A Simple Approach to Recognize a Person Using Hand Geometry

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Abstract— A new method is presented for person verification based on inner joining lines of fingers of right hand. This paper attempts to improve the performance of hand geometry based verification system by reducing the amount of features and integrating new features. It also decreases computational time by introducing a moderated edge detection method based on high pass filter. The image acquisition of this system is different than other hand geometry based biometric systems. The system requires only the upper portion of a palm image instead of image of full palm. Hence it reduces the database size. The proposed system is suitable for capturing images by a digital camera or a normal scanner. The best performance of the proposed system will be found by Euclidean distance metric. The method has been tested on a medium size dataset of 100 images with promising results of 0.02% false rejection rate (FRR), 0.02% false acceptance rate (FAR) and 99.98% total success rate.

Keywords— Hand geometry, verification, authentication, recognition, FAR, FRR, GAR, TSR.

1 INTRODUCTION

AUTOMATIC human identification has become an important issue for today's information and network based society. The techniques for automatically identifying an individual based on his physical or behavioral characteristics are called biometrics. The personal attributes used in a biometric identification system can be physiological, such as facial features, fingerprints, iris, retinal scans, hand, and hand geometry; or behavioral, such as voice print, gait, signature, and keystroke style.

From anatomical point of view, human hand can be characterized by its length, width, thickness, geometrical composition, shapes of the palm, and shape and geometry of the fingers. It is generally accepted that fingerprint, retinal and iris patterns can uniquely define each member of an extremely large population which makes them suitable for large-scale recognition (establishing a subject's identity). However, in many applications, because of privacy or limited resources, we only need to authenticate a person (confirm or deny the person's claimed identity). Moreover, suitability of a particular biometric to a specific application depends upon several factors [1]. In these situations, we can use different distinguishing features with less discriminating power such as face, voice or hand shape. One distinct advantage the hand modality offers is that its imaging conditions are less complex, for example a relatively simple digital camera or flatbed scanner would be sufficient. Consequently, hand-based biometry is user-friendlier and it is less prone to disturbances and more robust to environmental conditions and to individual anomalies. Moreover, hand geometry has long been used for biometric verification and identification because of its acquisition convenience and good verification and identification performance [2]-[4]. Hand geometry measurement is non-intrusive and the verification involves a simple processing of the resulting features [5]. Hand geometry based authentication is also very effective for various other reasons. Almost all of the working population have hands and exception processing for people with disabilities could be easily engineered [6] In contrast, face modality is known to be quite sensitive to pose, facial accessories, expression, and lighting variations; iris or retina-based identification requires special illumination and is much less friendly; fingerprint imaging requires good frictional skin etc., and up to 4% of the population may fail to get enrolled [7]. Therefore, authentication based on hand shape can be an attractive alternative due to its unobtrusiveness, low-cost, easy interface, and low data storage requirements. Some of the presently deployed access control schemes based on hand geometry range from passport control in airports to international banks, from parents' access to child daycare centers to university student meal programs, from hospitals, prisons, to nuclear power plants [8]. In fact, there exist a number of patents on hand information-based personnel identification, using either geometrical features or on hand profile [8]. Sanchez-Reillo et al. [9] select 25 features, such as finger widths at different latitudes, finger and

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palm heights, finger deviations and the angles of the inter finger valleys with the horizontal, and model them with Gaussian mixtures. Jain et al. [10] have used a peg-based imaging scheme and obtained 16 features, which include length and width of the fingers, aspect ratio of the palm to fingers, and thickness of the hand. Öden et al. [11], in addition to geometric features such as finger widths at various positions and palm size, have made use of finger shapes. These shapes have been represented with fourth degree implicit polynomials, and the resulting sixteen features are compared with the Mahalanobis distance. A recent work utilizes both hand geometry and palm print information as in Kumar et al. [12], which use decision level fusion. Alexandra L.N. Wong [13] use 16 features, such as finger lengths, finger widths and fingertip regions.

In this paper, we present a system where are two phases one for enrollment and another for verification purpose. Both phases have common phase consists of image acquisition, preprocessing, feature extraction, template construction, and creation of reference database. During the enrolment phase three samples have been taken. After feature extraction, calculated mean value and standard deviation of individual feature will construct the template of the person. The verification phase consists of image acquisition, preprocessing, feature extraction, classification and decision. During verification, this input data is compared with the corresponding data. The reference data is selected from the reference database when user enters their personal identification number. In the proposed system six coordinate values will be taken from hand image. Using these six points 9 features will be obtained. The features will be used to construct the template data.

2 METHODOLOGY

When the input data is fed into the biometric system it may be unsuitable for feature extraction. This is due to the several noise elements which may creep into the data. After removing noise the resized image is used to extract and store features. The last module of the biometric system is matching.

2.1 Image Acquisition and Resizing

The images are captured using a flatbed scanner with 24 bit color and 200 dpi resolution. The input image is a colored image of the right palm (fingers are combined together) without any deformity. The captured image, shown in Figure 1(a) is stored in *tif* format. In cases of standard deformity such as a missing finger the system expresses its inability to process the image.

For resizing and cropping the captured image a photo editor is required such as Microsoft paint. The hand image will be converted to 25% of the original image. By cropping eliminate the unnecessary portion of the hand and stored in *bmp* file format as shown in Figure 1(b).

This image acquisition setup is simple and neither the employs require any special illumination nor uses any peg to cause any inconvenience to users. Only the users will be requested to place their hands on the surface of the scanner in such a manner that their fingers touch neighbor fingers. If the quality of the image is not satisfactory then the image is rejected. As a result, the database contains only good quality templates and the system accuracy improves.

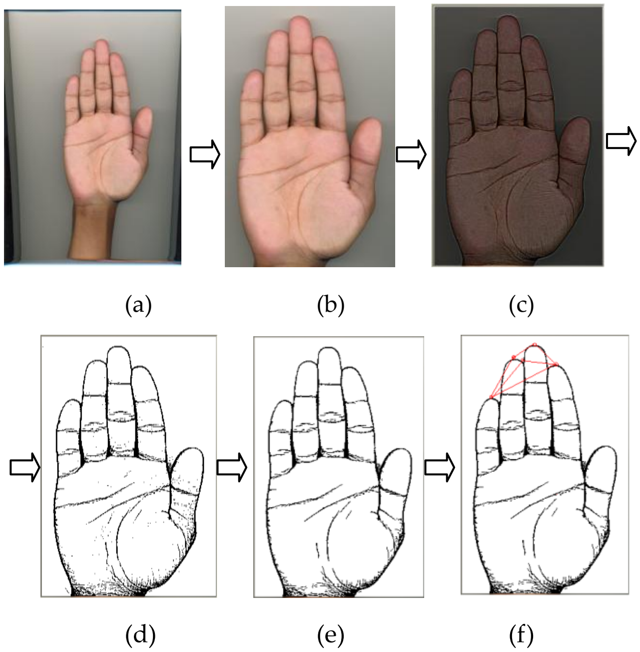

Figure 1: Process of features extraction (a) Original image, (b) Resized image, (c) Filtered image using 5x5 high pass filter, (d) Monochromic image, (e) Monochromic noise free image, (f) Extracted features.

2.2 Preprocessing

In this section, a moderated edge detection algorithm, based on high pass filer is applied to extract contour of hand. The first step of this edge detection algorithm is translating the hand image in such a way that all edges become black, shown in Figure 1(c). Then extract only edges by applying a threshold a value as shown in Figure 1(d). Noise exists between the fingers, the inside of the palm perimeter or in background. A convolution filter is applied which checks if a black pixel is surrounded on all sides by white pixels. If that is found will be considered as noise and is converted to a white pixel, shown in Figure 1(e). The size of the convolution filter is variable. First the filter uses a 3*3 template, then a 5*5, after that a 7*7 and finally a 9*9. This progressively removes larger and larger noise elements from the image.

2.3 Feature extraction

Initially the coordinate values of the five points are detected from the acquired and preprocessed image. Four points of them are the topmost four points of four fingers. The first, second, third, and fourth points are the top points of the little, ring, middle and index finger respectively. These four points are named as A, B, C, and D respectively. The last and fifth one is between middle and ring fingers named E. All of these five points are marked and shown in Figure 2.

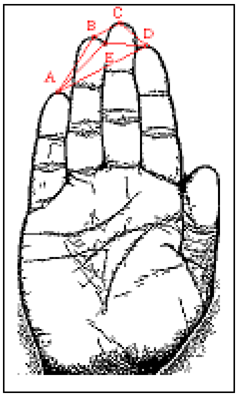

Figure 2

Using these five points, features of hand geometry verification are extracted. At first, possible distances are considered. There are six possible distances are taken by using these five points. The distances are AB, BC, CD, AE, DE and AD.

2.4 Template Construction

Templates are only data representing key or distinctive features of a biometric and are not a complete image or record of the original biometric (such as a fingerprint, voice recording or digital image).

In this work, the template will be generated from three snapshot of each person. At first, we calculate distances for individual snapshot. Four distance metrics [9] are used for verification. Two of them need only mean values another one needs both mean values and standard deviation and the rest one needs both mean values and variance of individual distances. Thus mean values, variance and standard deviations of individual distances are calculated. The mean values will be used to construct the template for each person. That means,

Template $F = (d_1, d_2, \ldots\ldots\ldots, d_i)$

Where d_i average value of individual distance

i=1, 2, 3 number of features.

2.5 Matching

Matching is the process of calculating a similarity and dissimilarity between current feature representation of the biometrics data of a user and the respective reference data set. Snapshot of the hand are taken and the feature vector is computed. The given feature vector is then compared with the feature vector stored in the database associated with the claimed identity. Let $F = (f_1, f_2, \ldots, f_d)$ represent the d-dimensional feature vector in the database associated with the claimed identity and $Y = (y_1, y_2, \ldots\ldots, y_d)$ be the feature vector of the hand whose identity has to be verified. The size of the feature vector dimension is nine. The verification is positive if the distance between F and Y is less than a threshold value. Four distance metrics i) absolute, ii) weighted absolute, iii) Euclidean, and iv) weighted Euclidean corresponding to the following four equations were explored [10]:

i) $$\sum_{j=1}^{d} |y_i - f_i| < \varepsilon_a \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

ii) $$\sum_{j=1}^{d} \frac{|y_i - f_i|}{\sigma_j} < \varepsilon_{wa} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

iii) $$\sqrt{\sum_{j=1}^{d} (y_i - f_i)} < \varepsilon_e \quad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

iv) $$\sqrt{\sum_{j=1}^{d} \frac{(y_i - f_i)^2}{\sigma_j^{\,2}}} < \varepsilon_{we} \quad \ldots\ldots\ldots\ldots\ldots(4)$$

where σ_j^2 is the feature variance of the j_{th} feature and ε_a, ε_{wa}, ε_e, and ε_{we} are threshold values for each respective distance metric.

3 EXPERIMENTAL RESULT

One of the tasks to be studied for the enrollment process is the number of feature vectors that form the user's template. It is obvious that the bigger the number of samples used the better the calculated template will be created.
The hand geometry authentication system was trained and tested using a database of 18 users. At least four images of each user's hand were captured over different sessions. Total 125 images were made available. Out of 125 images, only 100 were used for testing our hand geometry system. The remaining 25 images were discarded due to incorrect placement of the hand by the user. Thus, user adaptation of this biometric is necessary. Three images of each user's hand were randomly selected to compute the feature vector which is stored in the database along with the user's name.

3.1 FAR-FRR Analysis

The performance of a biometric system is measured in certain standard terms. These are given below:
False Acceptance Rate (FAR) is the ratio of the number of unauthorized (unregistered) users accepted by the biometric system to the total of identification attempts made.

$$\text{FAR}(\lambda) = \frac{\text{Number of False Attempts}}{\text{Number of Impostor accesses}}$$

(λ) = Security Level

False Rejection Rate (FRR) is the ratio of the number of number of authorized users rejected by the biometric system to the total number of attempts made.

$$\text{FRR}(\lambda) = \frac{\text{Number of False Rejects}}{\text{Number of Client accesses}}$$

(λ) = Security Level

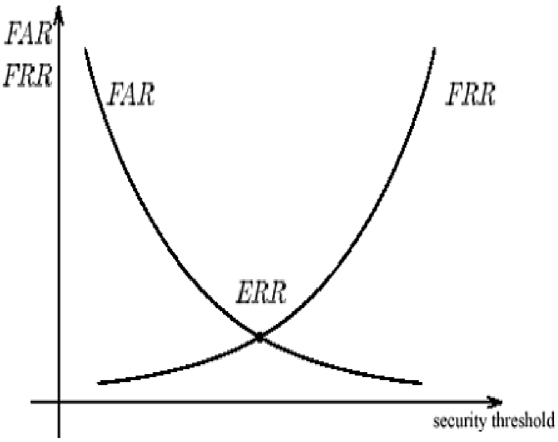

Figure 3 : FAR-FRR Rate

False acceptance poses much more serious problem than false rejection. It is therefore desired that the biometric system keep the FAR to the minimal possible limit. This can be achieved by setting a high threshold so that only very near matches are recognized and all else are rejected. The higher the security requirement from the system the higher the threshold required to maintain it.

Now FAR-FRR analysis is going to be conducted for each of the distances used in this study.

For Absolute Distance

Initially an arbitrary threshold, roughly at the center of the match-score spread was chosen. After testing with the images the arbitrary threshold proved to be fairly good. In 100 tests for false acceptance there are a total of 6 false acceptances, giving the threshold 17 an FAR of 0.06. Also in 100 tests for false rejections it is found to be 1 false rejects giving the FRR a value of 0.01.

During these tests the match-score for each false acceptance has been noted. Also the match-score for each false rejection are noted The FAR-FRR curve is shown in Figure 4(a). The ERR obtained from this curve is 0.04.

For Euclidean Distance

For threshold value 8 FAR is 0.03 and FRR is 0.01. The FAR-FRR curve is shown in Figure 4(b). The ERR obtained from this curve is 0.02.

For Weighted Absolute Distance

For threshold value 12 FAR is 0.03 and FRR is 0.02. The FAR-FRR curve is shown in Figure 4(c). The ERR obtained from this curve is 0.03.

For Weighted Euclidean Distance

For threshold value 5 FAR is 0.02 and FRR is 0.02. The FAR-FRR curve is shown in Figure 4(d). The ERR obtained from this curve is 0.02.

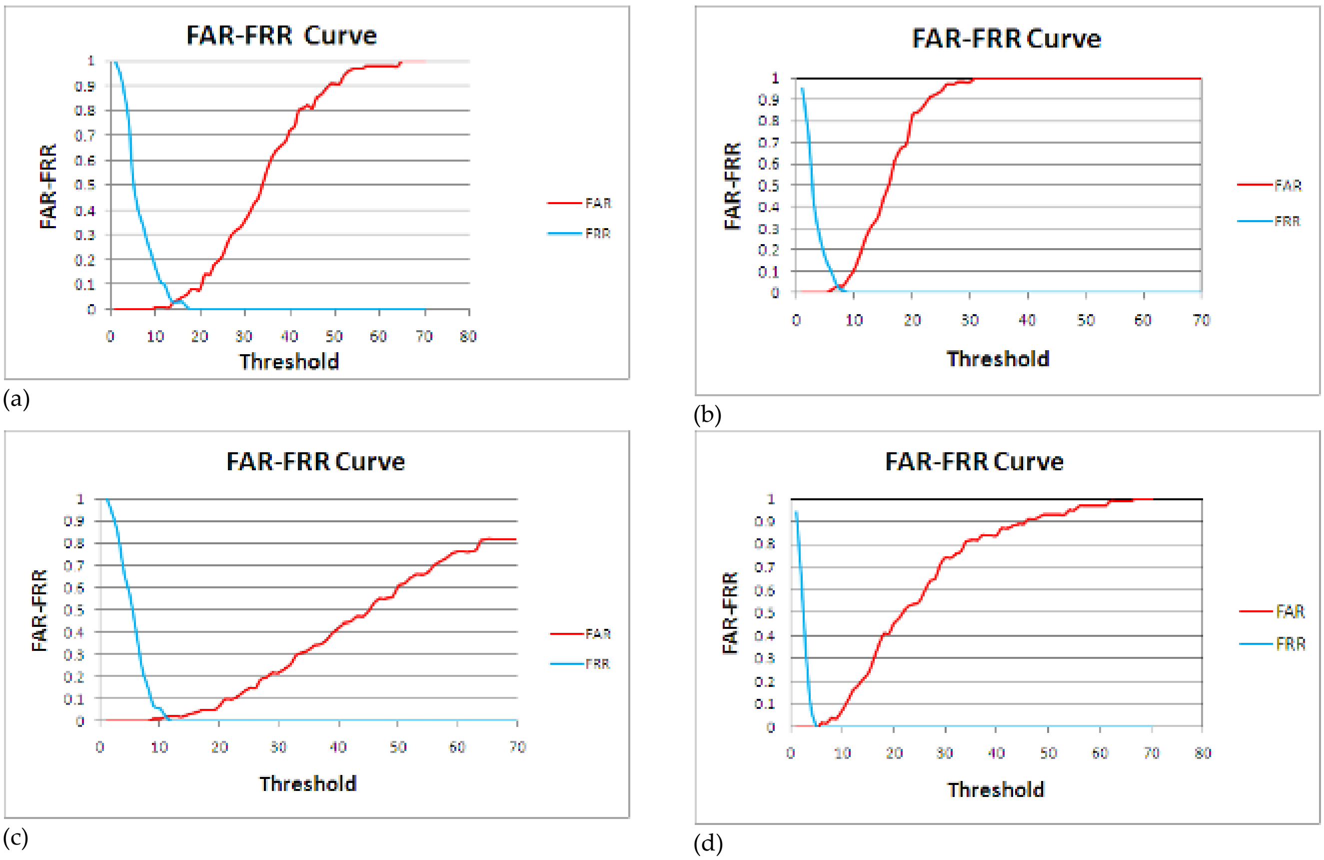

Figure 4: FAR - FRR curve for (a) Absolute Distance, (b) Euclidean Distance, (c) Weighted Absolute Distance, and (d) Weighted Euclidean Distance.

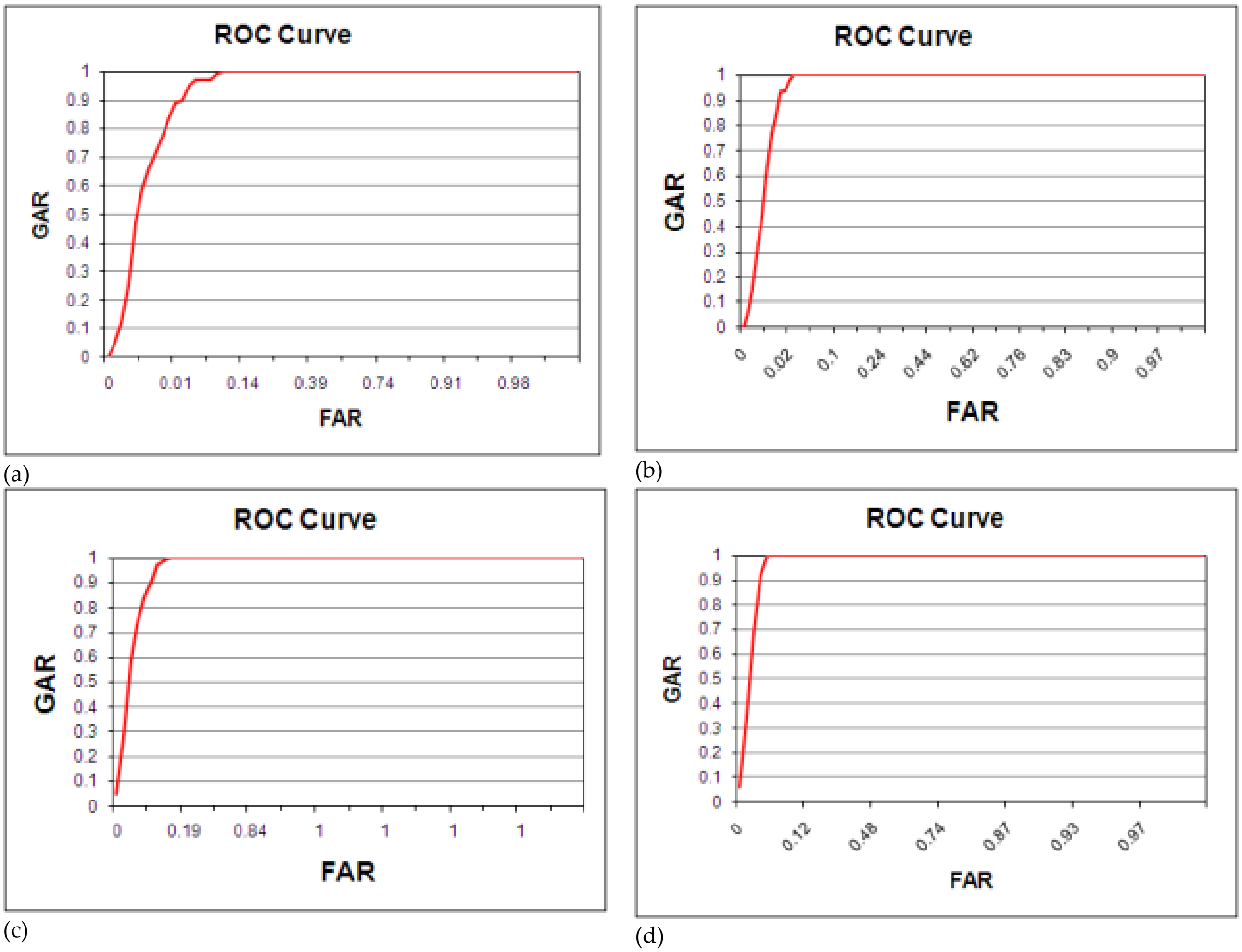

Figure 5: ROC curve for (a) Absolute Distance, (b) Euclidean Distance, (c) Weighted Absolute Distance, and (d) Weighted Euclidean Distance.

3.2 ROC Curve Analysis

The **Receiver Operating Characteristic (ROC)** is used instead of thresholds for this purpose. The ROC is a plot depicting the genuine acceptance rate along the Y-axis and the false acceptance rate along the X-axis. Time in some cases is of crucial importance in the performance of a biometric system. In a offline system it is not crucial but in the case of online systems it is of importance that the system works fast enough so as not to cause the user unnecessary annoyance.

The ROC curve shown in Figure: 5 depict the performance of the system for the Absolute, Euclidean, Absolute, Weighted Euclidean distance. From the above curves we get best hit ratio against the false acceptance rate by Euclidean distance.

3.3 Comparison Analysis

To evaluate the system performance, three well-known measurements are used, such as False Rejection Rate (FRR), False Acceptance Rate (FAR) and Total Success Rate (TSR). The system performance could be significantly improved by having habituated users.

A relative comparison is made based on the outcomes of Absolute, Euclidean, Weighted Absolute and Weighted Euclidean distance of proposed system and shown in Table1.

In Table 2, a comparison is made among the results of the proposed method and the results of the existing methods.

TABLE I

COPMPARISON STUDY OF FOUR DISTANCE MATRICS

Feature Vector Dimension	Name of the Distance Metrics	Decision Threshold	FAR %	FRR %	TSR%[9]
6	Absolute	17	0.06	0.01	99.96
	Euclidean	8	0.03	0.01	99.98
	Weighted Absolute	12	0.03	0.02	99.97
	Weighted Euclidean	5	0.02	0.02	99.98

TABLE II
COMPARISON AMONG PROPOSED METHOD AND EXISTING METHODS

Name of the Paper	Techniques Applied for Verification	Feature Vector Dimension	Classification Success Rate (%)
Biometric Identification through Hand Geometry Measurement [7]	Euclidian distance Metric	15	86
Hand Reorganization using Implicit Polynomial and Geometric Features [9]	Geometry	16	89
Personal Verification using Palmprint and Hand Geometry Biometric [10]	Normalized Correlation	16	91.66
A prototype Hand Geometry Based Verification System [8]	Absolute Distance Metric	14	94.99
Peg-Free Hand Geometry Recognition Using Hierarchical Geometry and Shape Matching [11]	Gaussian Mixture Models (GMMs)	16	96
A Simple and Effective Technique for Human Verification with Hand Geometry [13]	Distance Based Nearest Neighbor (DBNN)	15	99.11
Authentication of Individuals Using Hand Geometry Biometrics: A Neural Network Approach [12]	Multi layer perception (MLP)	10	99.62
Personal Authentication Using Hand Geometry [14]	Absolute without mean	15	99.71
Proposed System	Euclidean & Weighted Euclidean distance Metrics	6	99.98

3.4 Computational Complexity Analysis

The first three steps of the proposed system can be performed using only simple image processing tools such as image resizing, filtering and point selection. The last step can be done using only simple and tiny arithmetic. Both are fully computationally non-intensive operations.
The proposed system is examined on a heterogeneous dataset collected for real world experiment environment. It can be observed evidently that the performance of the proposed system is better than existing systems in broad perspectives.

4 CONCLUSION

This system is based on new features selection for hand geometry based personal verification systems. This systems is very much user friendly and convenient to implement. The system is peg free and images can be captured by a normal scanner. Organizer need not to manage a high image captured instrument or pegged scanner so it can be implemented in where any time. User can place his/her hand in any orientation less than 45 degree along vertical axis. Generally a large number of feature decrease the performance of computation here only one set of feature vector (nine features) are used which improves the computational efficiency. One special contribution of this system is that it can detect actual valley points although there is a small gap between tips of two fingers. This system runs on hand with nailed finger accurately. The remarkable achievement obtained from the proposed method is the result of verification, which is best among the prevailing techniques of hand geometry based verification system. The system showed promising results with accuracy around 99.98%. The FRR is found to be close to 0.02 and the FAR to be around 0.02.
The proposed approach utilizes primarily the geometry of the hand and work on colored images. If a grayscale image is utilized for the system, then databases search will take a short time and decreases computational time more. If the system works properly when a user placed his/her hand in any angle, it will be more users friendly. The use of neural network based classifier trained on a larger database may result in further improvement of the system accuracy.

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