Feature Extraction Techniques for Dorsal Hand Vein Pattern

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ABSTRACT: *So far many biometric systems such as fingerprint, palm print and iris have been developed for several years. Nowadays, many researchers are interested in developing new and more efficient biometric systems by using alternative features. In line with this, a newer characteristic that is dorsal hand vein patterns are used to identify an individual because its uniqueness, reliability, permanence and difficulty to forge. To develop a dorsal hand vein biometric security system, the hand vein images are first captured using an appropriate setup. Several preprocessing techniques are then applied to obtain a thinned version of the image. One challenging phase in biometric security system is the feature extraction phase. In this work, three feature extraction and representation techniques namely Hough lines transform, Pixel by Pixel Method and Directional Coding Method have been explored and implemented. These techniques are applied on 500 images obtained from 100 individuals of different age. For matching, Mahalanobis Distance and Correlation Percentage have been used. From the experimental results, it was deduced that Pixel by Pixel Method proved to be the best feature extraction technique with a False Rejection Rate (FRR) of 0.03%.*

Keywords: Dorsal Vein, Hough Lines Transform, Pixel by Pixel, Directional Coding Method, Mahalanobis

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1. Introduction

Due to the globalization and the development of sophisticated recognition system, it is crucial to provide more secure recognition system to fight against the rising crime rate. Most people are identified based on something they know such as a password or a PIN (Personal Identification Number) code. Recognition can be based also on something they own like magnetic swipe cards, keys and smart cards. However, these kinds of identifications are not dependable and convenient because password or PIN code can be forgotten or be divulged and smart card can be lost or stolen.

As a result, biometric is gaining much attention. It analyzes the human biological, physical and behavioral characteristics. It is not easy for intruders to copy and falsify biometric features compared to conventional methods [1]. Biometric authenticates a person from physical characteristics for instance iris, fingerprint, face, thermal image, retina recognition and ear recognition. A person can also be authenticated through his/her personal trait such as voice recognition, signature, gait, lip motion and keystroke.

Many biometric features such as fingerprint, iris and face have been used. Unfortunately, people are finding ways of forging these existing biometrics. Consequently, dorsal hand vein patterns are being adopted over the popular biometric since they are found below the skin of a person and they are not visible with naked eyes. Moreover, the form of the vascular patterns in the dorsal hand is distinct from each other. The image of a dorsal hand vein pattern can be captured only at a live body too [1]. Thus, it is very difficult to falsify it. In addition, as the veins are internal features the state of the skin, humidity, temperature does not have much effect on the vein image.

2. Literature Review

Researchers have deployed different stages, viz, image capture, preprocessing, feature extraction and matching. For matching, Soni et al. (2010) [2] have used an uncomplicated digital SLR camera with an infrared filter to capture the images along with a low cost night vision lamp. For the setup, a wooden box with a hollow rod found in the middle to house the infrared lamp was used. In another work, Badawi (2006) [3] used a non-harmful infrared lightning accompanied with a CCD (charge-coupled device) video camera. The latter has an infrared filter equipped on its objective lens which helps to obtain an untainted infrared image by stopping invisible light to attain the CCD sensor. Wang and Leedham (2005) [4] have used a thermal camera to capture the dorsal hand vein pattern.

Sathish et al. (2012) [1] applied normalization first to the image acquired to extract the most discriminating features of the hand vein. The technique is called contrast stretching which fix the upper and lower limits to discriminate between features. Next, the image is segmented by using local adaptive threshold procedure. To remove noises relative to their size, the area sizes of the black and white backgrounds are calculated. A block considered as noise if the area size of the background was smaller than the known size. On the other hand, Crisan et al. (2008) [5] have used polarized filters in front of the illumination source to reduce specular reflection of the skin, hence increasing the contrast of the image.

To process vein patterns, Soni et al. (2010) [2] presented a method of extracting forkings from a skeleton image. This is done by inspecting the nearby ridge pixel by means of a 3×3 window. The forkings are found out by calculating the number of arms starting off from a pixel. On the other hand, Dhawan (2012) [6] employed Bifurcation structures to extract dorsal hand vein structures. The author classified the vein minutiae points in three ways such as ending point, bifurcation point and double bifurcation point.

To match vein patterns researchers have devised several methods. Wang and Leedham (2005) [4] used Hausdorff distance to match the image captured against the templates of the database. This method compares the similarity of the shapes by measuring the distance between two point sets [4]. To make this technique more efficient for dorsal hand vein patterns, the authors have used a modified version of the Hausdorff Distance to match the vein curves. On the other hand, K Nearest Neighbor matching algorithm was proposed by Nandini et al. (2012) [7]. In this method, the nearest neighbors were first determined and consequently its corresponding class.

3. Proposed Preprocessing Techniques

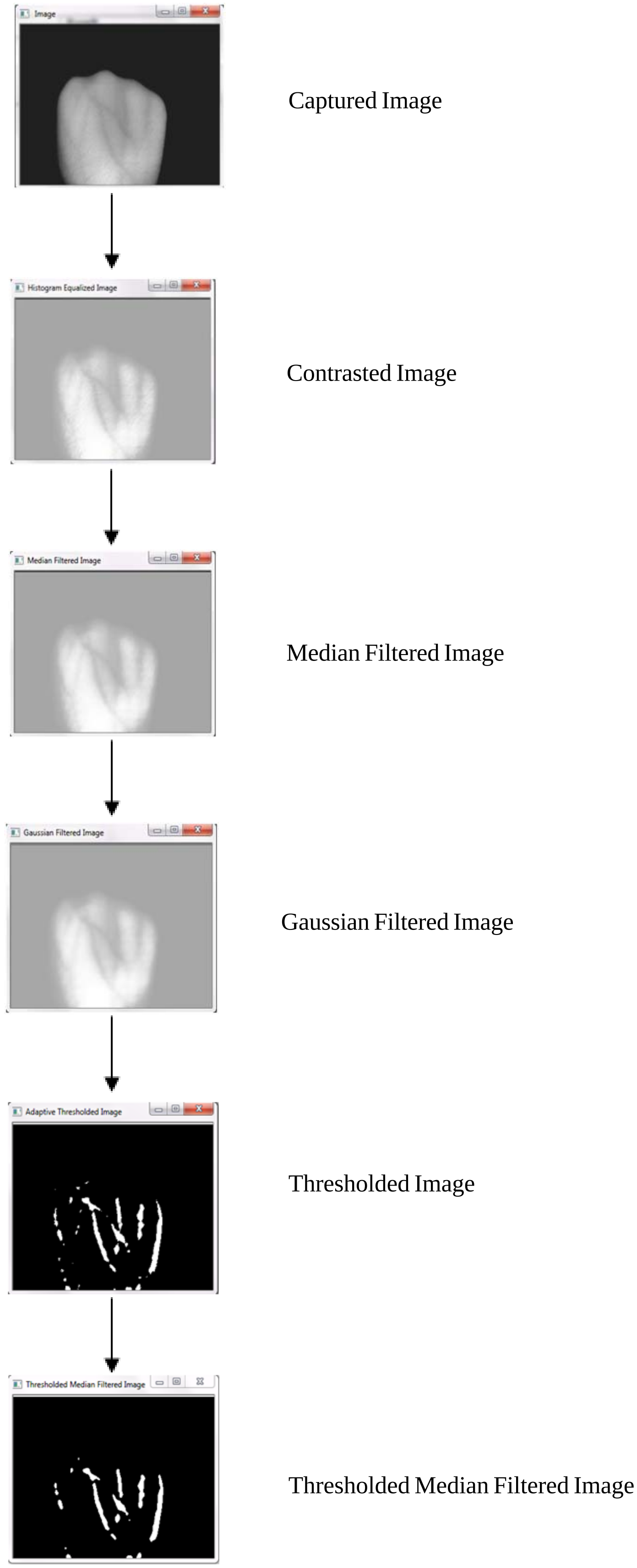
Dorsal hand vein images are acquired by using a normal CMOS camera with an infra-red filter whose wavelength is 720 nm. The dorsal hand vein patterns were then preprocessed using Histogram Equalization function which enhances contrast of the images. Median Filter is then applied to smooth the contrasted image. Thirdly, Gaussian Filter function is used to remove salt and pepper noises. Local adaptive threshold is utilized to segment the filtered image. Noises on the thresholded image are removed by again applying Median Filter and Gaussian Filter. Finally, the Morphological operations namely erosion and dilation are applied to the filtered image to get a thinned image. The following figure shows the results of the preprocessing steps:-

4. Feature Extraction Techniques

To extract dorsal hand vein patterns, the three feature extraction techniques namely Hough Lines Transform, Pixel by Pixel Method and Directional Coding Method have been used.

4.1 Hough Line Transform

Hough Line Transform is a technique that detects straight lines in a thinned vein image. It determines the lines and segregates the features in the vein image. Probabilistic Hough Line Transform which is an enhanced version of the Hough Lines Transform


Captured Image
Contrasted Image
Median Filtered Image
Gaussian Filtered Image
Thresholded Image
Thresholded Median Filtered Image

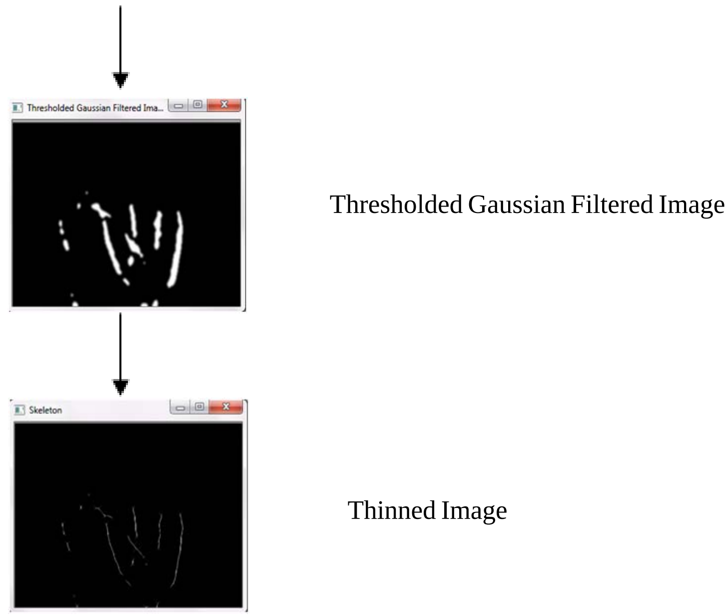


Figure 1. Preprocessing techniques

is applied on the preprocessing vein patterns. It gives extremes of the spotted lines as output. When this feature is extracted, it allows easy comparison between the subject's image and the template image. An example of the detected lines in the veins of the image after applying this method is shown in Figure 2.

Figure 2. Hough lines

4.2 Pixel by Pixel Method

In pixel-by-pixel method, each pixel in the hand vein image is compared with those of the image template. This method is to superimpose two vein projections on one another and they are compared pixelwise. The subject's image is rotated to bring it into line with the template image. The maximum percentage correlation is the calculated which is the ratio if the count of overlapped white pixels between the two images and the image with the highest count of white pixels. A pair of pixels is mismatched if two corresponding pixels are found in different categories. The figure below shows the overlapping of the test image and the template image.

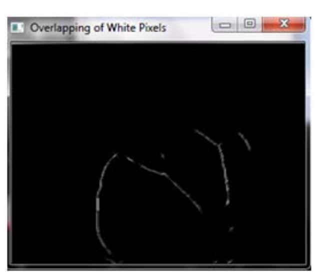


Figure 3. Overlapped Image

4.3 Directional Coding Method

This method extracts the discriminative line information from the dorsal hand vein pattern. The objective is to encode the line pattern based on the adjacent position of the lines. First, Wavelet Transform is applied on the image to break up the hand vein image into a reduced resolution image. Then, the Sobel function is utilized on the transformed image to detect hand vein edges in horizontal, vertical, $+45^0$ and -45^0 orientations. Figure 4 shows the vein image without preprocessing and Figure 5 shows the vein image with preprocessing when applying Directional Coding Method.

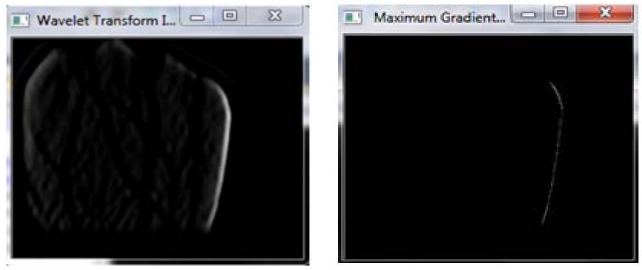


Figure 4. Extracted lines without applying preprocessing techniques

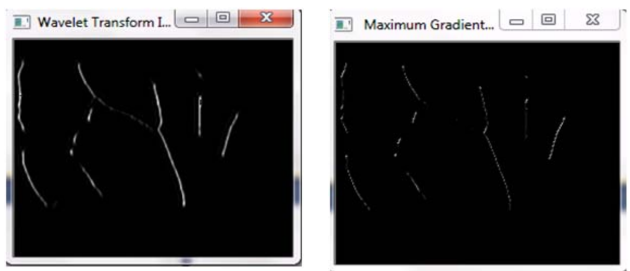


Figure 5. Extracted lines after applying preprocessing techniques

5. Vein Pattern Matching

After extracting the vein features, distance measures are used to compare the similarity between a test image and a template. In this work, Mahalanobis Distance and Correlation Percentage are used.

5.1 Mahalanobis Distance

The Mahalanobis Distance is utilized to calculate the nearest distance between the subject's image and his/her corresponding template image for the Hough Lines Transform and Directional Coding Method feature extractions. This distance depends on the correlation between the covariance matrixes of the two input images. The Mahalanobis Distance is given by

$$D_{Mahalanobis}(x, y) = \sqrt{((x-y)^T \Sigma^{-1} (x-y))} \tag{1}$$

Where,

D: Distance between two images;

x: Subject's image;

y: Corresponding template image;

Σ^{-1}: Covariance matrix

5.2 Correlation Percentage

This method is applied on the Pixel by Pixel method feature extraction. The percentage of the ratio of the number of overlapping white pixels between test image and template image to the least number of white pixels of the two images being matched is calculated.

6. Experimental Results and Evaluation

To evaluate the performance of the biometric security system, the following performance measures are used:

1. False Acceptance Rate (FAR) which is the probability that an unauthorized person gets access to the system,
2. False Rejection Rate (FRR) which is the probability that an unauthorized person is rejected.
3. Equal Error Rate (ERR) which is the point where the FAR is equal to FRR.

A test was carried out on 500 images obtained from 100 individuals. Each individual had 5 instances which were taken at different time interval. To test the performance of the biometric security system, genuine scores and imposter scores are generated. Different training sets and test sets are formed to obtain the scores.

6.1 Test 1: Hough Line Transform using Mahalanobis Distance

First the threshold value is obtained. After experimentations, the value 3.036 has been obtained. This value separates the genuine set from the imposter set. In this way, the FAR and FRR is plotted to obtain the point where they both meet. The value obtained is known as the EER. The table below illustrates the FAR and FRR for 10, 20, 30, 40, 50,100, 200 and 400 images tested respectively. The Receiver Operating Characteristic (ROC) curve is demonstrated in Figure 6.

Number of Images	FAR (%)	FRR (%)
10	0.2000	0.3000
20	0.1000	0.0500
30	0.0667	0.0667
40	0.0750	0.0250
50	0.0200	0.0200
100	0.0100	0.0100
200	0.0000	0.0050
400	0.0000	0.0025

Table 1. Performance Measures for Hough Line Transform

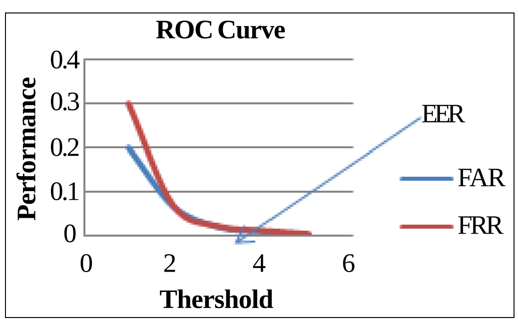


Figure 6. ROC curve for Hough Line Transform

6.2 Test 2: Counting the Number of Overlapped Pixel

The final optimal value calculated from the threshold values of 3 test sets is 49.775. The performance measures are tabled and the ROC Curve is shown below:-

6.3 Test 3: Directional Coding Method using Mahalanobis Distance

For this test, only a few images have been used. The reason behind this is that it takes approximately 11 minutes to generate a wavelet image. The optimal threshold of Directional Coding Method using Mahalanobis Distance is 0.7263.

Number of Images	FAR (%)	FRR (%)
10	0.2000	0.1000
20	0.1500	0.0000
30	0.0333	0.0667
40	0.0250	0.0000
50	0.0600	0.0600
100	0.0500	0.0100
200	0.0100	0.0050
400	0.0000	0.0025

Table 2. Performance Measures for Pixel by Pixel Method

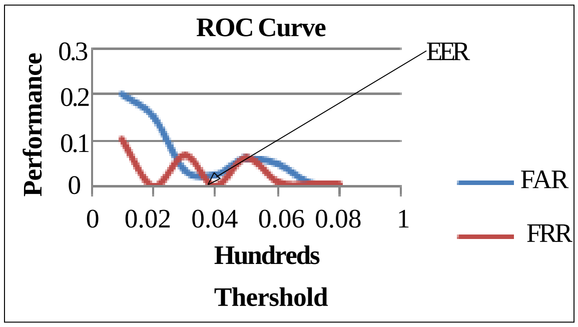


Figure 7. ROC curve for Pixel by Pixel Method

Performance measures for instance FAR and FRR using this feature extraction technique are illustrated in Table 3.

Number of Images	FAR (%)	FRR (%)
10	0.2000	0.2000
20	0.1000	0.1500

Table 3. Performance Measures for Directional Coding Method

7. Conclusion

Three extraction techniques have been explored and implemented for dorsal hand vein pattern namely Hough Lines Transform, Pixel by Pixel method and Directional Coding method. Mahalanobis Distance and Correlation Percentage have been used to match test image with template images. 500 images have been tested from which 100 images were tested as non-existing subjects and genuine score and imposter score for several data sets have been generated. According to performance measures obtained, Hough Lines Transform feature extraction method has a lower False Acceptance Rate using Mahalanobis Distance by 0.01% when compared to Pixel by Pixel method which uses Correlation Percentage. However, the latter has a higher False Rejection Rate by 0.03%. On the other hand, Directional Coding method has a higher False Acceptance Rate and False Rejection Rate in comparison with the two methods when using Mahalanobis Distance. Moreover, it takes approximately 11 minutes to display a wavelet image. Hence, Directional Coding method is not an appropriate feature extraction technique for this biometric system. To conclude, the best feature extraction technique is Pixel by Pixel method because it does not allow access to many non-existing subjects with a FRR of 0.03%.

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