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Finger Vein Identification Based on Maximum Curvature Directional Feature Extraction

Yuhanim Hani Yahaya, Siti Mariyam Shamsuddin and Wong Yee Leng

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ABSTRACT

Finger vein identification has become an important area of study especially in the field of biometric identification and has further potential in the field of forensics. The finger vein pattern has highly discriminative features that exhibit universality, uniqueness and permanence characteristics. Finger vein identification requires living body identification, which means that only vein in living finger can be captured and used for identification. Acquiring useful features from finger vein in order to reflect the identity of an individual is the main issues for identification. This research aims at improving the scheme of finger vein identification take advantage of the proposed feature extraction, which is Maximum Curvature Directional Feature (MCDF). Experimental results based on two public databases, SDUMLA-HMT datasets and PKU datasets show high performance of the proposed scheme in comparison with state-of-the-art methods. The proposed approach scored 0.001637 of equal error rate (EER) for SDUMLA-HMT dataset and 0.00431 of equal error rate for PKU dataset.

Keywords: Finger Vein Identification . Maximum Curvature . Directional Feature .
SDUMLA-HMT . Equal Error Rate

✉ Y.H. Yahaya

Faculty of Science and Defense Technology, Universiti Pertahanan Nasional Malaysia, 57000
Kuala Lumpur
E-mail: yuhanim@upnm.edu.my

S.M. Shamsuddin . W.Y Leng

UTM Big Data Centre, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor
Faculty of Computing, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor
E-mail: mariyam@utm.my

W.Y Leng

E-mail: yeeleng@utm.my

1 INTRODUCTION

Biometric can be defined as identification of an individual based on individual physiological characteristics or behavioural traits. A physiological characteristics that are used for identification includes fingerprint, facial, hand geometry, iris and retina. While behavioural characteristics refers to voice, signature, keystroke and gait. Although these biometrics have been successfully implemented in various real-world applications, they are vulnerable to variety of problems such as noise in sensed data, non-universality and spoof attacks [1].

Fingerprint is vulnerable to forgery because fake fingers made from gelatin or silicon has the ability to attack the system. Furthermore, fingerprint with some cuts or small injuries can lead to noisy biometric data [2]. In voice identification, if the person suffers from cold, the voice may not match for identification. In addition, signature is not universal and can be changes with time. Offline signature can exposed to forgery while online signature cannot be applied for documents verification such as bank cheques or government documents [3].

Considering the disadvantages of the existing biometric traits, there is a need for a new biometric trait in order to enhance the identification performance. Finger vein identification has drawn increasing attention from biometrics community in recent years [4-5]. Finger vein biometric is a new physiological biometric which uses the pattern of blood veins on the finger palmar side to perform identification. Every person has unique vein patterns which provide high degree of security. Only the vein in a living finger can be captured and used as identification. As the finger vein is underneath of the skin, it is difficult to copy and steal. With these advantages, there are increasing related works on finger vein identification such as region of interest (ROI) extraction, image restoration, image enhancement and feature extraction [6].

Finger vein feature extraction plays an important role in finger vein identification. Determining and extracting the features of finger vein are the important steps in identifying the individual's unique characteristics. Many research efforts have contributed in developing an effective feature extraction method in finger vein identification such as repeated line tracking [7], maximum curvature [8], wide line detector [9] and so on. However, these methods have problems that the vein characteristics extracted are not satisfying due to the segmentation results of low quality images and sensitive to the variation of finger vein image. It is worth noting that feature extraction methods for finger vein identification still need improvement. This lead to the purpose of this study, that is to enhance the feature extraction method in order to improve the performance of identification.

The rest of this paper is organized as follows: Section 2 presents the proposed feature extraction scheme. While section 3 report the experimental results and section 4 provides the conclusion to this study.

2 PROPOSED FEATURE EXTRACTION SCHEME

The proposed feature extraction scheme in this research was based on the combination of maximum curvature feature extraction method and directional based feature extraction method (MCDF).

2.1 Maximum Curvature Feature Extraction Method

In this section, we describe the maximum curvature feature extraction method which consists of three steps. This method works on checking the curvature of the image profiles and emphasizing only the centerlines of veins. The centerlines are detected by searching positions where the curvatures of a cross-sectional profiles of a vein image are locally maximal.

Extraction of the Center Position of Veins. In this step, we extract the centerlines of vein by checking the cross-sectional profile of finger vein image. The cross-sectional profile looks like a dent because the vein is darker than the surrounding area around the vein [9]. The center position of veins can be obtained by calculating local maximum curvatures in cross-sectional profiles. Let $P_f(z)$ denote as a cross-sectional profile acquired from $F(x, y)$ at any direction and position where z is a position in a profile and $F(x, y)$ is the intensity of pixel (x, y) . To relate a position of $P_f(z)$ to that of $F(x, y)$, the mapping function T_{rs} is defined as $F(x, y) = T_{rs}(P_f(z))$.

The curvature, $k(z)$ can be defined as:

$$k(z) = \frac{d^2 P_f(z) / dz^2}{\{1 + (dP_f(z) / dz)^2\}^{3/2}} \quad (1)$$

If the value of $k(z)$ is positive, then the profile $P_f(z)$ is classified as concave (dent) otherwise it is convex. At each concave area, the local maximum of $k(z)$ is calculated. This point indicates the center positions of the vein. The positions of these points are defined as z'_i , where $i = 0, 1, \dots, N-1$ and N is the number of local maximum points in the profile.

Next, the scores S_{cr} is calculated to indicate the probability that the centre positions lie on the veins are assigned to each centre position. A score $S_{cr}(z)$ is defined as follows:

$$k(z) = \frac{d^2 P_f(z) / dz^2}{\{1 + (dP_f(z) / dz)^2\}^{3/2}} \quad (2)$$

Where $W_r(i)$ is the width of the region where the curvature is positive and one of the z is located. If the value $W_r(i)$ is large, the probability that it is a vein is also large. The curvature at

the center of a vein is large when it appears clearly. Therefore, the width and the curvature of regions are considered in their scores.

Scores are assigned to a plane, V which is a result of the emphasis of the veins. That is,

$$V(x'_i, y'_i) = V(x_i, y_i) + Scr(z'_i) \quad (3)$$

Where (x'_i, y'_i) represents the points defined by $F(x'_i, y'_i) = T_{rs}(P_f(z'_i))$.

To obtain the vein pattern in an entire image, all the profiles in four directions are analyzed. The directions used are horizontal, vertical and the two oblique directions intersecting the horizontal and vertical at 45° . All the center positions of the vein are calculated by local maximum curvatures.

Connection of vein centers. Next step, filtering operation is performed to eliminate noise and connect the centers of vein. Two neighboring pixels on the right side and two neighboring pixels on the left side of pixel (x, y) will be checked. If (x, y) and the pixels on both sides have large values, a line is drawn horizontally. When (x, y) has a small value and the pixels on both sides have large values, a line is drawn with a gap at (x, y) . Therefore, the value of (x, y) should be increased to connect the line. When (x, y) has a large value and the pixels on both sides of (x, y) have small values, a dot of noise is at (x, y) will marked [9]. Therefore, the value of (x, y) should be reduced to eliminate the noise. This operation can be formulated as follows:

$$C_{d1}(x, y) = \min \{ \max(V(x+1, y), V(x+2, y)) + \max(V(x-1, y), V(x-2, y)) \} \quad (4)$$

The operation is applied to all pixels. The calculation is repeated for four directions in the same way and C_{d2} , C_{d3} and C_{d4} are obtained. Finally the vein features $G(x, y)$ is obtained by selecting the maximum values of C_{d1} , C_{d2} , C_{d3} and C_{d4} of each pixel. That is, $G = \max(C_{d1}, C_{d2}, C_{d3}, C_{d4})$.

Labeling the image. The vein pattern $G(x, y)$ is binarized using a threshold. Pixels with smaller values than the threshold are labeled as parts of the background and those with values greater than or equal to the threshold are labeled as parts of the vein region.

2.2 Directional Based Feature Extraction

Directional-based feature extraction is originally developed for character recognition [10]. This algorithm extracts a geometric feature that mainly focuses on the different basic lines. This approach uses traversal process in each lines and return feature vectors as its output. As acknowledged, finger vein structure features related to the curve segments and junctions. As such, this method was chosen as feature extraction method because it works well with multi-direction structures pattern. The following section explains how this method works on finger

vein identification.

Zone The Finger Vein Image into Equal Sized Windows. Finger veins form a network along a finger and a network can be further decomposed into curve segments and junctions. The best way to extract the features points from the curve segments and junctions is by zone the extracted finger vein image into 3x3 equal sized windows.

Traverse Each Different Line Segments of the Finger Vein Skeleton. For this purpose, three types of pixels in a finger vein network will be considered and selected for traversal purpose. The three types of pixels were defined as initializer or starters, intersections and minor starters. Determine Different Line Segments of the Finger Vein Skeleton. After the line has been found in the finger vein skeleton, they will be categorized into one of the four basic types of line segments. The line segments that would be determined in each finger vein images can be categorized into 4 types: 1) vertical lines, 2) horizontal lines 3) right diagonal lines and 4) left diagonal lines. A direction vector based on 3x3 matrix neighbouring from the line segment will be used to determine the line type.

Extract the Vectors from the Feature. After the line type is specified, the vector is extracted from each of the curve segments. Every zone consists of a feature vector corresponding to it. According to this algorithm, the feature vector is extracted individually for each zone. If there are N zones, there will be 9 x N elements in feature vectors for each zone. There also could be some zones that are empty. For this problem, the value of that particular zone in the feature vector will be represented as zero.

3 EXPERIMENTAL RESULTS

In this section, we compare the performance of the proposed feature extraction, MCDF method with the other finger vein feature extraction methods in the literature. The experiments are performed using the finger vein images from SDUMLA-HMT (referred to as DB1) [11] and PKU (referred to as DB2) [12] finger vein datasets. Results from these comparisons are reported in Table 1. It is evident that the proposed method significantly outperformed other methods. The best results for MCDF is EER equals 0.001637 for DB1 and 0.00431for DB2. Although Maximum Curvature Points (MCP) produced good performance, it was less robust than MCDF. The reason for this is that the finger vein pattern extraction in MCP only emphasize the pixel curvature therefore the noise and irregular shading are easily enhanced. The Repeated Line Tracking (RLT) method was less accurate than MCDF even though it can extract the pattern from an unclear image. However, due to the low quality of finger vein image, segmentation errors occur during feature extraction process. Moreover, the accuracy of finger vein segmentation is easily affected by the image rotation and uneven illumination. The Wide Line Detector (WLD) performs the poorest compared to other methods as it affected strongly by rotation and noise.

Table 1. Result of Performance Comparison of MCDF and the Existing Finger Vein Feature Extraction Methods (Equal Error Rate)

Methods	DB1	DB2
MCP	0.01	1.32
RLT	0.145	5.90
WLD	0.87	2.73
MCDF (Proposed)	0.001637	0.00431

4 CONCLUSIONS

In this paper, we develop the proposed feature extraction scheme using combination of Maximum Curvature and Directional based feature extraction for extracting the finger vein features. It aims to show the improvement of finger vein identification and the enhancement feature extraction method. To demonstrate this improvement, the proposed scheme is compared with MCP, RLT, and WLD. The proposed scheme produces best results in terms of EER compared to the existing methods.

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