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Enhance Region of Interest Extraction method for Finger Vein Images Based on Machine Learning

Hindrustum Shaaban*1 and Haider Salih Mahdi ²

1,2 Department of Computer Science, Faculty of Mathematics and Computer Science,
University of Kufa, Iraq.

* Corresponding author: Hindrustum Shaaban¹, hindrustum.shaaban@uokufa.edu.iq

Abstract

Extracting region of interest (ROI) is an important process for finger vein recognition system. It is determined the part of the image that we need for extracting features. This paper presents an ROI extraction method that overcomes the problems of finger rotation and displacement based on machine learning. First is to locate the finger midline, which will be used in correcting the oblique images. Then, use a sliding window to determine the proximal interphalangeal joint and to further identify the ROI height. Finally, from the corrected image of a certain height, the ROI is obtained by using finger edges internal tangents as ROI boundaries. The results prove that our method is accurate and effective (EER rate of 0.12577), compared with other researchers (EER rate of 0.16296), and thus the proposed method for enhancing the performance of the system.

Keywords: Region of Interest; ROI Height; ROI Width; ROI Extraction

1. Introduction

Security is a major concern in today's world due to the increased rate of crimes and identity thefts. To overcome this problem, there is a great need for efficient authentication and authorization systems. Several authentication systems proposed and implemented; however, finger vein biometrics are increasingly used as foolproof method of automated personal identification. Finger vein recognition is a biometric technique that based on personal physiological characteristics, as it veins patterns in human finger to authenticate identity. Near-infrared light (wavelengths between 700 and 1,000 nanometers) is used to capture finger vein images (Miura, N. et al., 2004; Hashimoto, J., 2006). The principle is that the vein blood hemoglobin can be intensive absorber the near-infrared light; however, this light transmits other finger tissues easily. Thus, finger vein patterns will appear as shadows. As a biometric characteristic, finger vein has several desirable properties, such as universality, distinctiveness, permanence and acceptability. In addition to, compared with other biometric characteristics (for example, face, gait, fingerprint and so on) (Miura, N. et al., 2004).

The important task in finger vein image preprocessing is to locate image ROI, where ROI is assigned to the region, which includes the vein pattern of the finger. Extraction of ROI is important to determine which essential part of finger vein is proper for the next process, saving important parts of veins in ROI and removing useless parts. So, ROI extraction has an essential role in the finger vein recognition system and it is necessary for finger vein images. Accurate ROI extraction will improve the recognition system and reduce the computation complexity. Yang (Yang et al., 2018) proposed a multi-biometric system that combines the minutiae-based fingerprint feature set and the image-based finger-vein feature set. They developed a method with a feature-level fusion strategy with three fusion options for Matching the performance and security strength. The proposed method results were compared with the original partial discrete Fourier transform (P-DFT) method, proving strengthened security. Boucherit (Boucherit et al., 2020) deployed a deep Neural Network called Merge Convolutional Neural Network (Merge CNN) for Finger vein identification. The proposed method was trained using the FV-USM dataset. The results have shown that the proposed method obtained high performance of dataset recognition with a rate of 96.75%. Image enhancement plays a vital role in image recognition. There are many techniques available to remove different noises from the image and enhance the biometric photos, such as finger vein recognition system (Al-Hatmi et al., 2017). Image enhancement plays a vital Zhao (Zhao et al., 2020) introduced an enhanced identification method based on Convolutional Neural Networks (CNNs) using center loss function and dynamic regularization. The proposed method was to implement different Experiments using MMCBNU_6000 and FV-USM datasets. The results have shown that the proposed method is obtained to minimize the loss function's error rate and less time-consuming than other studies. Abbes (Abbes et al., 2020) proposed a combined feature extraction approach using Difference of Gaussian (DoG) and Local Line Binary Patterns (LLBP). The proposed method is deployed two different classifiers, including Support Vector Machine (SVM) and Artificial Neural Network (ANN). The experiments were trained using the dorsal hand vein BOSPHORUS and finger vein MMCBNU_6000 databases. The results presented that ANN achieved a small mean square error (MSE) of 0.001, and SVM achieved a rate of 0.0042 equal error rate (EER). A sliding window based-region of interest (ROI) extraction method was proposed by (Yang, L. et al., 2013). Yang, L. et al., extracted ROI by obtaining the obliqueness angle of the image through the size of the oblique angle, The ROI height using human fingers physiological structure and the ROI width based on finger edges internal tangents. The method was good for oblique images, but the ROI height is sensitive to the light access through the two fingers interphalangeal joints so that the ROI height will change with the value of the distance between the two fingers interphalangeal joints. Through our experiments on finger vein images, we found that the proximal joint position of the finger vein image shows a row with a higher sum gray value compared to all rows in the finger image including the distal joint position. We take the proximal joint position for a reference to determine image ROI height with a fixed window of 300 pixels, as we describe it in the rest of the paper.

2. Proposed method

The proposed method is shown in Figure 1, which explains the main step of processing the input image and getting the output figure. The framework is based on the machine learning approach to identify and recognize the finger vein images and accurately determine the extraction region. In the finger vein images, useless information and noise are found. Thus, the finger vein images are first submitted to ROI extraction to execute the next recognition processes efficiently.

3. ROI Extraction Background

This section will present the needed information related to the RIO extraction method. Three main steps are involved.

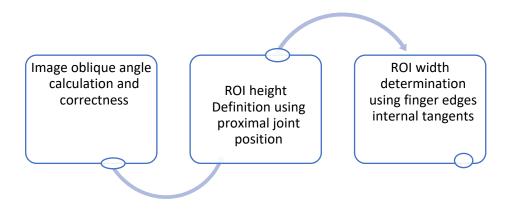


Figure 1: The proposed method architecture

3.1. Finger Vein Image Obliqueness Angle: Calculation and Correction

In the process of acquiring finger vein image, vertical and horizontal displacement occurred due to imperfect placement of the finger in the finger vein reader so that number of oblique finger vein images shows a certain degree of distortion. For more accurate results in the feature extraction, matching processes and correctness of recognition system, we must overcome the problem of distortion and correct the finger oblique angle. This problem is solved in two steps:

- a) Recognize if the finger vein image is oblique or not, and evaluate the obliqueness angle.
- b) Based on the value of obliqueness angle, the finger vein image is corrected.

To calculate obliqueness angle of the finger image, we use a linear fitting method. In detail, we determine the discrete middle points of the finger edges and by applying the linear fitting method, the discrete middle points of the finger's edges are synthesized into a straight line, and the angle between the vertical line direction of the image and the straight line is known as the obliqueness angle of the finger vein image.

In the following points, we will describe the producer of detection and correction the obliqueness angle of finger Vein image:

I. Locate ROI nominee region. In the database (Lu, Y. et al., 2013) that we used in testing our method, the size of the finger vein image is (640 * 480) pixels, we first resized the enrolled finger vein image to (500 * 260) pixels by using the bilinear interpolation method to reduce mathematical calculations. Then, we cropped the image with a predefined window of size (460 * 220) pixels to obtain nominee region for ROI extraction. In

this step, we noticed some fundamental issues. This includes removing unwanted information and noise in the background of the image and keeping consolidated finger region. In Figure (2a), the yellow window is a predefined window. Figure (2b) shows the finger vein nominee region.

- II. Determine finger edges. We convert the finger vein nominee region from grayscale image to binary image by using a threshold of value 0.005. Then we applied "sobel edges" detector to the resulting binary image to create a binary image with the edges of the finger vein nominee region. In Figure (2c), we see the resulting binary image with the edges of the finger.
- III. Determine all midpoints between the edges of the finger. In the result of step II, we determine the rows that contain finger edges. We must consider that the distance between the two edges of the finger must not be less than 80 pixels, where we calculate the finger edge midpoints in this row. A straight line is obtained from the midpoints by applying a linear fitting method. The straight line is the finger edge midline. Figure (2d) shows the finger edges midline.

Determine and correct the obliqueness angle of the finger. The obliqueness angle is determined using the difference between maximum and minimum midpoints column coordinate values. The image is normal when the difference is less than or equal to 5, and the image is oblique when the difference is more than 5. So, we calculate the slope of the midline of the finger by substituting the start and end points of midline of the finger in equation (1), and the finger obliqueness angle is determined using the midline slope.

$$Y = (a * x + b) \tag{1}$$

From equation (2), the straight-line obliqueness angle is computed i.e., α refers to the finger vein image obliqueness angle that is used to correct the obliqueness of the finger image.

$$\alpha = \arctan(a) * 360/2\pi \tag{2}$$

The Figure (2e) shows the finger vein image after correction.

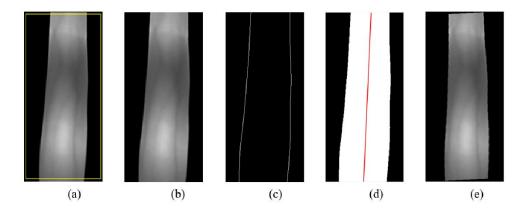


Figure 2: Detection and correction of Oblique image: (a) A predefined window in yellow, (b) Finger vein nominee region, (c) finger edges, (d) finger midline, (e) The corrected image.

3.2. ROI Height Calculation

The variation of finger location in finger vein images of one finger is related to the finger displacement in finger vein reader. As an example, Figure (3) shows that the location of the two interphalangeal joints of one finger exists in different locations in different images. White lines refer to the different locations of the two interphalangeal joints of different finger images in one finger. This problem was solved when we used the proximal joint in the finger as a reference to determine the ROI height of the finger image. Figure (4) shows the two finger interphalangeal joints.

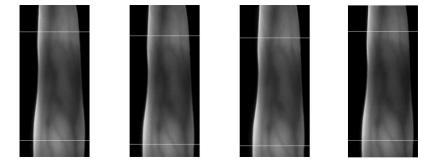


Figure 3: Two phalangeal joint positions in different images of same finger.

From our deep experiment results, we found that the near-infrared light is access through the proximal joint region more than other regions in the finger, including the distal joint. The proximal joint region represents the row with higher gray values sum of the finger image, and generally the location of the proximal joint region lies after the 200th row based on the database that used in experiment works, and this reduce the mathematical calculations that needed to find the proximal joint region

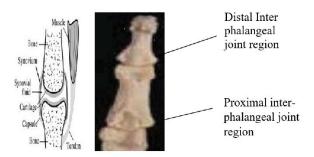


Figure 4: Phalanx structure.

In details, below the steps of determining the ROI height:

- I. Determine the internal tangent of the finger edges. After detecting and correcting the oblique finger image, the sobel edge detector was used again in the vein nominee region to get a binary image of the edges. For non-oblique finger images, the internal tangents of the edges can be taken from the step of finger vein image obliqueness angle calculation and correction, shown in red in Figure (5b). The key area will be obtained when we crop the outside region of the internal tangents in the nominee region, Figure (5 c).
- II. Calculate the sum of key area gray values. Row by row, the key area is pushed from the 200th row to the end of the area. Equation (3) is used to calculate the sum of gray values (where w is the key area width; e is the key area end).

$$S_i = \sum_{j=1}^{w} F(i,j) \quad (i = 200: e)$$
 (3)

III. Estimate the proximal joint position. The row sum of the proximal joint position shows a higher value compared to the other rows, so the higher gray values sum will be shown by the proximal joint slide window. The proximal joint position can be determined using equation (4) (r: proximal joint position): $r = \arg\max(S_i) \ (i=200: e) \tag{4}$

By searching the space from the 200th window to the end of the key area, we can determine the proximal joint window. In figure (5d), the white line refers to the proximal joint position detected.

IV. Determine the ROI height. From step 3, the position of the proximal joint slide window is used to calculate the ROI height, where we employ equation (5) and (6) to determine the start and end rows of the ROI height on the basis of proximal joint position determined by fixed height of 300 pixels calculated in equation (7), figure (5e only ROI height is shown):

$$h1 = r - 250$$
 (5)

$$h2 = r + 50$$
 (6)

$$Height = h2 - h1 \tag{7}$$

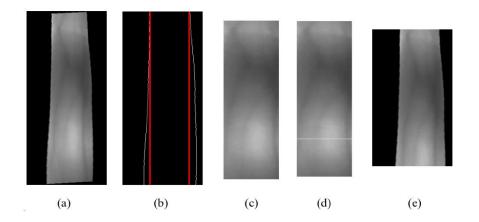


Figure 5: ROI Height. (a) Finger vein image corrected. (b) Binary image of finger edges internal tangents, (c) Key area, (d) Proximal joint position detected, (e) Finger image with ROI height defined.

3.3. ROI Width calculation

The calculation of ROI width is subject to:

- I. Keep the utmost valuable information of the finger region for the feature extraction process,
- II. Overcome the mismatch problem resulting from the horizontal finger displacement. In the finger vein image, where ROI height is determined as shown in Figure (6a), the finger edges internal tangents should be identified again in finger vein image. ROI right and left boundaries are the finger edges internal tangents, Figures (6b, 6c).

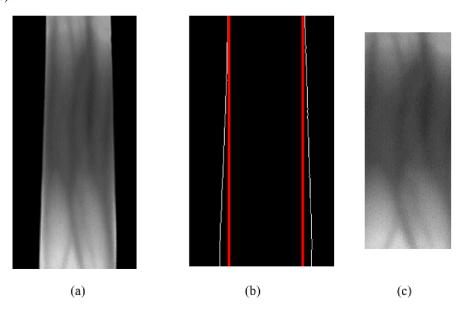


Figure 6: The ROI width: (a) ROI height defined, (b) Binary image of finger edges internal tangents, (c) Finger vein image ROI.

4. Experiments Results

This section will present the experiments data and results.

4.1. Database used in experiments and setting

To assure the accuracy of our method in extracting ROI, we executed accurate experiments on the database of the finger vein images taken from MMCBNU_6000 (Lu, Y. et al., 2013). MMCBNU_6000 consists of four aspects:

- I. It comprises 6000 images (100 subjects \times 6 fingers \times 10 images), where 100 volunteers of 20 countries with different skin colors were involved.
- II. Information regarding blood type, gender, age and nationality is recorded to be later used to analyze the images of finger vein.
- III. Just like a real application, effects of finger tissue and pressure, collection posture, scattering, uneven illumination, scale, rotation and translation are taken into consideration in the process of image acquisition.
- IV. The images acquired in MMCBNU_6000 is similar in image quality to the images from available databases.

To show the robustness of the performance of the proposed method, two experiments are designed for full evaluation.

First, the results of the proposed method in determining ROI height are compared with the method used in (Yang, L. et al., 2013). Then, the results of the proposed method in ROI extraction are compared with the method used in (Yang, L. et al., 2013).

4.2. Experiment 1

In this experiment, we have randomly chosen four images of one finger from our database (Lu, Y. et al., 2013) to test our proposed method and the method in (Yang, L. et al., 2013) and compare the results after correct the obliqueness angle of images if found, we found that the distance between the two phalangeal joints that is in method used by (Yang, L. et al., 2013) as a reference to determine the ROI height region differs from one image to another of the same finger, Figure (7 b) in white lines, and the value of the difference between the two phalangeal joints in method (Yang, L. et al., 2013) determine the height of ROI region as shown in Figure (7c). In our proposed method, from the experiment results, we found that the position of the proximal joint in finger vein image has the row with higher gray

value sums compared with other rows in finger vein image including the position of the distal joint, so that, we take the proximal joint position as a reference to determine finger vein image ROI height, Figure (7d, 7e).

4.3. Experiment 2

In experiment 2, the results of the proposed method for ROI extraction are compared with the results of other methods. In Figure (8), several finger vein images are selected from the database of the same finger and their ROIs extracted by our proposed method and the method in (Yang, L. et al., 2013), for Figure (8b), the height of extracted ROI of the finger by method in (Yang, L. et al., 2013) depends on the distance between the two interphalangeal joints, and from the experiment results, this distance change from image to the other so that the height of ROI extracted will change depending on the change of the value of the distance. In Figure (8c), ROI extracted in our proposed method depends on the proximal joint position in determining ROI height and the two finger edges internal tangents to determine finger ROI width.

To further prove that the method we used for ROI extraction has high accuracy in recognition system than the method of (Yang, L. et al., 2013), size normalization of finger vein images ROI was used so that the size of ROI used to extract features is (192 * 64) pixels. Besides, we use the Local Binary Pattern (LBP) techniques proposed by (Lee Eui et al., 2013) to extract veins features and Euclidean distance (ED) is used to rating the similarity of the binary code extracted and the enrolled code.

We randomly choose fore finger image class of 40 volunteers from our database, each class consists of 6 finger vein images, as a result, there are 1200 matching results in all classes to determine False Rejection Rate (FRR) and 56160 matching results between each class to determine False Acceptance Rate (FAR). Equal Error Rate (EER) was used to evaluate the performance of our method and that of (Yang, L. et al., 2013). Figure (9) explains The Receiver-Operating Characteristics (ROC) for the two compared performances, and Table (1) summarizes the EER values of the two methods.

We can say that from Figure (9) and Table (1), shows that our method has a higher performance than that of (Yang, L. et al., 2013). Particularly, as we used the proximal joint as a reference to calculate finger vein image ROI height.

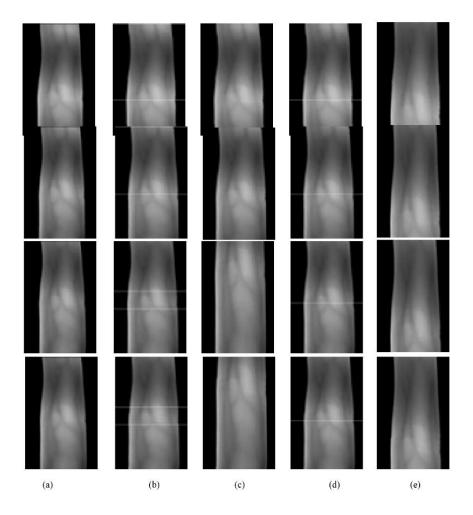


Figure 7: Phalangeal joints position detection: (a) multi-images of one finger. (b)The two phalangeal joints positions detected using (Yang, L. et al., 2013) (c) ROI height detected using (Yang, L. et al., 2013). (d) The proximal joint position detected using our method.

(e) The ROI height detected with our method.

One hundred finger vein images were randomly selected to measure the average time of our method. A laptop of Intel Core i7-2720QM CPU and 4 GB RAM was used in experiments. The average time to extract ROI per image is 320.3 MS. compared to 475 MS. in (Yang, L. et al., 2013), indicating that our method can be applied in real time.

Table 1 Comparison in performance of our method and that of (Yang, L. et al., 2013)

Method	EER
Proposed method	0.12577
Method in (Yang, L. et al., 2013)	0.16296

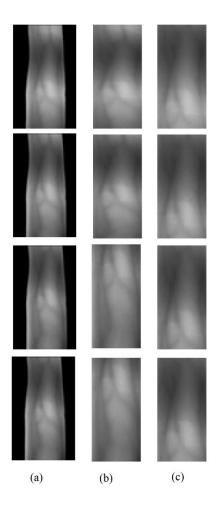


Figure 8: Samples and ROIs: (a) Multi images of one finger, (b) ROI using (Yang, L. et al., 2013), (c) ROI using our method.

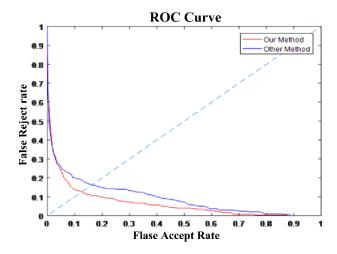


Figure 9: Comparison of ROC curves in our method and that of (Yang, L. et al., 2013)

5. Conclusion & Future Work

This paper proposed an efficient and accurate method for ROI extraction. We determined and corrected the finger image's oblique angle; then, we used the proximal joint as a reference to confirm the ROI height. Finally, we used the finger edges internal tangents as the ROI boundaries. Our method's advantages come from detecting and correcting the oblique images and the definition of ROI height using a sliding window. This way, we can overcome the mismatch that results from finger displacement. Compared with other methods used to extract ROI, our approach achieved high accuracy and minimum error rate. Suppose we want to overcome the problems of oblique finger vein image, vertical and horizontal displacement of the finger image, and reduce the complexity of mathematical processes in preprocessing and extracting the finger vein image features. In that case, we must enhance the finger vein reading accuracy. Future work should focus on implementing deep learning approaches that could enhance the recognition process. Also, implement more loss functions in the experiments, analyze the performance for each loss function.

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