0.25
3	0.20	45.52	0.50
4	0.25	11.65	4.75
5	0.26	4.995	8.50
6	0.30	1.11	22.75
7	0.35	0	51.25
8	0.40	0	75.12

Figure 8 shows the graph of FAR and FRR obtained for different values of threshold to compare the performance of signature verification system. The value of Equal Error Rate (EER) obtained is 7.2 corresponding to optimal threshold of 0.256 at a point where FAR equals to FRR. This value of ERR is better compared to many of the existing off-line signature verification systems.

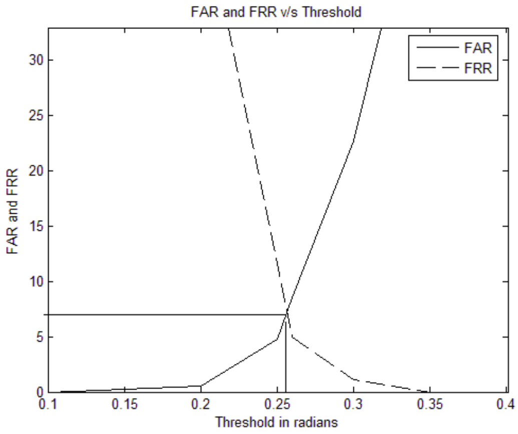

Fig. 8. FAR and FRR against threshold

V. Conclusion

The OSVAF algorithm based on the angular features is more efficient and gives better results than the existing techniques. The angular features from preprocessed signature are extracted in two phases. The angular features are compared with a threshold for comparison between database and test signatures. The number of differences greater than the threshold is counted and if the number is greater than 133 out of 168, then test signature is considered as genuine signature. In future, the better results can be produced by preprocessing the image in the transform domain. The use of SVM may further reduce error rates.

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