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FINGERPRINTS IDENTIFICATION AND VERIFICATION BASED ON LOCAL DENSITY DISTRIBUTION WITH ROTATION COMPENSATION

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ABSTRACT

The fingerprints are the more utilized biometric feature for person identification and verification. The fingerprint is easy to understand compare to another existing biometric type such as voice, face. It is capable to create a very high recognition rate for human recognition. In this paper the geometric rotation transform is applied on fingerprint image to obtain a new level of features to represent the finger characteristics and to use for personal identification; the local features are used for their ability to reflect the statistical behavior of fingerprint variation at fingerprint image. The proposed fingerprint system contains three main stages, they are: (i) preprocessing, (ii) feature extraction, and (iii) matching. The preprocessing stage is accomplished by removing some artifacts in order to ensure high identification rates. The extracted features are collected as a feature vector; then they are used to distinguish different individuals. In the matching stage, the nearest neighbor classifier is used to make recognition decisions. The results for identification of the proposed system indicate high identification performance reach to 100%, while the verification test results indicate error rate 99.88% using FVC2004 databases.

Keywords: *Fingerprints Features, Fingerprints Identification, Fingerprints Verification, Biometric Traits, Biometric Database.*

1. INTRODUCTION

The biometric systems work on the physiological and the behavioral biometric data to recognize a person. The physiological features like the fingerprint, iris, palm print, and face stay not changed during the lifetime of a person. The behavioral biometric parameters are keystroke, speech, gait and signature change with environment and age [1]. Fingerprints have used for biometric identification and verification since long for their individuality, immutability, and high acceptability. The Individuality is associated with the uniqueness of ridge details across the individuals while the immutability indicates the persistence of the fingerprints over time [2]. Fingerprints are the feature pattern of the fingers; everyone has his own fingerprints with the permanent uniqueness. Fingerprints are contained many valleys and ridges. The fingerprint is not recognized using valleys and ridges, it is not a recognized minutia, which is some abnormal points on the ridges [3]. It is complicated to extract reliably minutia from the bad quality fingerprint impressions arising from fingers mutilated through scars, scratches because of injuries, accidents and from very dry fingers [4]. The first step to perform fingerprint recognition is enrollment; it is the operation to register the biometric data to the database as a template then fingerprint recognition determines either verification or identification process that is relying on the objective of the study. The person's fingerprint is verified from the database by using matching algorithms this is called verification process (also, it is called (1:1) Matching). Verification is the matching of a claimant fingerprint with enrolling fingerprint, initially, the user enrolls the fingerprint inside the verification system, after that the result demonstrates if the fingerprint that takes from the person is comparing with the fingerprint store as a template in the database or not compares [5]. In the situation of the identification process, the fingerprint obtained from one person is compared with whole fingerprints who store in the database. It is utilized in the process of looking for the criminals and It is known as (1: N) matching [6].

Through the few last years, numerous of the identification and the verification technologies by utilizing biometric features of fingerprints developed. Ravi et al. implemented Fingerprint Recognition by Minutia Score Matching mode (FRMSM). The pre-processing includes binarization, thinning, and noise removal. In the thinning process, the block filter is applied. In order to extract the minutiae from the thinned image and to maintain the quality of the image, the image at the boundary is scanned. The results show that the false matching ratio is best when compared to the current algorithm. The results show the false matching ratio is better when compared to the existing algorithm [7]. Cao et al. implemented two novel features for the nonlinear distortion in the fingerprint. First one is the finger placement direction that is determined from fingerprint foreground while the second one is the ridge compatibility that is extracted using the singular values of the affine matrix estimated using and matched minutiae and their associated ridges. These features are the simple and fixed length to insert into matching result. These two features combined with local minutiae structure and orientation descriptor to enhance the matching performance; that is used to apply fingerprint matching. Minutiae set appeared such as a graph, iterative robust least square (IRLS) and use graph connect the component to detect creases and remove spurious minutiae close to creases. The results on FVC2004 (DB1 and DB3) obtain promising results. The equal error rates (EER) are 3.35% and 1.49% on DB1and DB3 respectively [8]. Choi et al. introduced an enhanced fingerprint recognition system based on a compensating the non-linear distortions may occur in fingerprints. The used features are derived from the geometry of minutiae features and the ridge features. The proposed ridge features are composed of four elements: ridge type, ridge curvature direction, ridge length, and ridge count. These features can appear as the topology information inside ridge patterns appearing through two minutiae; the ridge-based coordinate system in a skeletonized image defined in order to extract ridge features. To perform matching between the determined ridge features and the determined minutia pairs the breadth–first search is used. The maximum score will compute after that; in order to use it as a final matching score between the two extracted fingerprints vectors. The tests implemented on the databases: FVC2002 and FVC2004; the proposed system method compared with the traditional minutiae-based method. It accomplished higher matching scores. These features gave more information for fingerprint matching with little increment in the template size and raised the robustness and accuracy of fingerprint recognition systems by using in conjunction with the existing minutiae features [9]

Medina-Pérez et al. introduced a new fingerprint matching algorithm, it is called M3gl. It consists of three elements: (i) a new feature utilization consisting of clockwise-organized minutiae and do not need to a central minutia, (ii) a new similarity measure which shifts the triplets to locate the better minutiae correspondence, and (iii) a global matching process to determine the alignment using maximizing the amount of global matching minutiae. The method involves using optimizations methods to ignore the matched minutia triplets do not need for conducting matching for the entire representation; this will make M3gl does faster. The results on FVC2002 and FVC2004 databases, with a comparison to six verification algorithms the M3gl obtained the highest accuracy in the less matching time [10].

In our contribution to this is that to execute the fingerprint identification and verification system using a set of local features on rotation fingerprint image to achieve high identification (recognition) and verification (authentication) accuracy. A set of features is extracted from the thinned rotation image then save them in the template. Finally, the images (i.e.; input fingerprint and template) are undergoing to the matching process and the matching score is to be determined through that best results could be established. The hypothesis that will be tested is that the geometric rotation transform is performed on fingerprint image to acquire local distribution of statistical features; then the system utilized the matching results to accept or reject this hypothesis.

2. SYSTEM MODEL

The system workflow contains two main phases: (i) enrollment phase and (ii) identification and verification phase. In the enrollment phase, the system is trained to the identity of every person using its characteristic features. While in the cognition phase the system works either as an identification process or a verification process. The layout for the suggested system is shown in figure 1; it consists of three stages: fingerprint pre-processing, feature extraction using local distribution for statistical features to each block, and matching stage using similarity measures.

2.1 Fingerprint preprocessing stage

The preprocessing stage is the operation in the fingerprint image to remove unwanted data like reflection, noise and so on. This stage is utilized to raise the clearness of the ridge structure. In the proposed system, the preprocessing stage is similar to that mentioned in [11, 12]; this applied stage consists of the steps:

2.1.1 Enhancement of the input image: Fingerprint Image enhancement is to make the image clearer for easy further operations. It includes four steps: **A)** Color Inversion, **B)** Removing noise, **C)** Contrast Enhancements, and **D)** Segmentation and **(E)** Smoothing spatial filter.

2.1.2 Image Binarization (Thresholding): Binarization is a process of converting a gray image into a binary image, it consists of two sets of pixels values {0, 1}. The Otsu is applied [13], who attempts to figure out a single threshold value for the entire image. Then, each pixel is assigned either to image foreground or background according to its intensity value comparing with the threshold value.

2.1.3 Image Thinning: Thinning is the process of reducing the thickness of every line of patterns to only a single pixel width. Then Zhang-Suen algorithm (ZS algorithm) is applied to reduce finger width to a single pixel. These procedures are applied iteratively until no further points are deleted [14].

2.2 Features Extraction Stage

A set of key information in this stage is extracted from the final process for the fingerprint image. The extracted information explained the set of required features to distinguish between persons. In the proposed system, the geometric rotation transform is applied on fingerprint image to obtain a new level of features from these rotated blocks and to modify the spatial relationship between pixels in an image; these features are explained in table 1.

The limitation of this work is to apply the rotation on the image using ɵ angle and extract the five local features.

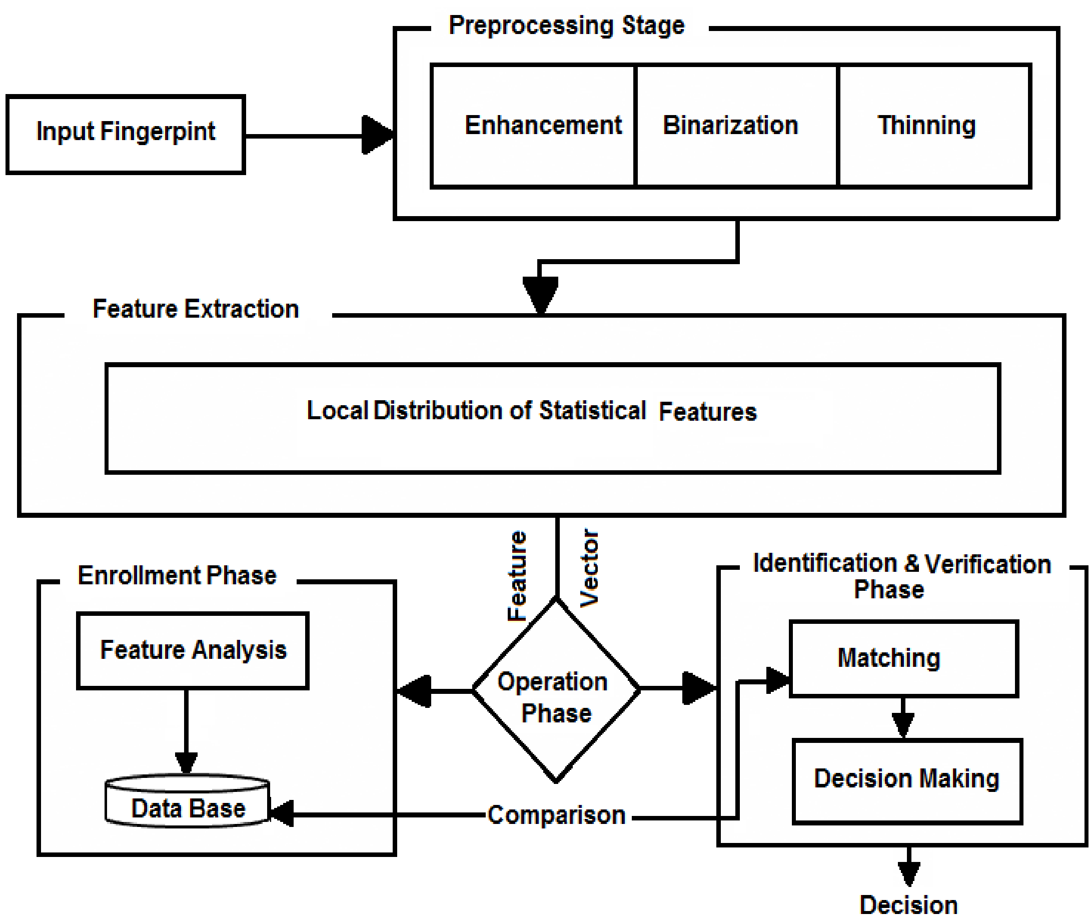

Figure (1): The System Model

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Table (1): Local distribution features

Features	Description
Den	A statistical probability Density function model
Avr_x	Average (mean) for x coordinate
Avr_y	Average (mean) for y coordinate
σ_x	The standard deviation for x coordinate
σ_y	The standard deviation for y coordinate

The involved steps for determining the local projection of the fingerprint image are the following:

Step 1: For each fingerprint image calculate the coordinated to the center of image x_c, y_c using the following equation:

$$x_c = \frac{1}{WH}\sum_{y=0}^{H}\sum_{x=0}^{W} x\, I[x,y] \qquad (1a)$$

$$y_c = \frac{1}{WH}\sum_{y=0}^{H}\sum_{x=0}^{W} y\, I[x,y] \qquad (1b)$$

W & H are the width and height (in pixels) of each image, I() is fingerprint image after preprocessing stage.

Step2: Determine the angular distribution for image using the equation:

$$\theta_{rec} = \frac{1}{2} Atan2\,(S, C) \qquad (2)$$

$$S = 2\sum_{y=0}^{H}\sum_{x=0}^{W}(x - x_c)\,(y - y_c)\, I[x,y] \qquad (3a)$$

$$C = \sum_{y=0}^{H}\sum_{x=0}^{W}((y - y_c)^2\ (x - x_c)^2)\, I[x,y] \qquad (3b)$$

Throughout this paper, the term (x_c,y_c) will refer to coordinates of the center of a fingerprint image.

Step 3: Perform rotation on an input fingerprint image that maps the position picture element in an input fingerprint image to a position in an output fingerprint image through rotating it using ɵ angle as in equation:

$$x' = (x - x_c)cos\theta - (y - y_c)sin\theta + x_c \qquad (4a)$$

$$y' = (x - x_c)sin\theta + (y - y_c)cos\theta + y_c \qquad (4b)$$

Where θ is the angle of rotation with clockwise rotations having positive angles. The output locations will be neglected if they are outside the boundary of the image that means pixel locations out of which an image has been rotated are commonly filled with black pixels.

The fingerprint image is rotated to generate rotation fingerprint image $R_{img}()$.

Step 4: Partition the fingerprint image into blocks.

Step 5: For each block five local features are calculated:

- Density as follow:

$$Den(x,y) = \frac{\sum_{y=ys}^{ye}\sum_{x=xs}^{xe} R_{img}(x,y)}{(x_e - x_s + 1)(y_e - y_s + 1)} \qquad (5)$$

- Average and standard deviation as follow:

$$Avr(x,y) = \frac{1}{N}\sum_{y=ys}^{y=ye}\sum_{x=xs}^{x=xe} R_{img}(x,y) \qquad (6)$$

$$\sigma(x,y) = \sqrt{\frac{1}{N}\sum_{y=ys}^{y=ye}\sum_{x=xs}^{x=xe}\left(R_{img}(x,y) - Avr(x,y)\right)^2} \qquad (7)$$

Where (x_s, y_s) start point for each block, (x_e, y_e) endpoint for each block. N is the total numbers of a pixel in the block. $R_{img}()$ is the rotation fingerprint image.

Step 6: Recall **Step 5** for each rotated block to obtain features.

2.3 Matching Stage

This stage is an operation to compare the obtained feature with the template in the database. That means, the matching stage is to compute:(i) the degree of similarity in both the input test image (for person when he wants to prove his identity) and a training image from database (the template that generated at the time of enrolment) and (ii) to determine if these features for the same fingerprint or from different fingerprint. In the proposed method, two types of distance measures have been tested: (1) Normalized Mean Absolute Differences (NMAD) (2) Normalized Mean Square Differences (NMSD). The best one that; leads to the highest classification rate is adopted, the used distance measure is expressed mathematically as follows:

A. Normalized Mean Absolute Differences (NMAD)

$$NMAD(p,f) = \sum \left| \frac{(F(p,i,f) - \bar{F}(p,f)}{\sigma(p,f)} \right| \quad (8)$$

B. Normalized Mean Square Differences (NMSD)

$$NMSD(p,f) = \sum \left(\frac{F(p,i,f) - \bar{F}(p,f)}{\sigma(p,f)} \right)^2 \quad (9)$$

Where, *(p, i, f)* are the person number, sample number, and feature number, respectively. $\bar{F}$ is the mean feature vector for each person and σ the corresponding standard deviation.

The proposed system is compared to the previously published works [11, 12]; this system has the next distinguish:

- The geometric rotation transform is performed on each fingerprint image.
- There are five local features (Density, Avr_x, Avr_y, σ_x, and σ_y) are extracted from each rotated blocks.
- The statistical conditions are implemented to reject the abnormal situation in features and to get better results.
- The rotation fingerprints images are used for biometric identification and verification.

3. TESTS RESULTS

The dataset used for testing in this research is taken from a FVC2004 database that is publicly available [15]. Every image is a gray scale that is stored in "bmp" format with following properties: To construct the dataset, it consists of four databases (i.e.; DB1, DB2, DB3, and DB4). Each database was taken from 10 persons (subjects), everyone was asked to provide images of his/her index fingerprint to obtain 8 images for each person. Therefore, each fingerprint database is composed of 80 images. Table 2 demonstrates databases properties. The results of the performed tests are described in details in the next subsections.

Table (2): Databases properties

Database	Image Size	Resolution
DB1	640×480 pixels	96 dpi
DB2	328×364 pixels	
DB3	300×480 pixels	
DB4	288 ×384 pixels	

3.1 Identification(Recognition)Results

The system performance is evaluated in the identification process by the correct recognition rate (CRR); that is the ratios between the numbers of corrects recognition decisions (n_C) and the totals number of tried tests (n_T):

$$CRR = \frac{n_C}{n_T} \quad (10)$$

The recognition accuracy is specified using two situations: (i) using three sets of local features: Den, Ave, and σ, and (ii) using a combination of features comprised of four combined features: Den_Avr; Den_σ; Avr_σ; and Den_Avr_σ.

Table 3 lists the attained recognition values for the block size (15×17) and using two differences methods (NMAD and NMSD). The results presented that the standard deviation feature gives enhancement in results.

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Table (3): The Recognition rate

Mean Absolute Differences							
	Features			Combination Features			
	Den	Avr	σ	Den_Avr	Den_σ	Avr_σ	Den_Avr_σ
DB1	65	72.5	66.25	71.25	68.75	77.5	76.25
DB2	53.75	53.75	78.75	53.75	75	70	68.75
DB3	66.25	61.25	81.25	67.5	85	75	76.25
DB4	73.75	77.5	83.75	77.5	87.5	86.25	83.75

Mean Square Differences							
	Features			Combination Features			
	Den	Avr	σ	Den_Avr	Den_σ	Avr_σ	Den_Avr_σ
DB1	70	85	85	80	88.75	88.75	90
DB2	66.25	66.25	98.75	67.5	98.75	97.5	96.25
DB3	82.5	80	97.5	82.5	97.5	97.5	96.25
DB4	90	92.5	93.75	92.5	97.5	97.5	97.5

Also, the statistical conditions are applied to remove abnormal cases in features and to enhance results. These conditions are:

Statistical condition1:

When $\sigma(p, f) \leq 0.1 \times \bar{F}(p, f)$ then

$$\sigma(p, f) = 0.1 \times \bar{F}(p, f) \quad (11)$$

Statistical condition2:

When $\sigma(p, f) \leq \frac{1}{5} \times \sigma_A(p)$ then

$$\sigma(p, f) = \frac{1}{5} \times \sigma_A(p) \quad (12)$$

Where, *(p, f)* are the person number, and feature number. $\bar{F}$ is the mean feature vector for each person and σ the corresponding standard deviation. σ_A is the average standard deviation for each person.

Table 4 shows the effects of using statistical conditions on recognition rate using NMSD because it gave a better result than NMAD and block size 15×17. The results indicated that these conditions had improved the recognition accuracy especially in combination with conditions in the Den_ σ features.

For this set of parameters, the recognition results are evaluated according to the quantitative basis. The values of the number of blocks effect on the recognition performance behavior. The effects of different values on the number of blocks are presented in table 5. The test was done on DB4 (because it gave better results) using NMSD. The results refer that the best recognition rate is attained when the number of blocks is taken (13x15, 15x17, and 17x19).

Also, the results of FAR, FRR and accuracy versus different threshold values are given in table 7 for database4.

Table (4): The Recognition rate with statistical conditions

a. The Recognition rate using statistical condition 1

	Features			Combination Features			
	Den	Avr	σ	Den_Avr	Den_σ	Avr_σ	Den_Avr_σ
DB1	70	85	85	80	88.75	88.75	90
DB2	66.25	67.5	98.75	67.5	98.75	97.5	96.25
DB3	82.5	78.75	97.5	80	97.5	97.5	95
DB4	90	92.5	93.75	92.5	97.5	97.5	97.5

b. The Recognition rate using statistical condition 2

	Features			Combination Features			
	Den	Avr	σ	Den_Avr	Den_σ	Avr_σ	Den_Avr_σ
DB1	73.75	41.25	86.25	45	92.5	48.75	53.75
DB2	71.25	47.5	98.75	50	98.75	72.5	72.5
DB3	83.75	72.5	97.5	75	97.5	88.75	88.75
DB4	93.75	85	96.25	86.25	100	91.25	91.25

c. The Recognition rate using statistical condition 1 and statistical condition 2

	Features			Combination Features			
	Den	Avr	σ	Den_Avr	Den_σ	Avr_σ	Den_Avr_σ
DB1	73.75	41.25	86.25	45	91.25	48.75	53.75
DB2	71.25	47.5	98.75	50	98.75	75	73.75
DB3	83.75	71.25	97.5	72.5	97.5	88.75	87.5
DB4	93.75	85	96.25	86.25	100	91.25	91.25

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Table (5): The Recognition rate with the different block size

Block size	Features			Combination Features			
	Den	Avr	σ	Den_Avr	Den_σ	Avr_σ	Den_Avr_σ
5×7	71.25	68.75	86.25	70	86.25	86.25	85
7×9	72.5	73.75	90	73.75	88.75	87.5	86.25
9×11	86.25	83.75	93.75	86.25	98.75	100	98.75
11×13	82.5	86.25	95	83.75	97.5	97.5	96.25
13×15	85	90	97.5	87.5	98.75	98.75	98.75
15×17	90	92.5	93.75	92.5	97.5	97.5	97.5
17×19	92.5	95	96.25	95	97.5	97.5	97.5

3.2 Verification (Authentication) Results

The Receiver Operating Characteristic (ROC) curve is used to evaluate the performance of verification system that appears the False Rejection Rate (FRR) versus the False Acceptance Rate (FAR) in various similarity distance thresholds values. Also, the Equal Error Rate (EER) is used to evaluate the performance, that is defined as the error rate of FAR and FRR when they are equal. The EER indicate the minimum attained verification error, thus, the threshold value is chosen according to the minimum error. A small error indicates better verification performance. In order to measure FRR for the proposed method, the samples of each class have been matched against their template, while for measuring FAR; each sample of a certain class is matched against all templates of other classes. The FAR and FRR are defined, respectively, as [16]:

$$FAR = \frac{Number\ of\ accepted\ Impaster}{Total\ number\ of\ Impaster\ access} * 100\% \quad (13)$$

$$FRR = \frac{Number\ of\ rejected\ genuine}{Total\ number\ of\ genuine\ access} * 100\% \quad (14)$$

In addition, the performance of biometric systems can be computed by accuracy (i.e., the ratio of valid predictions) without considering which is positive (P) and which is negative (N) [17].

$$Accuracy = \frac{(TP + TN)}{P + N} \quad (15)$$

The verification performance is tested for the parameters setup that led to the best recognition rate which was achieved by using NMSD in DB4 with statistical conditions and feature Den_σ. Figure 2.a presents the results of the dependency of the four verification rates upon the similarity distance threshold value. The ROC curve between the FAR and FRR for various thresholds values presents in figure 2.b. The optimal thresholds values with the intersection point of the pair (FRR and FAR) presents in the table 6.

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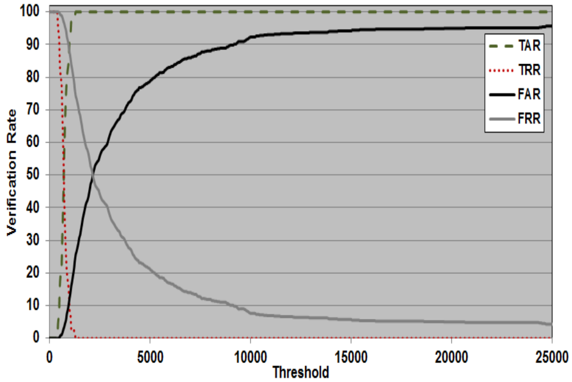

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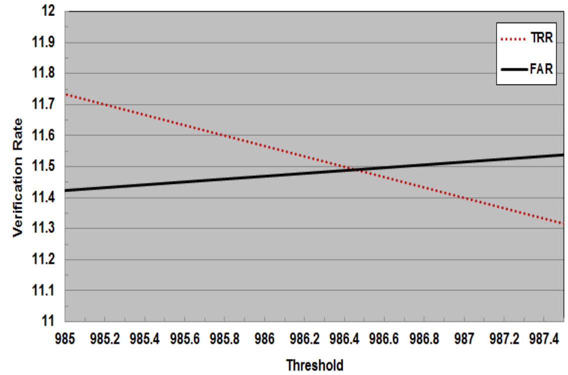
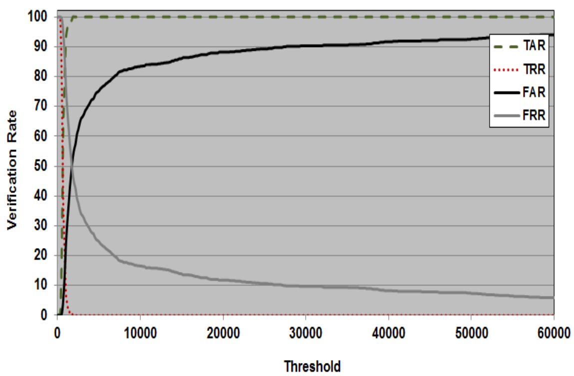


b.

Data Base 1



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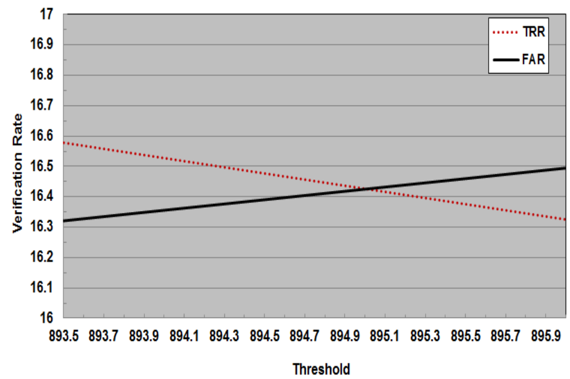

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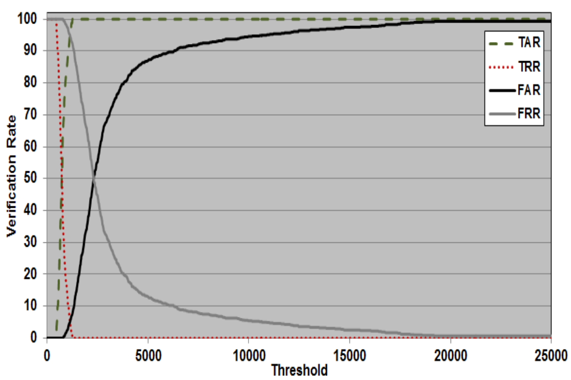

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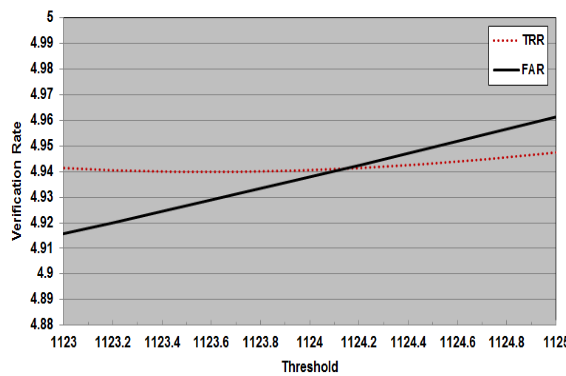

b.

Data Base 3

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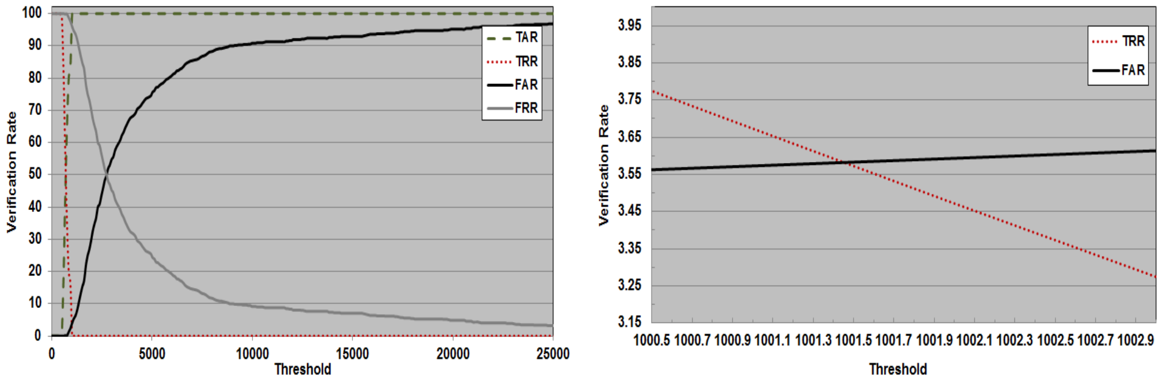

a. b.

Data Base 4

Figure (2): a. The verification rates against the distance threshold values; b. The ORC curve

Table (6): EER point with the threshold value

Database	EER point	Threshold
DB1	11.48%	986.5
DB2	16.42%	895
DB3	4.94%	1124.1
DB4	3.55%	1001.5

Table (7): FAR, FRR, and accuracy versus different threshold values

Threshold	FAR %	FRR %	Accuracy %
70778.149	98.33	1.67	98.50
71034.282	98.47	1.53	98.63
71461.17	98.75	1.25	98.88
139421.85	98.89	1.11	99.00
159485.62	99.03	0.97	99.13
161107.8	99.17	0.83	99.25
169133.31	99.31	0.69	99.38
169474.82	99.44	0.56	99.50
169560.2	99.58	0.42	99.63
169645.57	99.72	0.28	99.75
170670.11	99.86	0.14	99.88

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4. CONCLUSION

The system performance in the identification mode is computed by the re-extraction stage in the fingerprint image was well enhanced. The experimental results demonstrate that the system accomplished recognition rate 98.75%. The best-achieved results indicated perfect recognition rate of (100%) and verification rate was (99.88%) when using the statistical conditions. For future work, our module can be extended in the different direction such as: using another enhancement method that may provide us with higher enhancement, applying another type of features, using another matching method which may increase the power of our system.

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