Finger Vein Detection Using Gabor Filter and Region of Interest

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Abstract One of the most biometric recognition systems is Finger vein recognition. It affords authentication using veins, which are within the finger of individuals. This technology has the dominance of being defiant to falsification because the vein pattern is hidden inside a finger. In this paper, we present the key problems and feature extraction methods in order to acquaint finger vein recognition research domain. In our proposed method, vein image is subjected to Gabor filter in conjunction with Region of interest during the preprocessing and to efficiently enhance the invisible vein pattern of given image. Observations are present that our proposed could obtain patterns staunchly when vein dimensions and illumination oscillate, and also the experimental errors for personal identification are very low, in comparison with that of traditional methods.

Keywords Biometric finger vein · Gabor filter · Region of interest
Feature extraction

1 Introduction

Biometrics is in wide spread use at present, as security is of major concern in this modern and networked world. This has led the extensive use of biometrics i.e., the physiological or behavioral characteristics of human beings for authentication purpose. Authentication plays a vital role to protect sensitive data from unauthorized access. The notable features of biometrics such as Universality, Uniqueness, Collectability, Performance, Permanence, Acceptability and Circumvention have made them suitable for authenticating individuals based on their unique traits. This paved the way to biometric authentication and its applicability in areas such as access control, e-commerce, automated teller machines, remote access, financial transactions and network security. Biometric Authentication is primarily used for user identity verification using either physiological or behavioral traits such as finger print, iris, finger vein, palm vein, hand geometry, signature, voice, gait etc.

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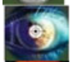
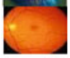
Biometric authentication can be accomplished using any kind of biometric trait but each has its own set of merits and demerits [1–3].

Facial recognition is non-intrusive and a cheaper technology but requires camera for identification [4]. Aging, facial expressions, changes in lighting may decrease the recognition accuracy and also incurs high cost to build. Fingerprint is a widely used and accepted technology for personal authentication but it suffers from low genuine recognition rate and is relatively easy to forge. The finger image quality is highly dependent on the contact between the finger and the sensor and is also susceptible to various conditions such as sweat or wetness of fingers, age etc. [5, 6]. Hand shape recognition has attracted many people as the images are acquired in a user-friendly and non-intrusive manner using low cost sensors [7, 8], can use low quality images along with providing high recognition rate. The demerits would be the size of the hand that makes it applicable to a few applications and hand injury may affect the user acceptance rate. Keystroke is economical and can be easily integrated into the security systems. But the key stroke may differ each time leading to low accuracy in the feature extraction process. Another personal identification system is palm vein recognition using individual veins of palm [1]. But in comparison to the finger vein technology, it is relatively expensive; the size of template is large, and may not be applicable to a human subject who doesn't possess both the palms. Iris pattern possess many advantages such as distinctiveness, life time stability, difficulty to forge etc. that makes it an acceptable trait for biometric authentication. Iris has high recognition accuracy but during image capture it poses few demerits such as necessity of proper amount of light to capture the image, can be obscured by objects such as eyelids and eyelashes and individuals who are blind and having cataract eventually results in the difficulty to capture the iris image. Retinal recognition is difficult to replicate and has high accuracy but it is intrusive and very expensive. Signature is a behavioral trait that can be used for identity check and is also easy to implement. But the signatures may vary with time, leading to low genuine recognition rate and can easily be forged. Voice recognition is non-intrusive with high social acceptability, affordable technology and has less processing time. But it poses few demerits such as the voice of an individual can easily be recorded and used for authentication and the voice may become difficult to recognize during illness which in turn leads to low recognition accuracy [9].

To overcome these challenges, we have opted finger vein as a reliable biometric trait to authenticate persons that assures good recognition accuracy and high security. Our proposed system relies on the finger vein patterns which are more reliable for personal identification [2] needs. The contact less capture of finger vein images by passing infrared light signals through the finger would be an added benefit. Finger vein patterns reside beneath the skin surface and are distinct for each human being. High levels of recognition accuracy, security, long-term stability and sufficiency of less memory to store the vein template are the notable advantages of finger veins. The main aim would be to emphasize the integrity and resilience of finger veins that are user friendly and tamper resistant for authentication purpose (Table 1).

Table 1 Comparison of various biometric traits

Biometric		Uni-versality	Uniqueness	Per-manence	Col-lectability	Per-formance	Accept-ability	Cir-cumvention
Face		☼	☻	☺	☼	☻	☼	☻
Finger Print		☺	☼	☼	☺	☼	☺	☼
Hand Ge-ometry		☺	☺	☺	☼	☺	☺	☺
Key Strokes		☻	☻	☻	☺	☻	☺	☺
Palm vein		☺	☺	☺	☺	☺	☺	☼
Iris		☼	☼	☼	☺	☼	☻	☼
Retianl		☼	☼	☺	☻	☼	☻	☼
Signature		☻	☻	☻	☼	☻	☼	☻
Voice		☺	☻	☻	☺	☻	☼	☻

☼ – good, ☺- normal, ☻ –insufficient

Finger images can be easily captured by passing infrared rays from the back of the hand without causing any harm to the human subject. But most of the captured images have the finger veins with capricious obscure and noise. Hence, there is a necessity to pre-process the image in contemplation of restoring the quality of the image by reducing the noise, irregular shading etc., so that the vein pattern is clearly visible which helps in better recognition rate. Finger vein pattern as it resides internal to a finger, it can be used to provide confidentiality that makes it a reliable security solution. The below mentioned features or advantages makes finger vein pattern the best option for constructing a secure and a safe uni-modal recognition system.

1. Veins reside within the finger and are hence difficult to forge.
2. Vein pattern is distinct to each individual.
3. Image acquisition is resilient to conditions such as oil, sweat and dirt.
4. Vein pattern has long-term stability, as it doesn't deteriorate with time.
5. Images can be captured in a contactless manner.
6. Vein pattern matching is very fast as it completes within the span of an eye blink.
7. Veins are more reliable to ensure both privacy and security.
8. Vein authentication devices are compact and can be easily used as embedded devices in various applications.

The related work reveals the existing methods for finger vein detection. In proposed work reveals proposed method with limitations of existing work. In experiment results, discussed the database considering for experiments and gave results of proposed system. In last section reveals the conclusion.

2 Related Work

Naoto et al. [3] used digitization of the vein images and transform of distance for degradation process. Disadvantage is that more amount of time is being consumed for pre-processing due to the iterative nature of repeated line tracking algorithm. In [6], the features were extracted using bifurcation points and termination points that led to single isolation points around the main detected pattern. To overcome this Gaussian filters are used. In [9], Tanushri Chakravorty, used the linear transformation and histogram equalization technique to enhance the image features but could not produce accurate results with feature extraction. In [10], J. Yang proposed detection of finger vein by combining the Gabor wavelet transformation and Gabor filter. It could produce good result using Gabor filter but could not highlight the vein regions accurately. In [11], X. Chen used the Maximum Margin Locality Preserving Projection feature extraction by processing the input image. Region of Interest localization is a fundamental activity for a finger vein recognition system to capture required regions from the input image [12]. It gives best caliber to the recognition system. It is generally composed of finger vein segmentation of required regions, rotation correction, and detection of interested regions.

The demerits of the above mentioned works such as consumption of more storage space and processing time is due to the fact that they have considered the entire image. As Gabor filter performs best at image enhancement and feature extraction, We are proposed a method which both Gabor Filter along with Region of Interest for reducing the time of processing and only required portion in the input image. The features obtained from the vein image can be stored as a single feature vector [13].

3 Proposed Work

Biometric authentication system basically aims at recognizing individuals based on their unique physical or behavioural traits. It generally involves many phases such as Image Acquisition, Pre-processing the image to enhance the image quality which helps in better recognition rate, Next step to extract the features from the preprocessed image and finally a matching algorithm is used to match the stored template with the acquired image features to identify a human subject either as genuine or imposter. In our work, the input image is taken from the SDMULA-HMT database and we have pre-processed this image to enhance the quality of the vein pattern. In

Fig. 1 Basic flow of biometric authentication system

the pre-processing phase, initially we have extracted the region of interest from the input vein image and then applied proposed method to predominantly improve the quality of the required pattern (vein). Extracting the feature points are depends on the quality of the image. This would eventually increase the genuine acceptance rate of the vein biometric system. The below figure specifies the basic flow of the general biometric authentication system in Fig. 1.

4 Acquiring the Image

One of the advantage of the Finger veins are not visible to the human eye, only when the near infrared rays (NIR) of wavelength between 700 and 1000 nm are passed through the finger [14]. There are two techniques namely light reflection method and light transmission method to acquire the required patterns as shown in Figs. 2 and 3.

When the light source (NIR) is passed through the finger, the light will be reflected in haemoglobin. From this reflected light, a charge coupled device camera captures the vein pattern image. From this captured image, the vein pattern is

Fig. 2 Reflection method

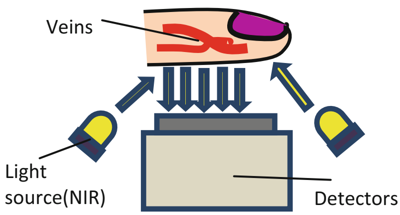
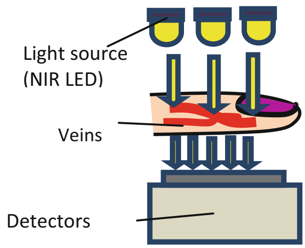


Fig. 3 Transmission method



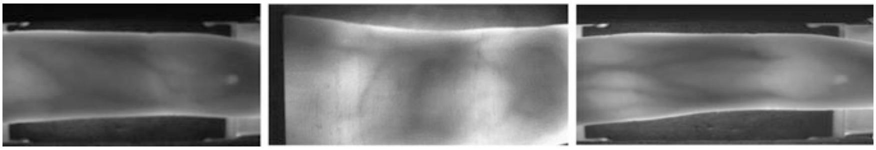


Fig. 4 Sample of finger vein images

constructed using image processing techniques. This pattern is then compressed, converted into digital form and hence registered as a template which is then put in comparison to the stored template of the user. Then process of comparing between images to determine a match. The sample of finger vein images as shown below is taken randomly from the databases of different universities (Fig. 4).

5 Image Enhancement

Input is enhanced based on contrast and noise reduction using spatial filters. Median filter is used for noise reduction in the input image. If we are not gone through this phase, we can get low level features to process in the feature extraction. In Fig. 6g represent the image after median filter on given image.

6 Feature Extraction

In this paper, different existing techniques are put in comparison to augment the need of the proposed method. One of the preprocessing techniques is region growing method; another one is on histogram equalization, median filter and segmentation. Finally, the proposed method is compared with these methods that show the better performance of proposed method.

6.1 Region Growing

This method is used to segment the image based on regions. It is one of the simplest segmentation methods to detect discontinues and regions from the image [15]. It follows edge detection and region identification. The performance of these methods differs with individual segmentation and both will not provide us with the same result. The main criterion for this method is homogeneity of regions like gray level, color, shape, texture etc. Initially, we have to segment the image into small regions and varies aspect ratios of pixels. Region description is compared with neighbour

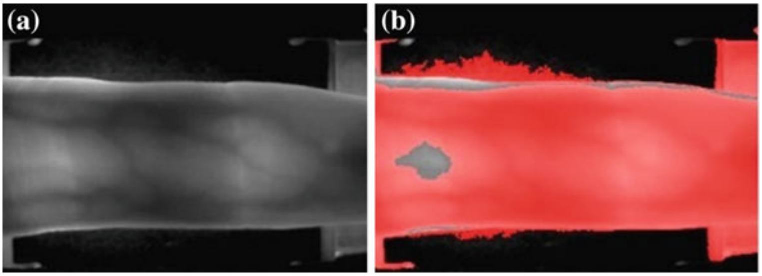


Fig. 5 Image segmentation using region growing **a** input image **b** region growing segmented image

regions. If they match, then those regions will be combined to make a large region until required segmentation of the image (Fig. 5).

Algorithm: Region Growing

Step 1: *Find the Rmin (smallest regions)*
Step 2: *Find the regions which are similar to Rmin, based on homogeneity.*
Step 3: *Merge those regions.*
Step 4: *Repeat the steps 1, 2, 3 until the homogeneity criteria is satisfied.*

6.2 Image Histogram

Histogram is the process of representing the tonal dissemination of image in graphical manner. Characterize the pixels at every tonal value and represent density of pixels each tonal value. It is a simple scanning process that counts the density of pixels found at every change in gray levels. In one of the gray scale image, having 256 possible gray levels and hence the representation will depict the distribution of pixels amongst those 256 gray scale values. The notable advantage of image histogram is that we can decide upon a threshold value when converting a gray scale image to a binary one. Manually we can adjust the scale on the y-axis. If it is automatically, will give high peak values and lead to force a scale. It will negotiate the smaller features. Image histograms can be used by other operations such as contrast stretching and histogram equalization. These operations assume the full intensity range to show the maximum contrast i.e., pixels are distributed or spread evenly over the intensity range.

Histogram equalization is a global enhancement technique that enhances the image contrast by adjusting the intensities of pixels in an image. But this method does not provide us with required contrast to further enhance and segment the finger veins [16]. To overcome this problem, Contrast Limited Adaptive Histogram Equalization (CLAHE) is used to enrich the contrast of a gray scale image to a greater extent as it is a local region based enhancement technique. It divides the entire image into tiles known as regions and operates on these regions, instead on the entire image. It also produces less noise and CLAHE can be calculated as

$$S = Histogram(i) * \frac{255}{M * M} \tag{1}$$

where *Histogram* is the representing the tonal dissemination of regions of image that emulates number of pixels of the i region. S represent calculated occurrence of new pixel value. M represent regional filter or window size. Median filter is a non-linear smoothing filter which is good at removing noise from the image along with preserving the edges and uniformity. This will enhance the image quality. Figure 6g shows the smoothness and noise reduction of the Fig. 6a. The input image has low contrast and hence is difficult to detect and segment the venous regions. As the tip of the vein is not highlighted properly, we consider the segmentation with local and global threshold which will extract the veins with low contrast based on local or regional threshold. Figure 6h shows the segmented image, but some regions near the tip of the vein are difficult to segment. Regions with high visual quality can be observed clearly.

6.3 Gabor Filter and Region of Interest (ROI)

Our proposed technique encompasses the Gabor Filter with Region of Interest (ROI). Region of Interest extracts the required regions from the input image to improve the performance of proposed method due to it is taking less computation time. Existing methods have considered the whole vein image during the process of

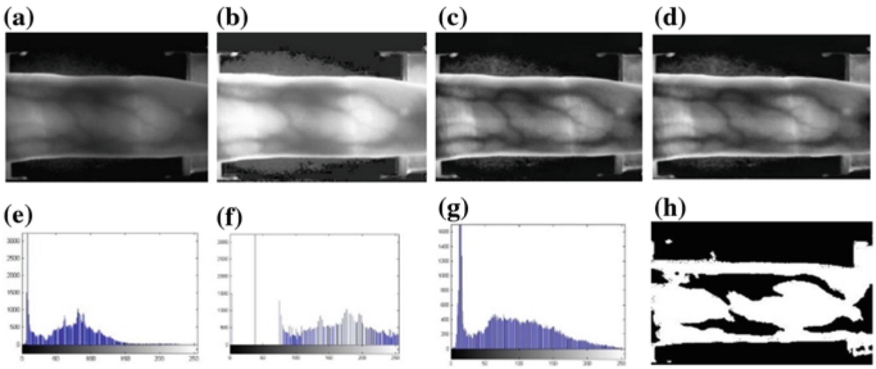


Fig. 6 Seconds method histogram, CLAHE, median filter and segmentation. **a** Input image, **b** image after histogram equalization, **c** CLAHE applied on input image, **d**–**f** histogram of **a**–**c**, **g** image after median filter on input image, **h** segmented image

filtering due to which the computation time increases. The integration of ROI with the Gabor Filter decreases the processing time and also solves the problem of low contrast of the vein images. The Gabor filter is a two-dimensional, adjustable band pass filter; it performs the vein filtering efficiently by considering the magnitude, phase, orientation and peak of the pixel values. As specified above, the finger veins are spread across the finger, the tip of the veins is of non-linear size and the dimension of the veins is also different [17]. It captures the local rotation and frequency occurrence of the venous network. The extraction of features from the image by the using below equation

$$G(x, y, f, \theta) = e^{\left\{\frac{-1}{2}\left[\frac{x'^2}{\delta_{x'}^2} + \frac{y'^2}{\delta_{y'}^2}\right]\right\}} \cos(2\pi f x') \quad (2)$$

where x' and y' are the oriented points after rotation in x and y direction and $\delta_{y'}^2$, $\delta_{x'}^2$ are Gaussian filter spatial constants about the new oriented points, x' and y'. f is the frequency of one of the wave along plane orientated. Obtained features represent the finger venous network.

7 Experimental Results

The results to confirm robustness of the finger vein detection using the Gabor filter with ROI for larger database SDUMLA-HMT [18]. The database helped to experiment proposed method and it is open to researchers with minor authentication.

An Acquisition system was designed by the intelligent computing of Shandong University. Images were acquired through light transmission method for 106 persons (subjects). 6 finger numbers per subject and each finger 6 images are captured and total number of images is 3816 with 320 × 240 pixels image size (Table 2).

Table 2 Performance metrics for finger vein extraction

Feature extraction	Number of images	Performance evaluation metrics	Execution time
Conventional method [19]	3816	EER = 2.36	9 s
Region growing method [19]	3816	Mean sensitivity = 0.711	13 s
Histogram	3816	EER = 0.89	10 s
CLAHE	3816	EER = 0.13	8 s
Proposed method	3816	EER = 0.0009	2.5 ms

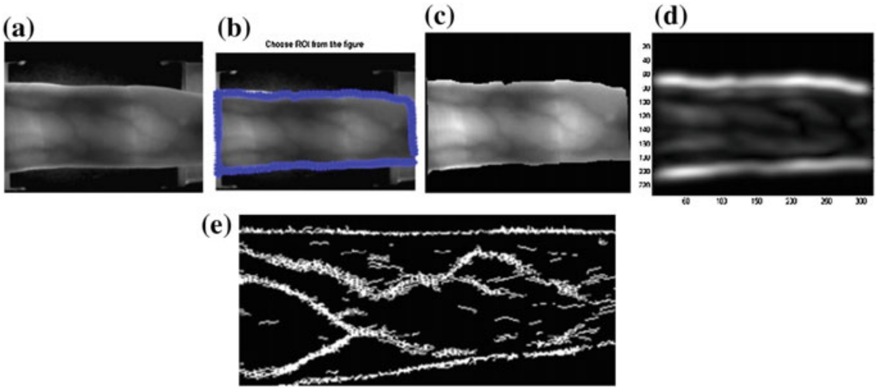


Fig. 7 Feature enhancement with gabor filter. **a** Input image **b** choosing ROI region **c** processing for ROI **d** output of gabor filter **e** detected finger veins

The above experiment gave good results and took less processing time to detect the finger vein regions based on Region of Interest in Fig. 7. But the existing methods consider the total input image that includes unwanted regions.

8 Conclusion

The performance of the finger vein detection by using the Gabor filter and ROI is improved by considering the existing systems. The finger vein pattern identification has improved and also the processing time for extracting the vein pattern is very low with our proposed method. The proposed method was tested and the above results presented were based on the finger vein images of the SDUMLA-HMT [18] database. Our proposed system combining Gabor and Region of Interest can be considered as the most appropriate method in comparison with the above mentioned existing methods for finger vein detection.

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