Gradient based vein Extraction Algorithm for Biometrics System

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Abstract
In Present days, Authentication by means of biometrics systems is used for personal verifications. In spite of having existing technology in biometrics such as recognizing the fingerprints, voice/face recognition etc., the vein patterns can be used for the personal identification. Finger vein is a promising biometric pattern for personal identification and authentication in terms of its security and convenience. Finger vein has gained much attention among researchers to combine accuracy, universality and cost efficiency. We propose a method of personal identification based on finger-vein patterns. An image of a finger captured under infrared light contains not only the vein pattern but also irregular shading produced by the various thicknesses of finger bones and muscles. The proposed method extracts the finger-vein pattern from the unclear image by using gradient feature extraction algorithm and the template matching by Euclidean distance algorithm. The better vein pattern algorithm has to be introduced to achieve the better Equal Error Rate (EER) of 0.05% comparing to the existing vein pattern recognition algorithms.

Keywords: Equal Error Rate (EER), Personal Identification Numbers (PINs), False Rejection Rate (FRR) and False Acceptance Rate (FAR).

I. Introduction

Personal identification technology is used in a wide range of systems for purposes such as part access control, logins for PCs, bank ATM systems, investigation, driver identification, e-commerce systems and many more. Biometric procedures for identifying personalities are attracting attention because conservative techniques such as keys, passwords, and PIN numbers carry the risks of being stolen, lost, or forgotten. There has been considerable research in biometrics (Allain et al,1991), (Berke,2010) over the last two decades. The list of physiological and behavioral biometric characteristics that has to date been developed and implemented is long and includes the face (Lee et al, 2008); (Jain et al,2004), iris (Kilic et al,2011), (Li et al,2011), fingerprint (Miura et al,2004), palm print (Novianto et al, 2002), hand shape (Miura et al,2004), voice (Peleg et al,1984), signature (Song et al,2011), and gait (Wang et al,2010). Notwithstanding this great and increasing variety of biometrics, no biometric has yet been developed that is perfectly reliable or secure. For example, fingerprints and palm prints are usually frayed; voice, signatures, hand shapes, and iris images are easily forged; face recognition can be made difficult by occlusions or face-lifts; and biometrics such as fingerprints, iris and face recognition are susceptible to spoofing attacks (Wang et al , 2010), i.e., the biometric identifiers can be copied and used to create artifacts that can deceive many currently available biometric devices. The great challenge to biometrics is thus to improve recognition performance and be
maximally resistant to deceptive practices (Yang et al., 2009). To this end, many researchers have sought to improve reliability and frustrate spoofs by developing biometrics that are highly individuating; yet at the same time, highly effective and robust. Finger vein pattern is just a promising qualified candidate for biometric-based personal identification.

We designed a special device for acquiring high quality finger-vein images and propose a DSP based embedded platform to implement the finger-vein recognition system in the present study to achieve better recognition performance and reduce computational cost.

The rest of this paper is organized as follows. An overview of the system which proposed here is in Section 2. The device for capturing the finger-vein image acquisition is introduced in Section 3. Our recognition method is addressed in Section 4. Experimental outcomes are discussed in Section 5. Finally, conclusion and future enhancement of the algorithm is described in Section 6.

II. Overview of the System

The proposed system consists of three hardware modules: image acquisition module, DSP main board, and machine communication module. The hardware diagram of the system is shown in Figure 1. The image acquisition module is used to collect finger-vein images. The DSP main board including the DSP chip, memory (flash), and communication port is used to execute the finger-vein recognition algorithm and communicate with the peripheral device. The human machine communication module (LED or keyboard) is used to display recognition results and receive inputs from users. A special imaging device is used to obtain the infrared image of the finger. An infrared light irradiates the back side of the hand and the light passes through the finger. A camera located in the palm side of the hand captures this light. The intensity of light from the LED is adjusted according to the brightness of the image.

![Figure 1. The hardware diagram of the proposed system.](image-url)
The proposed finger-vein recognition algorithm contains two stages: the enrollment stage and the validation stage. Both stages start with finger-vein image preprocessing, which contain detection of the region of interest (ROI), image segmentation, align the scanned image, and enhancement. For the enrollment phase, after the pre-processing and the Gradient extraction stage, the finger-vein template recorded into database is built. For the verification stage, the finger-vein image is inputted for matched with the corresponding template after its features are extracted. Figure 2 shows the flow chart of the suggested algorithm. Some altered methods may have been proposed for finger-vein identical. In view of the computation complexity, competence, and feasibility, however, we propose a novel method based on the Gradient theory, which will be introduced in Section 4 in detail.

III. Image Acquisition

To obtain high quality near-infrared (NIR) images, a distinct device was developed for acquiring the images of the finger vein without being affected by ambient temperature. Mostly, finger-vein patterns can be imaged based on the principles of light reflection or light transmission (Novianto et al, 2002). We developed a finger-vein imaging device based on light transmission for more discrete imaging. Our device mainly contains the following modules: a monochromatic camera of resolution 580 × 600 pixels, daylight cut-off filters (lights with the
wavelength less than 800 nm are cut off), transparent acryl (thickness is 10 mm), and the NIR light foundation. The construction of this device is illustrated in Figure 3. The transparent acryl serves as the platform for locating the finger and removing uneven illumination. The NIR light exposes the backside of the finger. In (Miura et al, 2004), a light-emitting diode (LED) was charity as the illumination source for NIR light. With the LED enlightenment source, however, the shadow of the finger-vein perceptibly appears in the captured images. To address this problematic, an NIR laser diode (LD) was used in our system. Compared with LED, LD has robust penetrability and higher power. In our device, the wavelength of LD is 808nm. Figure 4 shows an example raw finger-vein image captured by using our device.

Figure 3. Illustration of the imaging device.

Figure 4. An example raw finger-vein image captured by our device.

IV. Proposed Algorithm

A. Image Preprocessing

The Captured finger vein image can contain various noise and distortion on it. To extract the feature vein patterns, the image captured have to be normalized by means of image pre-processing techniques. The resultant image is the high contrast image which is to be further processed for the extraction of vein patterns by the algorithm proposed. The procedure for pre-processing the image as follows:

- Read the initial image
- Convert the RGB image to the Gray scale image
- Increase the contrast of the gray scale image by multiplying the image pixel value with the constant
- Noise removal of the contrasted image by adding the “Salt and Pepper” noise onto the image
Distortion of the image has been done by using median filter

Convert the image to Double precision image

The flow of pre-processing is shown below.

Figure. 5. Pre-Processing of Finger Vein Image

B. Image Enhancement

The pre-processed image has to further enhance to improve the contrast of the image. The mean of the Double precision image has been identified and the contrast has been increased by means of floating point accuracy (eps) of the image. The fig.6 shows the resultant contrast images are shown below based on the power of eps.

Figure.6. Enhanced Image

C. Gradient Image Extraction

The feature veins have been extracted from the enhanced image by means of the proposed Gradient Feature Selection Algorithm. An image of a finger captured under infrared light contains not only the vein pattern but also irregular shading produced by the various thicknesses of the finger bones and muscles. The gradient direction representation provides better discrimination ability than the image intensity, and it shows that the combination of gradient directionality and intensity outperforms the gradient feature alone.

In the proposed algorithm, the gradient magnitude has been identified by the given equation

\[ |G| = \sqrt{Gx^2 + Gy^2} \tag{1} \]

The Gx and Gy give the value of the n-dimensional filtering of the gray-scale image with the sobel operator matrices in “Replicate” as border options. The Sobel operator creates the own filter and performs a 2-D spatial gradient measurement of the image that corresponds to the edges. The Absolute gradient magnitude at each point of the Input gray scale image is calculated by the equation (1). The gradient is high at borders of the image and low at rest of the image as shown in the fig 7.

The Gray scale image is converted to the double precision image for finding the gradient magnitude. The double precision image along with the filter created by the sobel operator has been used to perform the magnitude calculation.

For Gx, The Sobel matrix is given as
Sx = \begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix} \quad (2)

For Gy, The sobel matrix is the transpose of Sx,
\[ Sy = Sx^T \quad (3) \]

\[ Sy = \begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix} \quad (4) \]

The Sx and Sy along with the Double precision grayscale image is processed separately for Gx and Gy respectively. Based on the equation (1), The Gradient Magnitude of the gray scale image has been calculated. Figure 4.4 shows the resultant feature extracted image.

**Figure. 7. Gradient Feature Image**

**D. Feature Matching**

Euclidean distance is considered from the center of the source cell to the center of each of the neighboring cells. True Euclidean distance is calculated in each of the distance tools. Conceptually, the Euclidean algorithm works as follows: for each cell, the distance to each source cell is determined by calculating the hypotenuse with \( x_{\text{max}} \) and \( y_{\text{max}} \) as the other two legs of the triangle. This scheming derives the true Euclidean distance, somewhat than the cell distance. The shortest distance to a source is determined, and if it is less than the specified maximum distance, the value is allocated to the cell location on the output raster.

The output values for the Euclidean distance raster are floating-point distance values. If the cell is at an equal distance to two or more sources, the cell is assigned to the source that is first encountered in the scanning process. You cannot control this scanning process.

The above description is only a conceptual depiction of how values are derived. The actual algorithm computes the information using a two-scan sequential process. This process makes the speed of the tool independent from the number of source cells, the distribution of the source cells, and the maximum distance specified. The only factor that influences the speed with which the tool executes is the size of the raster. The computation time is linearly comparative to the number of cells in the Analysis window.

**V. Experimental Results**

**A. Dataset for the experiment**

The Dataset has been archived from different organizations. In the dataset that had taken for the processing contains a set of 2110 finger samples. Each sample having the dimension of 170 x 76 Grayscale image. The dataset contains 106 sets where each set emphasis the 36 finger image of different dimensions. From the archiving data of finger-vein based personal
authentication system introduced in section 2, we eliminate some not active users from the all 1000 users because they have too few records. Because of the vacancy of common finger-vein image database for finger-vein recognition, we build an image database which contains 4500 finger-vein images from 100 individuals. Each individual contributes 45 finger-vein images from three different fingers: forefinger, middle finger and ring finger (10 images per finger) of the right hand. All images are captured using a homemade image acquisition system. The captured finger-vein images are 8-bit gray images with a resolution of 320×240.

![Figure. 8. Finger-vein images from different fingers after preprocessing](image)

**B. Performance Evaluation**

**a. False Acceptance Rate (FAR)**

FAR is also called False Match Rate (FMR). It mentions to the prospect that the system erroneously matches the input decoration to a non-matching template in the database in other words, it procedures the percentage of inacceptable inputs which are erroneously accepted.

**b. False Rejection Rate (FRR)**

FRR is also called false non-match rate (FNMR). It is definite as the likelihood that the organization fails to detect a match flanked by the input pattern and an identical template in the database. That is, it procedures the percentage of valid participations which are imperfectly rejected. It is judicious that the FAR reductions but the FRR increases due to the compassion of the biometric device upsurges. In practical applications, the FAR should be very low to provide high enough confidence and the FRR must be sufficiently low. If the threshold set in the decision stage is reduced, it is expected that less false non-matches but more false accepts generated. In other words, a higher threshold corresponds to a smaller FAR and a larger FRR.

**c. Receiver Operating Characteristic (ROC) Curve**

The ROC curve is used for illustrating the relationship between FAR and FRR. It is a pictorial classification of the trade-off flanked by the FAR and the FRR, i.e., in a ROC curvature the vertical and horizontal axes are FAR and FRR or vice versa, separately.

**d. Equal Error Rate (EER)**

EER is also called Crossover Error Rate (CER). It refers to the error rate at which the FAR equals to the FRR and hence can be effortlessly gained from the ROC curve. In addition, it is usually used for comparing the accuracy of devices with different ROC curves.

**e. Failure to Enroll Rate (FER)**

Besides FAR, FRR and ROC, there are other two factors usually considered in a vein recognition system. One is the failure to enroll rate often caused by low quality inputs. It resources the rate at which challenges to create a template from a participation is unsuccessful. The other is called failure to capture rate. It refers to the probability that the system fails to detect a correctly presented biometric input.
f. Response Time
In practical application, the response time must be taken into account. It is jointly determined by two factors. Unique is the computational complication of vein recognition algorithm and the extra is the competence of processing platform including the accepted software, performance of CPU and the scope of memory, etc.

g. Performance for Personal Authentication
To examine the performance of proposed method for personal authentication, we did an experiment using the method described in to evaluate the false accepted rate (FAR) and false rejected rate (FRR). The proposed Algorithm has been related with the existing line tracking method then the mean curvature method for Equal Error Rate (EER). Here by comparing all the algorithms using the pattern normalization have lower error rates than the version without normalization.

![Figure 9. Genuine Accept Rate (GAR) at Different Thresholds](image1)

![Figure 10. Genuine Reject Rate (GRR) at Different Thresholds](image2)
C. Comparison with Previous Methods

Miura et al. y y n used a database that contained 1356 different infrared images of fingers. These images were achieved from persons working in their laboratory aged 20 to 40, approximately 70% of whom were male. Song’s finger-vein image dataset contained 5000 images together using an infrared imaging device they constructed. Seven images were taken for each of 105 fingers. Compared with these databases, ours is greater and the data-collection interval is longer. Thus, our database is more stimulating. Moreover, our system is implemented on a general DSP chip. Table 1 shows that the average times required for feature extraction and matching in our system are 225 ms and 12 ms, respectively. For the whole system, plus the time for image capturing, the time required for the authentication of a user is less than 0.8 s. Even though the feature extraction in our system is a little bit more difficult than that in Song’s
method, our system achieves an EER of 0.05%, indicating that our method significantly outperforms previous methods.

### TABLE 1

<table>
<thead>
<tr>
<th>Method</th>
<th>Sample Images</th>
<th>EER (%)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Feature Extraction in ms</td>
</tr>
<tr>
<td>Our method</td>
<td>6000</td>
<td>0.05</td>
<td>225</td>
</tr>
<tr>
<td>Liu and Song’s Method</td>
<td>5000</td>
<td>0.07</td>
<td>343</td>
</tr>
<tr>
<td>Miura’s method</td>
<td>1356</td>
<td>0.145</td>
<td>450</td>
</tr>
</tbody>
</table>

VI. Conclusion And Future Enhancements

In this paper, we introduced a Gradient Feature detector to extract vein patterns. It can obtain all the points on the Gradient of vein in the image and increase the information of the feature. We also proposed a new pattern normalization method, which can reduce the irregular distortions caused by variance of finger pose. By using this method, we not only use the mutual information among different vein branches, but also treat every vein branch with independence. This is good for distinguishing the detailed differences among different finger vein patterns, and helpful for dealing with the non-rigid deformation of portions of vein branches during the feature matching process. The proposed system includes a device for capturing finger-vein images and a proposed algorithm to extract finger-vein images by considering various parameters like vein width, position, length, pixels and intersection of veins. Our system is suitable for mobile devices and ATM’s because of its low computational complexity and low power consumption. The advantage of this proposed system is more secured and confidential. The EER of 0.05% is achieved which shows the better performance than the existing vein recognition algorithms.

In the future, this project can be extended to Hand vein, due to ease of access with more security. For the hand vein we need to develop the high end system with several features to be extended. The performance of the hand vein system has to be compared here. The Proposed method extracts the vein features and save it as a template for matching or authentication. As a feature enhancement, the extracted features have been combined with encryption or other security technologies without diminishing authentication performance when converted by means of encryption technology, the vein pattern has been encrypted to generate multiple feature codes in a binary format from a single piece of biometric data, in the case of data leaks or theft; a new feature code can be generated. This technique can be applied to fingerprint authentication as well as palm vein authentication.

References


