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Palm Vein Recognition and Verification System Using Local Average of Vein Direction

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Abstract— During the last years, hand vein patterns recognition is one of the most recent biometric technologies used for the identification/verification of individuals. The vein trace is hard to damaged, changed or falsified since veins are internal to the human body. In this paper a novel palm vein recognition and verification system is presented. The first step in the proposed system is image enhancement and localization of veins grid which is a major challenge due to poor quality of veins images. The second challenging task is the palm vein feature extraction. In this research the spatial distribution of local averages of veins direction is introduced and used as feature vector.

The system was tested over a database collected from 250 volunteers, where 24 images for the 2 palms are collected for each person. In total, a database contains 6,000 images belong to 500 different palms. The attained identification result is encouraging (99.95%). The verification tests indicated the achieved minimum equal error rate (EER) is 0.24%.

Index Terms— palm veins, Identification, Verification, Recognition, Biomatric, Pattern Recognition.

1 Introduction

The prime responsibility of any technological development, concerned with access control issue, is to provide a unique and secure identity for citizens, customers or stake holders, and it is a major challenge for organizations. There is an increasing interest for biometric in the research community since the traditional verification methods (such as passwords, personal identification numbers (PINS), magnetic swipe cards, keys and smart cards) offer limited security and are unreliable [1].

Biometrics means "life measurement". A biometric system either makes identification or verifies an identity. It is based on the use of unique and measurable physiological or behavioral characteristics. Physiological characteristics include, but are not limited to, a person's vein patterns, facial structures, ocular characteristics, hand geometry, or fingerprint [2].

Each kind of physical biometrics has merits and demerits. In the case of fingerprints, direct contact of the finger with the fingerprint-image-extracting sensor causes degradation in performance, where good-quality fingerprints are hard to obtain due to oil from the finger, moisture, dirt,...etc. For retina scanning users must place their eye close to the scanner, causing an uncomfortable feeling and concerns of privacy. With hand-shape recognition devices, problems may arise with users who suffer from arthritis or rheumatism, leading to poor performance.

*scbaghdad.edu.iq*Compared with the other physical characteristics, vein pattern recognition is one of the newest biometric techniques were developed to resolve many problems facing the traditional biometric systems. The main reasons for adopting vein palm biometric techniques are:

1. The acquisition process of palm vein image needs no direct contact with the vein pattern-extracting sensor. Since contactless models are more hygienic than all forms of contact biometrics, so the user comfort is improved with use of vein imaging technology [3].
2. Vein pattern does not change over time [4], and they can represent the liveness of a person [5], so the cognition performance can be improved with use of vein imaging technology, and a stable operation is expected [3].
3. Vein recognition technology is notably less costly than many of other biometric technologies (like, iris scanning technology) [3]. In fact, the only biometric solution less expensive than palm-vein is fingerprint recognition but it has its own overheads on security feature [1].
4. For the case of veins imaging, in addition the blood vessels are hidden underneath the skin and are mostly invisible to the human eye; the vein patterns are much harder for intruders to copy, and extremely difficult to steal/misuse compared to other biometric features [6].

Hand veins biometric are robust and steady human authentication more than other biometric technologies so it is considered to be one of the most reliable biometrics for personal identification [4].

2 Literature Review

Many recognition and verification technologies using biometric features of hand veins have been developed over the few last years.

Heenaye and Ali [6] introduced a veins recognition method based on quadratic inference function to extract the

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dorsal hand vein features. For matching task they used the Euclidean distance measure.

Wang and et al [7] presented a new method based on Partition Local Binary Pattern (PLBP). After preprocessing, the image is divided into sub-images. A set of LBP uniform pattern features is extracted from each sub-image. Then, these sets are combined to form the feature vector for token vein texture features. Wang and etal [8]proposed a novel approach to extract multi-scale LBP features of hand vein images using wavelet decomposition. Wang and Chen [4]setup a creatively vein-image capturing system and presented a novel framework. It is composed of image enhancement, feature extraction, noise removal, thinning, skeletonization, and pruning for vein pattern extraction.

Liu and Zhang [9] presented a new method palm recognition based on Two-Dimensional FLD (2DFLD). They applied PCA, PCA+FLD and 2DFLD algorithms to extract the palm-dorsa vein feature subspace.

Wang and et al [10] introduced a novel method for hand vein recognition based on fusing multiple sets of key points extracted from the scale-invariant feature transform (SIFT).

Tang and et al [11] proposed a novel approach for hand dorsa vein recognition; it makes use of multi-level key point detection and SIFT feature based local matching. Prabu and Sivanandam [12] attempted to improve the performance of palm vein based verification system with the help of energy feature based on wavelet transform.

3 Palm Vein Recogniton and Verification System

The layout of the proposed system is shown in Figure(1). It is consist of three main modules: preprocessing, feature extraction and matching. Detail descriptions of the system modules are given in the following sections.

3.1 Preprocessing Stage

The performance of feature extraction algorithm relies heavily on the quality of the input images. In practice, the quality of the obtained raw images is very low because the images are blurred and noisy due to variations in environmental conditions, skin conditions, and acquisition devices, etc. A set of tasks are applied; they are necessary to improve the clarity of the vein pattern structure and localize the veins grid.

A. Image Enhancement

The purpose of this stage is to improve the imaging quality so that vein patterns can be more easily detected during the segmentation. This stage implies the following steps:

1. Image Preparation: The input image is converted to be8-bit gray image. Then, it is converted to the negative which make the ROI as bright region.

Fig.(1) The general structure of the proposed system

2. Brightness Stretching & Normalization: A simple linear type of contrast stretching is applied to enhance the visual appearance of the image details. The dynamic range of pixels values is adjusted to be [0,1]. This process is done using the following equation [13]:

$$N(x,y)=\frac{N_{\max}-N_{\min}}{O_{\max}-O_{\min}}\left(O(x,y)-O_{\min}\right)+N_{\min}$$

3. De-Noising & Integration: Despite the image is blurred, a simple mean smoothing filter is used to reduce the noise and to integrate the white ROI. Mean filter can lead to good result, when applying it in a specific way. The size of the applied mean filter is 7x7, and is applied four times to obtain an acceptable result, denoted $I_s()$.

B. Segmentation

Once the noise is reduced and the contrast enhanced, segmentation permits to separate the vein pattern from the background, it consists of the following tasks:

1. Thresholding: Because the images contain considerable background noise, and there is variation in contrast and illumination gradient. So, the local thresholding mechanism is more suitable to be used than the global thresholding. In this project, the applied local thresholding process implies the following steps:
   - Partition the image, $I_s()$,into small non-overlapped blocks, each has size (kxk).

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- For each block, make a scanning window (with area nxn) covers the block area and extends to the surrounding area (i.e., n>k), see figure (2).
- Determine the mean (m) and standard deviation (σ) of the pixels values located inside the window (nxn).
- Then for each pixel belong to the scanned block (mxm) apply the following thresholding criterion:

$$I_{thr}(x,y) = \begin{cases} I_s(x,y) & if \quad I_s(x,y) \geq m - \alpha\sigma \\ 0 & otherwise \end{cases}$$

In this project, the test results indicated that the setting (block size= 2x2, window size= 18x18 & multiplication factor α = 0.025) led to best thresholding results.

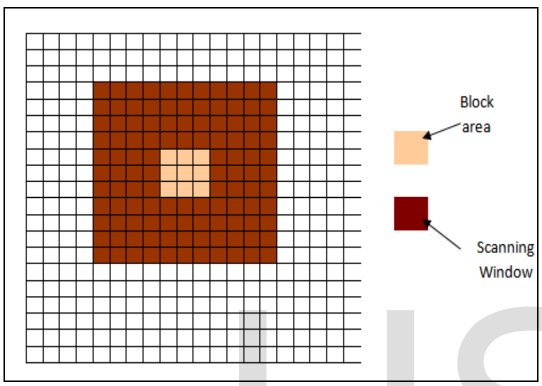

Fig.(2) The Scanning Block and Window Areas

2. Binarization: After applying local thresholding the produced vein image will have better background brightness, and in such case global thresholding becomes more suitable to do binarization. In our proposed system the following steps are adopted to do image binarization:
   - Get the highest pixel value (Max) found in the threshold image.
   - Map each pixel belong to threshold image using the following:

$$I'(x,y) = I_{thr}(x,y) \times \frac{255}{Max}$$

   - Binarize the pixels values using the following criterion

$$I_{bin}(x,y) = \begin{cases} 0 & if \ I'(x,y) < T \\ 1 & otherwise \end{cases}$$

The test results indicated that the best value for T is 100.

C. Post-Processing

This stage was used to process the image after the segmentation, in order to reduce the effect of undesired elements such as noise, and improve the shape of the vein grid. It consists of the following steps:

I. **Cleaning the Gaps and Pores:** In this stage we need to reconstruct the vein image in order to improve the shape of the veins; this was accomplished by: (1) eliminating the small objects in the image; these objects are noise and parts of the background, they were classified as veins due to misclassification, (2) eliminating protrusions, (3) smoothing the contour of the objects (veins), (4) solving the problem of existence of regions containing mixed white and black pixels, (5) removing small holes, and (6) conserving the necks and slim parts of veins from breakage. When applying closing morphological operation on the veins images several defects may appear in the resulting images, like: (1) the small objects are kept and strengthened instead of removing them from the image, (2) when two veins are too close to each other they may linked, (3) misclassification may occur for the regions containing mixed white and black pixels, because such regions are always considered as veins. Because of the above reasons, the closing operation is not useful to improve the studied images.

The opening morphological operation gives more acceptable results than the closing operation for allocating the shape of veins in the image. It is used to remove small objects from the image without altering the overall shape and size of the large objects (veins object). Also, its smooth the contours of the existing large objects. But when the traditional opening operation is applied on the veins images several defects appeared, like: (1) the vein in some places appears too skinny, or it may be narrow (like a neck) and due to traditional opening operation this part will disappear, (2) there are many regions in the vein image are mixture of white and black pixels; these regions may be parts of veins, parts of the background, or noise; they appear due to converting the image from gray to the binary. The traditional opening operation deletes all these regions without any consideration to the probability of being veins, (3) the holes are not removed from the veins regions. These defects significantly affect shape of veins grid.

For these reasons, a new algorithm is proposed to allocate and improve the shape of veins grid by cleaning the appeared gaps and pores from the image. This algorithm works to:

- Remove the small objects from the image.
- Smooth the boundary of veins (contour).
- Remove the small holes.
- Conserve the necks and slim veins regions from breakage defect.
- Take into consideration that the mixed regions could be part of the veins or not.

In the proposed algorithm the treatment of each pixel depends on its location. The applied steps of the introduced algorithm are:

1. For each corner pixel the algorithm counts the number of all the adjacent white pixels; then the pixel is treated depending on this number. There are two possible cases: For black pixel (i.e., 0): if the number is more than one, then the pixel is considered as gap and converted to the white pixel, otherwise it kept black. For white pixel (i.e., 1): if the number is zero then pixel is considered as pore point and converted to black, otherwise it is kept white.
2. For each pixel on the edge line the algorithm counts the number of all adjacent white pixels, then, the pixel is treated depending on this number. The number of white pixels. There are two cases: For black pixel (=0): if the number is higher than two, then the pixel is considered as gap point and converted to white, otherwise it is left black. For white pixel (=1): if the number is less than two, then the pixel is considered as pore point and converted to black, otherwise is left white.

3. For each pixel in the inner region: the algorithm counts the number of all the adjacent white pixels then the pixel is treated depending on this count value. The result depend on the value of the selected pixel, there are two cases: For black pixel (0): if the number is more than four, then the pixel is considered as gap point and converted to white, otherwise it is left black. For white pixel (1): if the number is less than four, the pixel is considered as pore point and converted to black, otherwise is left white.

II. **Thining:** The vein patterns could have different thicknesses due to physiological status of a person (for example, fatigue or non-fatigue) or it may due to the preprocessing operations. Therefore, vein thickness is not a stable pattern for recognition. So, the thinning operation is needed to ensure representation of veins objects that can correctly describe the main features like shape and connectivity.

A new thinning method is developed for more control to make thinning up to a certain width. The proposed thinning algorithm is designed to reduce the width of the pattern to five pixels width line. It will solve the problem of hand shift when taking its IR image. The algorithm tests only the white pixels in the image, either it decides to leave the pixel or convert it to black pixel (white pixels indicate vein and black pixels refer to background). The introduced algorithm consists of the following steps:

1. Apply the mask, M(),on the selected pixel in order to find if the pixel is inside the vein area or not, this implies counting the number of the white pixels surrounding the tested white pixel; this is done by applying the following equation:

$$F_{out}(x,y)=\sum_{j=-2}^{2}\sum_{i=-2}^{2} I(x+i,y+j)\,M(i+2,j+2)$$

Where, *I()* is the input image array, *M()* is the used mask (in our system a 5x5 mask is used because the required vein width is five pixels), F_{out} is the number of the adjacent white pixels. All the mask's element values are "1", except the corner pixels they set "0". This mask is designed to make the output vein as smooth as the natural veins. If the value of F_{out} is more than 20 then the tested white pixel is considered as part of vein and left as it is; otherwise the algorithm applies the multi-directional checks on that pixel.

2. In this step, the thinning operation starts after applying the full area test and knowing that the specific pixel is not inside the vein. A set of multi-directional checks are applied on the tested white pixel to decide if the pixel has to be removed (i.e., convert the white pixel to black) in order to thin the vein segment. The multi-directional checking operations imply checking along the horizontal extent: for each tested pixel the algorithm scans the four neighbor pixels on both sides horizontally to check the existence of the four successive white pixels. Now, if the algorithm found these successive white pixels on one side or both sides it will start the vertical checking. Otherwise, the pixel is left as white pixel and considered as a part of vein skeleton. This task is repeated for other directions (i.e., vertical, main diagonal, and second diagonal).
3. Apply the gaps and pores algorithm twice.
4. The algorithm repeats its steps until the required thinning achieved. The proposed algorithm rounds are stopped when the following conditions satisfied:

$$\beta > \frac{M_2}{M_1} > \alpha$$

Where,

$$M_1=\sum_{\forall y}\sum_{\forall x} I(x,y),\quad M_2=\sum_{\forall y}\sum_{\forall x} I'(x,y)$$

Where, *I()* is the input image array, *I'()* is the image array after processing. In this project, the parameters values (α=0.985 and β=1.015)led to the best skeleton result.

III. **Fine Thining:** The purpose of this stage is making better thinning for the veins body. More thinning can be achieved by applying the following steps:

1. Integration: In this stage, the integration process is applied to make veins thinner; this is done by increasing the brightness of vein's center, and reducing the brightness of the vein's sides. This step will give more characterization for the center of the veins.

The integration process works by opening a window (nxn) around each pixel and calculate the new value by applying the following equation:

$$I'(x,y)=\sum_{j=-r}^{r}\sum_{i=-r}^{r} I(x+i,y+j)$$

$$r=\frac{1}{2}\,(n-1)$$

Where, *I'()* is the resulted integrated image, *I()* is the input image and n is the window length.

2. Edge Normalization: now, the normaliza-tion process is applied to improve the intensity contrast between the center of veins and its sides. In this project, the applied normalization process consists of the following steps:

- For each non zero pixel, open a window (nxn) to determine the mean value (m) for all the pixels located inside the window. Then, the following threshold-ing criterion is applied:

$$I_{th}(x,y)=\begin{cases} I(x,y) & if \quad I(x,y)\ge \alpha m \\ 0 & otherwise \end{cases}$$

In our applied system, when the window size is taken (3x3) and the multiplication factor α is set 0.25; it was found that the attained normalization is the best.

- Determine the new value using the following equation:

$$I_R(x,y) = \frac{1}{m} I_{th}(x,y)$$

Then find the global maximum pixel value (I_{max}).

- Calculate the normalization value for each pixel by applying the following equations:

$$I_{norm}(x,y)=Slp\times I_R(x,y)$$

$$Slp=\frac{I'_{\max}}{I_{\max}\ \times\ \alpha}$$

Where, I_R *()* is the final process image array, I_{norm}*()* is the edge normalized image array, I'_{max} is set 255, I_{max} is the maximum found pixel value, and (α=0.9).

3. Binarization with Thinning: This stage aims to allocate the center of vein. In this stage, the gray image is converted to binary image to keep only the object of interest. Several

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global and local adaptive thresholding methods were investigated and founded that these methods lead to lose some parts of the veins.

In the proposed method each non-zero pixel in the image is compared twice with its four adjacent pixels. In the first check, the pixel is compared with the left and right pixels; and in the second check, it is compared with the up and down pixels, then by applying the following criteria the pixel is binarized:

$$I_{bin}(x,y)=\begin{cases}1 & \textit{if} \quad (I(x-1,y)\le I(x,y)\ge I(x+1,y)) \\ & \textit{or} \ (I(x,y-1)\le I(x,y)\ge I(x,y+1)) \\ 0 & \quad \textit{otherwise}\end{cases}$$

Where *I()* is the input gray image after normalization and $I_{bin}()$ is the output binary image. Figure (3) presents an illustration for the preprocessing stage.

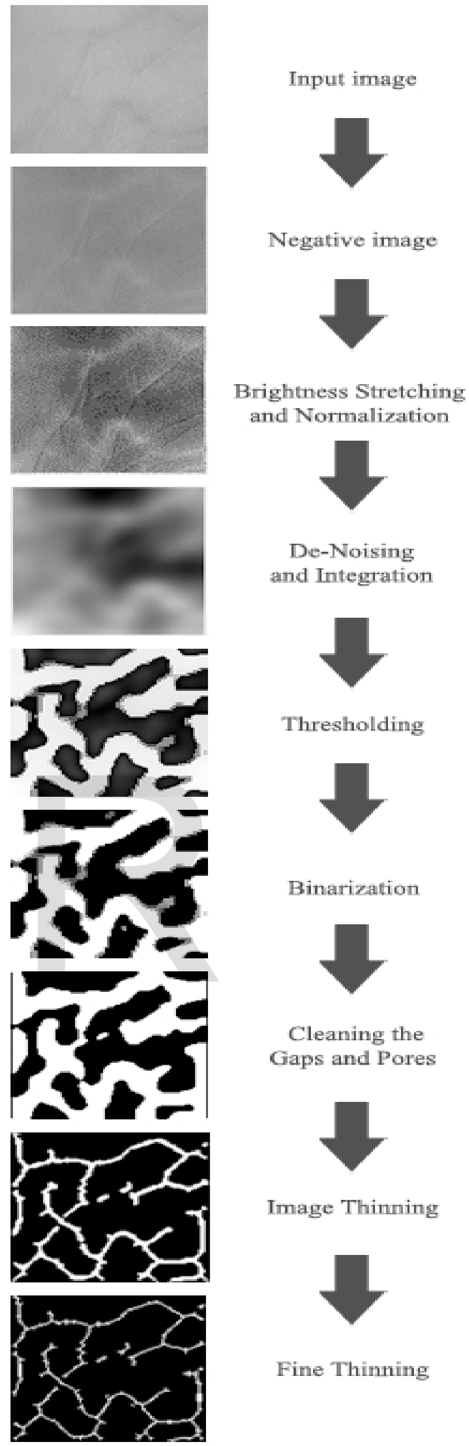

Fig (3) Illustration for the outcomes of preprocessing stage

3.3 Feature Extraction

In this stage, a set of key information is extracted from the final processed vein's image. The extracted information represents the set of required features to distinguish between persons. The local average of veins directions method is proposed as discriminating veins grid features.

The benefits of this method are: (1) it is applicable in spatial domain and reflects the directionality of veins tracks, and (2) it is indirect measure to the distribution of veins density in each parts of image. So, this set of features depends mainly on the distribution of vein's directions at different parts of the image.

The following steps have been applied to extract the features vector:

1. Determine the direction of each vein pixel in the image; that is by checking if the pixel is located in the vein body along the horizontal, vertical, main diagonal or second diagonal direction. This is done by checking all the connected pixels, surrounding the tested pixel, along the four directions and to count the extent of these pixels. Then, the longest extent is taken as the local direction of the vein at the tested pixel location.
2. The resulting 2D-array of vein direction is divided into blocks.
3. The average of local directions is determined for each block, separately; and the determined average values for all blocks are assembled as a feature vector. Four features extracted from each block, that is the densities of the (i) vertical, (ii) horizontal, (iii) main diagonal, and (iv) second diagonal veins direction. Each of these direction features is calculated by counting the number of pixels which have that direction, and then dividing it by the total number of veins pixels. Figure (4) presents an example of pixel with second diagonal feature.

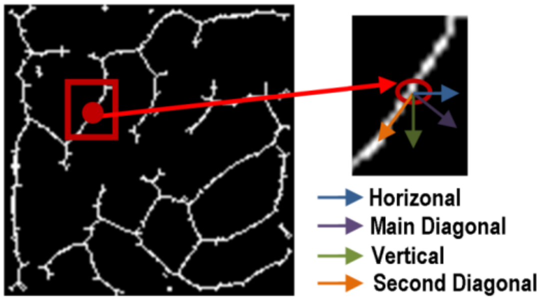

Fig. (4) Example of pixel with second diagonal feature

3.4 Matching Stage

This stage calculates the degree of matching between two vein patterns. The extracted vein patterns of the input image can directly be compared with the stored templates. A similarity measure should be used to evaluate the similarity degree between a template and an input pattern.

In this work the two Euclidean similarity measures (i.e., mean square difference and the mean absolute difference; called city block distance) have tested to evaluate their suitability for matching the veins feature vectors.

4 Experimental Results

The performance of the proposed system was tested using a database collected from 250 volunteers, including 195 males and 55 females. The age distribution of volunteers is from 17 to 60 years. The samples are collected in two separate sessions. In each session, the subject was asked to provide 6 images for each palm. Therefore, 24 images of each volunteer are collected, 12 of them for each of his/her 2 palms. In total, the database consists of 6,000 images taken from 500 different palms. The average time interval between the first and the second sessions was about 9 days. The proposed method have used the near-infrared (NIR) illuminations images of PolyU multi-spectral palm print database[14].

The results of the conducted tests are described in details in the following subsections.

4.1 Veins Localization Results

To achieve an efficient performance for vein recognition and verification, veins grid must be extracted correctly. The localization of vein can be subjectively evaluated by matching the extracted vein grid with the veins network that can be seen in the original image. Figure (5) presents the final vein localization image for one person and his image after projecting the vein localization on the enhanced original images (note: the original images have been modified for the purposes of assisting the subjective comparison task).

4.2 Identification (Recognition) Results

In the identification mode, the system performance is measured using the parameter correct recognition rate (CRR); it is the ratio of the number of samples being correctly classified to the total number of tested samples.

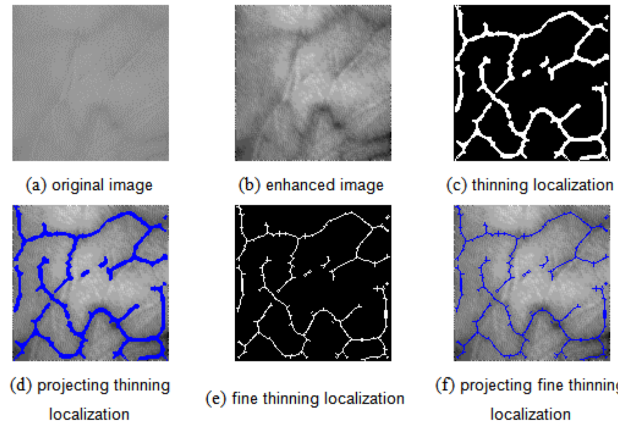

Fig.(5) Final vein localization image for one person

There is a set of system parameters that affect the recognition performance behavior, the main affecting ones are :

- Number of blocks (ROI divided into NxN block).
- The ratio of the overlapped blocks.

The recognition rate is determined for the two cases: (i) apply thinning only, and (ii) apply fine thinning. The Euclidean distance and City Block distance are used to measure the similarity between features vector. Table (1) lists the attained recognition values for different number of blocks.

TABLE 1

Recognition rate versus the number of blocks

No. of Blocks	Recognition Rate			
	With Thinning		With Fine Thinning	
	Seq. Distance	Abs. Distance	Seq. Distance	Abs. Distance
4x4	85.65%	85.65%	95.25%	95.90%
5x5	95.35%	95%	98.15%	98.65%
6x6	98.55%	98.35%	99.30%	99.60%
7x7	99.35%	99.30%	99.60%	99.80%
8x8	99.75%	99.70%	99.80%	99.80%
9x9	99.75%	99.80%	99.90%	99.95
10x10	99.65%	99.55%	99.75%	99.85%

The table shows that the recognition rate is improved when adding the fine thinning stage. Also, according to the blocks number parameter, the best recognition rate is achieved when dividing the image into 9x9 blocks, while the second best result came when dividing the image into 8x8 Blocks.

4.3 Verification (Authentication)

The performance of verification system is evaluated by the Receiver Operating Characteristic (ROC) curve, which illustrates the False Rejection Rate (FRR) against the False Acceptance Rate (FAR) at different thresholds on the matching score[15]. The performance is also evaluated by the Equal Error Rate (EER), which is defined as

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the error rate where the FAR and the FRR are equal. The EER indicate the minimum verification error. So, the threshold value is selected according to the minimum error.

The FAR and FRR are defined, respectively, as[16]:

$$FRR = \frac{\text{Number of rejection genuine}}{\text{Total number of genuine acssese}} \times 100\%$$

$$FAR = \frac{\text{Number of accepted imposter}}{\text{Total number of imposter acssese}} \times 100\%$$

Also the performance of biometric systems can be measured by accuracy; i.e., the proportion of correct predictions, without considering what is positive (P) and what is negative (N) [17].

Accuracy=(TP+TN) / (P+N)

Table (2) shows FAR, FRR and Accuracy values with different threshold.

TABLE 2

FAR,FRR AND ACCURACY VERSUS DIFFERENT THRESHOLD

Threshold	FRR%	FAR%	Accuracy%
0.003	0.95	0.00125	99.997
0.0032	0.3	0.01688	99.982
0.0034	0.25	0.1366	99.863
0.0036	0.2	0.7622	99.238
0.0038	0.05	2.9963	97.006

The ROC curve between the FAR and FRR with various thresholds is shown in Figure (6). Equal error rate (EER) is the point where FRR is equal to FAR. Our ROC curve shows that the EER point equals to 0.24% at the threshold value equals to 0.00348.

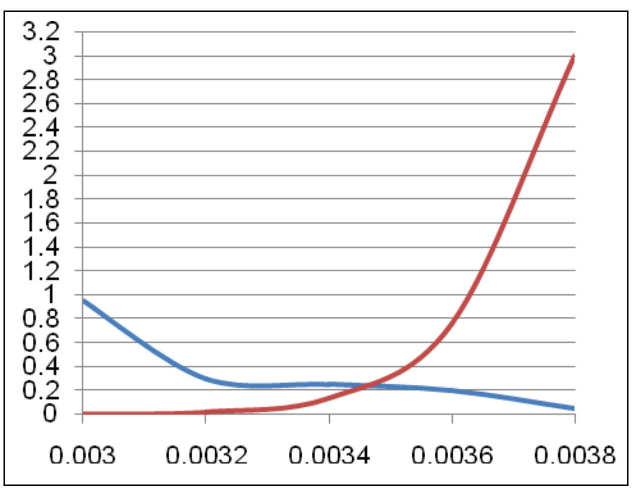

Fig.(6) The ROC curve for the local average of Veins Directions

4.4 Time Results

Another performance parameter in the recog-nition system is the time. The time details of the best achieved recognition rate are shown in table (3).

TABLE (3) EXECUTION TIME

Stage	Time (msec)
Preprocessing	1.704
Feature Extraction	170.14
Matching	158.415
Total	330.25

4.5 Comparison with Published Results

Many vein recognition methods have developed and published. Here, we give a comparison between the performance of our proposed method and some the published methods.

Table (4) presents the recognition(CRR)and verification(EER) results. These results demonstrate that the proposed method outperforms the other methods.

TABLE 4

PERFORMANCE COMPARISON OF SEVERAL METHODS

Method	Dataset	Performance		Time
		CRR	EER	
[Wan10]	2040 images102individuals	98.14%	NA	NA
[Wan11a]	2040 hand images, 102 individuals	99.02%	2.067%	0.368s
[Wan11b]	10 images forleft, andfor right hand, 25 persons	93.4% average	NA	NA
[Liu11]	500 images. 50 persons	98.44%	NA	0.4s
[Wan12]	2040 images with 10 for each hand, 102 person	97.95%	NA	NA
[Tan12]	Both 10 right and left hand 102 subjects	98.04%	NA	NA
[Pra13]	NA	96.66%	0.73%	0.121s
Proposed method	6,000images from 500 palms,250 persons	99.95%	0.2%	

5.CONCLUSION AND FUTURE WORK

In this work, we have proposed a reliable palm vein recognition and verification system. The proposed method to enhance the image and veins localization shows a high performance to extract the veins network, even though the vein images have poor-quality and suffer from many problem (blurry, noisy, etc..). Also, anew algorithm for feature extraction is proposed; it depends on the local average of veins direction.

The experimental results show that our system achieved high recognition rate 99.95%, and EER =0.24% which indicate high performance in verification. The total recognition time is around 0.33ms; which is fast enough for real time applications.

At present, the proposed system can be applied to various parts of the human body where the veins are accessible (like: Finger, wrist, and etc). The quality of image data is vital for the application; hence more work is needed in the data preprocessing stage. So, the current image enhancement methods can be improved to provide better enhancement results with lower complexity and time. Finally, attempts shall be made to integrate the vein pattern biometrics with other types of biometrics to become a multi-modal biometric system. And the candidate biometric technologies under current research include hand geometry and palm-print recognition.

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