



### Offline Signature Recognition Using Delaunay Triangulation

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**Abstract:** Biometric identification is evolving technology solving problem related to access control and identity verification. Signature can be used in various places to keep out thieves and intruder. For secure personal verification system offline signature has been recognized as a key competitor. However its replication has become a serious risk, fabricating various serious risks to access control and personal identification. To mitigate this risk, we propose a novel method to detect skilled forgery, consisting of some preprocessing steps, feature extraction, Delaunay triangulation, normalization and recognition. The aim of the proposed method is to decrease false acceptance rate and false rejection rate which is often used in signature verification method. The precision of recognizing genuine signature of the proposed method is 96% but rotation of the sample signature image decrease the desired result slightly. Comparative analysis of proposed method with other state-of-the-art techniques has been made in the experimental section, verifying its rationality.

**Keywords:** Biometric, Signature identification, false acceptance rate, Delaunay triangulation, false rejection rate .

#### 1. INTRODUCTION

Biometrics refers to on human traits, e.g., physical and behavioral characteristics can be used in various fields for personal identification and access control. The physical characteristic includes face recognition, fingerprints, Deoxyribonucleic Acid (DNA), retina scan, hand geometry, iris scan, but on the contrast behavioral characteristics includes voice recognition and signature recognition. The factors on which offline signature recognition do not depend are: age, occlusion, illumination and pose variation but in face recognition these factors are often involved (Radhika, *et al.*, 2009, Guest and Richard, 2006).

Signature verification is classified as on-line and off-line signature (Ooi, *et al.*, 2007). Offline signatures are scanned images of signatures while online signatures are obtained by pen tablets. Textures analysis cannot be discounted in signature recognition. A pattern is something that can be given a name e.g. fingerprint. Human beings are the highest pattern analysts in greatest cases and to make choices they use this ability. If one cannot recognize patterns and cannot differentiate humans, then the culture would have been very different. The pattern analysis aim is to classify patterns. The human skill to analyze pattern is greater than a machine but still there are many activities where machine recognition is more effective and appropriate for example screening of bank cheques. In this area of signature verification and identification many researches has been made, but still need some work to obtain perfection (Chen *et al.*, 2007).

Handwritten signatures are admitted validly as a useful source for document verification and writer identification (Sharma, *et al.*, 2010). Most banks use offline signatures as a vital element in verification and identification i.e. bank cheques. Signature verification validates that a signature is genuine or forged but signature identification states that which writer belongs to that sample signature. Forgery has three main types i.e. simple forgery, random forgery and skilled forgery (Majhi, *et al.*, 2006). In simple forgery the writer is aware of the shape of genuine signature but has not done enough practice duplicate a signature while in random forgery the writer does not know the actual shape of genuine signature. Skilled forgery is the most significant in which the writer has the knowledge about the shape of original signature and have sufficient training to duplicate that signature.

#### 2. PREVIOUS WORK

Template matching is the simplest method for pattern recognition. A pattern may be either dealing with an image or curve. DTW is the best matching technique for off-line signature verification. The DTW-based system uses the distance to align two observation structures during the feature extraction process and compute the distance between two signatures. (Guo *et al.*, 2001) describe a DTW method for off-line signature verification. In this technique the FRR of 6% is obtained and FAR of 11.5% is attained for skilled forgeries. (Fang, *et al.*, 2001) suggested technique for skilled forgeries recognition. Fang's first technique Average Error Rate of 20.8% and 18.1% was attained

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correspondingly, whereas Fang’s second method Average Error Rate of 23.4% is obtained. (Baltzakis, et al., 2001) illustrate a Neural Network scheme for the identification of random forgeries. False Rejection Rate and False Acceptance Rate of 3% and 9.8% are achieved. (Quek, et al., 2002) used a new approach which is used for recognition of skilled forgery. The Equal Error Rate is 22.4% in this technique. (Abdala, et al., 2009) discussed an efficient novel method by which the recognition rate of 95.95% was achieved. Hidden Markov Model is statistical technique implemented in many researches to attain accuracy. (Justino, et al., 2001) demonstrate a novel approach based on HMM. A FRR of 2.83% is achieved and FAR of 22.67% is attained for skilled forgeries correspondingly. (El-Yacoubi, et al., 2000) discussed a new technique of cross-validation in addition of HMMs for signature verification. (Justino, et al., 2005) describes a novel system using HMM. The purpose of the described technique is to make an efficient scheme for verification of off-line signature. (Samit et al., 2010) describe a new technique based clustering method. The clustering technique used k-Nearest Neighbour’s technique for offline signature verification.

**3. PROPOSED METHODOLOGY**

Our system for offline signature verification comprises of preprocessing stage followed by feature extraction and Delaunay Triangulation. After normalization stage at last the genuine signature is recognized. New technique of Delaunay triangulation is implemented for signature verification. Preprocessing phase of our method is discussed below. The framework for the proposed system is illustrated below in (Fig. 1).

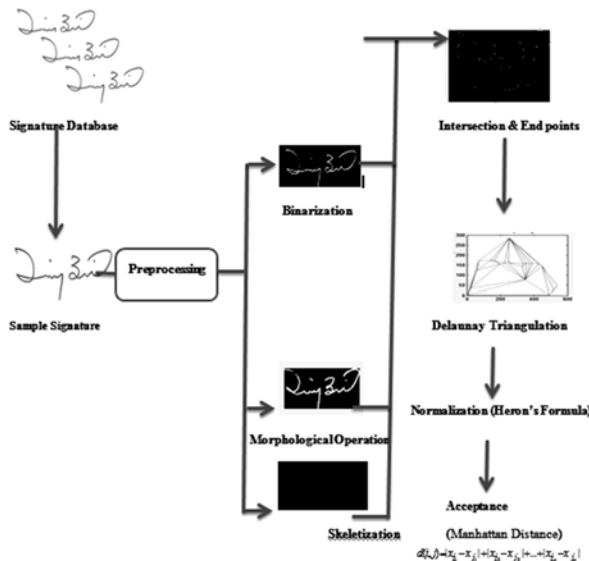


Fig 1: Framework of the proposed method based on Delaunay Triangulation

**Preprocessing**

The preprocessing stage of signature consists of conversion of image binarization, median filter and skeletization. The preprocessing stages are as under.

**Binarization of Signature Image**

To obtain the white and black pixels of signature, the original signature is converted into binarised form. Otsu’s method (Sezgin, et al., 2004) is implemented for image binarization which automatically executes clustering based Thresholding to covert the image into binary form. The pixels having intensity greater than a threshold are converted to white and less than the threshold are converted to black as shown in the figure below. (Fig. 2) shows (A) Original signature (B), Binarized signature.



Fig 2: A) Original Signature B) Binarization of Signature

**Morphological Operation**

Morphological operation is often performed in digital image processing and deals with shape of signature image. In this phase we have used opening operation on the signature image to break unessential parts. (Fig.3) shows (A) Binarized signature (B) Morphological operation.



Fig 3: (A) Binarization of Signature (B) Image After Opening

**Skeletization of Signature**

To obtain one pixel signature image value we used skeletization. It removes pixels which are on the margins of objects. The effect of the skeletization is shown in the figure below. (Fig. 4) (A) Signature image after image opening (B) Signature image after skeletization.



Fig 4: (A) Image after opening (B) Skeletization of Signature

**4. INTERSECTION AND END POINTS**

Intersection points and end points are obtained in feature extraction stage. End points have only one neighbour but intersection points have more than two neighbours. (Fig. 5) (A) Shows Skeletization signature (B) Stars indicate intersection points and end point of the signature.



Fig 5: A) Skeletization of Signature B) Feature Extraction

**5. DELAUNAY TRIANGULATION PHASE**

In Delaunay triangulation there is no point in the circumcircle of triangle. Delaunay triangulation was first used by Boris Delaunay (B. Delaunay 1934). The Delaunay triangulation is obtained by using built-in Matlab functions. (Fig. 6) A) Illustrates Intersection points and end points (B) shows the Delaunay triangulation of the signature.

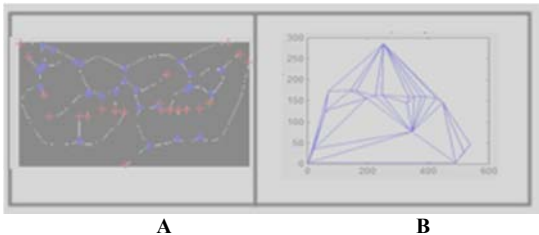


Fig 6: A) Feature Extraction B) Delaunay Triangulation of the signature

**6. NORMALIZATION**

In the stage of normalization Heron's formula is used to calculate the area of all Delaunay triangles which is computed by the formulas given below.

$$s = \frac{a+b+c}{2} \quad (1)$$

$$A = \sqrt{s(s-a)(s-b)(s-c)} \quad (2)$$

Where a, b, c are the length triangle sides. To find perimeter of the triangle we use the above formula. To calculate area of the triangles the formula is given as under.

To calculate relative area the formula is given as under.

$$\rho_{rel}(i) = \frac{\rho_i}{\rho_{max}} \quad (3)$$

Where  $\rho_{max}$  is the maximum area value,  $P_i$  is the current area value. Present area value is divided by of maximum area value so that we get relative area in range between 0 and 1. After that the relative area is organized in proper order. One feature vector is calculated for relative areas of triangles and the second feature vector is calculated for angles of triangles.

**7. ACCEPTANCE PHASE**

In the stage of acceptance and recognition the Manhattan distance of the resultant feature vectors are calculated and after that we compare the result with all other signatures feature vectors with original signature in database. If the aspect ratio of two signatures is less than or equal to 2, then that signature is genuine and it is accepted. On the contrast if the aspect ratio is greater than 2 then the signature is fake. The distance between point i and j indicates Manhattan distance and is denoted by  $\bar{ij}$ . In coordinates  $i = (i_1, i_2, \dots, i_n)$  and  $j = (j_1, j_2, \dots, j_n)$  which are the two points in Manhattan distance space. The distance i and j is as under:

$$d(i, j) = |x_{i_1} - x_{j_1}| + |x_{i_2} - x_{j_2}| + \dots + |x_{i_p} - x_{j_p}| \quad (4)$$

**8. EXPERIMENTAL RESULTS**

Signature database we used comprises of 420 signatures which is obtained from thirty different people. Out of 420 signatures 60 signatures are skilled forgeries and other 60 signatures are simple forgeries. The proposed system was matched with that of 60 feature point's method (D. Jena, Debashish Mahji, Sanjay Kumar, 2008). The accurateness of identifying original signature of the proposed method is 96%.

FAR and FRR of the proposed method is less than other existing methods. The FAR and FRR is obtained the succeeding formulas as given below.

$$FAR = \frac{\text{Number of forgeries accepted}}{\text{Number of forgeries tested}} \times 100 \quad (5)$$

$$FRR = \frac{\text{Number of original rejected}}{\text{Number of original tested}} \times 100 \quad (6)$$

The suggested system efficiently excluded skilled forgeries. Our method was compared with FAR and FRR of some additional structural features (S. Zafar and R. J. Qureshi, 2009). The false acceptance rate of this method for simple forgery is zero. However the false acceptance rate for skilled forgery is 1.66. We have tested 60 skilled forgeries by this system, in which 1 skilled forgery is accepted. Similarly for false rejection rate we have tested 60 signatures, out of which 6 signature were rejected. (Table 1) shows relative analysis of FAR while (Table 2) shows relative analysis of FRR.

Table 1: Relative analysis of FAR

Forgery Types	60 feature points technique[12]	12 feature points technique[12]	Proposed System
Simple forgery	0.98	9.75	0
Z. Sanjiv et al. forgery	2.08	16.36	1.46

Table 2: Relative analysis of FRR

False Rejection Rate	
60 feature points Method[12]	20.83
12 feature points Method [12]	14.58
Proposed technique	<b>9.25</b>

## 9. CONCLUSION

The proposed system will recognize original signature and to reject fake signature. This offline signature verification system is based on Delaunay triangulation. After preprocessing stage intersection points and end points are extracted. From these intersection points and end points Delaunay triangulation is obtained. From Delaunay triangulation the area of triangles is obtained through Herons theorem. From these area values relative area is calculated and is sorted. At last two feature vectors are obtained, one for relative area and other for angles of triangle. In the stage of recognition Euclidean distance formula is used to compare the result of two feature vectors. Delaunay triangulation will be beneficial in face recognition and finger prints identification. But this method should be enhanced by using correlation statistical method for future work by which the desired results will be obtained.

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