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Comparative Analysis of Finger Vein Pattern Feature Extraction Techniques: An Overview

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***Abstract*—** Nowadays, biometric technology has attracted lots of researcher's attention all over the world. Biometric based authentication provides the high-level security and confidentiality. Finger vein is one of the most accepted biometric traits for person identification. Finger veins are internal features of human body hence the effective security is guaranteed. These vein patterns are unique for each person so they are widely suitable for authentication. Feature extraction is the most important process of finger vein authentication. An efficient feature extraction technique which can improve the accuracy of the finger vein recognition. Further, various finger vein based feature extraction techniques are analyzed and discussed. In this survey, the feature extraction methods are categorized into following groups such as local binary-based methods, dimensionality reduction-based methods, minutiae-based methods and vein pattern based methods. Finally we concluded with the comparative analysis of different methods along with their Equal Error Rate (EER) and recognition rate (RR).

***Keywords*—** Finger-vein,Feature extraction, Authentication, Identification

I. INTRODUCTION

Biometric based personal identification technique is an effective authentication technology which is too difficult to forge. Physiological and behavioral are two divisions of biometric technology. Physiological biometric includes the attributes like face, iris, hand geometry, fingerprint, finger vein etc; where as human attitudes such as hand writing, signature, voice recognition are come under behavioral biometrics [1, 31].Easily forgettable traditional security methods such as passwords and Personal Identification Number (PIN) are replaced by the biometric methods to improve confidentiality and usability [4, 12].

Finger vein (FV) pattern-based identification has more advantages than all other biometric technology [39]. Finger veins for identification are captured only from living peoples [6] and it is too hard to copy or forge because it is an intrinsic feature of human body [1].

Key points

- **Distinct:** Finger veins are distinct even between twins [23].
- **Hygienic:** Unlike finger print and hand geometry systems, it is believed to be free of germs because of its contactless sensor [7].
- **Permanency:** It does not change by aging because before birth blood vessel network is formed [5].

Table 1. Compares Different Aspects of Common Biometric Recognition Methods [6, 40]

Trait	Level of security	Sensor	Merit	Demerit
Voice	Medium	Contact less	Natural	Noise
Face	Medium	Contact less	Remote capture	Lighting condition
Finger print	High	Contact	Broadly used	Skin
Iris	Excellent	Contact less	High accuracy	Glasses
Finger Vein	Excellent	Contact less	Excellent Security	Few

These factors play a major role in the growth of finger vein identification technology. The fundamental process of FV based identification system shown in Fig1.This includes image acquisition, pre-processing, feature extraction and matching.

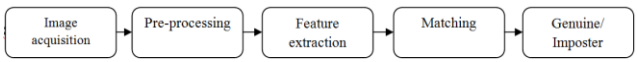


Figure1. Fundamental process of finger vein identification system

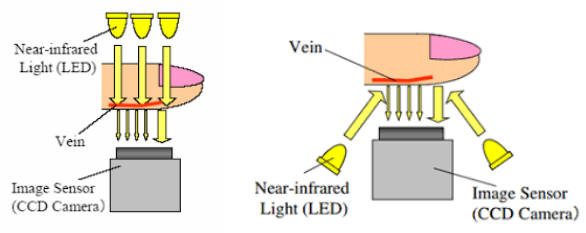
These factors play a major role in the growth of finger vein identification technology. The fundamental process of FV based identification system shown in Fig1.This includes image acquisition, pre-processing, feature extraction and matching. Various researchers studied and proposed a new method for finger vein identification with efficient feature extraction methodology by using vein pattern matching of a finger vein and explained the diversity of human finger vein patterns and the usefulness of patterns for personal identification [32, 33]. These are form the strong foundation for the finger vein recognition and prove the identity of finger veins.

Section II focused on fundamental process of finger vein identification which includes image acquisition, pre-processing, feature extraction and matching. Section III explained the types of feature extraction methods. In Section IV, comparative study of various feature extractions methods are given. Finally the conclusion is presented in Section V.

II. PROCESS OF FINGER VEIN IDENTIFICATION

A. *Image Acquisition*

Image acquisition is the initial and essential step in finger vein identification. The image acquisition device consists of an NIR assembly part for finger placement and a charge-coupled device (CCD) pre-processor camera is used to grab the finger vein image [42]. An infrared LED light is passed through the finger to capture the vein images.



(a) (b)

Figure2. Finger vein image acquisition methods [3]

(a). Light transmission, (b). Light reflection

The light is absorbed by the hemoglobin in the blood so that the blood vessels appear darker than the surrounding tissues such as bones, muscles and etc. [20]. This can be done by using either light transmission or light reflection [3] as shown in Fig2. In light transmission method, high contrast image is captured. Therefore most of the finger vein image acquisition devices perform light transmission method. By this way, the required vein images are being captured. The captured images always have problem such as noise, low contrast and translational and rotational variation that cannot be solved by the process of image capturing so that pre-processing is required [2].

B. *Pre-Processing*

Pre-processing is a next stage of finger vein identification which includes operations such as ROI detection, image enhancement, segmentation and filtering [5].The main objective of the image pre-processing is to remove the noise from captured image and provide the robust Region of Interest (ROI) for feature extraction that enhance the image quality. Accuracy and the efficiency of the recognition process are also based on the pre-processing of image [8]. Image quality assessment, Region of Interest (ROI) extraction, normalization and enhancement are considered as common pre-processing steps [21, 41].

C. *Feature Extraction*

Feature extraction is the major step of finger vein recognition. The transformation of input image or input data into set of features is known as feature extraction. This transformation can be linear as well as non-linear [7]. During this process, the basic biometric trait called as template is created which is used to identifying the individuals [43]. Different methods of feature extraction are proposed in finger vein identification.

D. *Matching*

The matching process is the final step of finger vein recognition which is used to show the input image is genuine or imposter. Distance-based matching and Classifier-based matching are the two types matching techniques [44]. Distance-based matching technique is used in the conventional finger vein identification approach where as the classifier-based matching technique is used in machine learning approach [3].

III. TYPES OF FEATURE EXTRACTION METHODS

Feature extraction methods are classified into the following categories [3]. They are

- Local Binary-Based Methods
- Dimensionality Reduction-Based Methods
- Minutiae- Based Methods
- Vein Pattern-Based Methods

A. *Local Binary-Based Methods*

In this group, the extracted features are in binary format. The Local Binary Pattern (LBP), the Local Line Binary Pattern (LLBP), Personalized Weight Maps (PWM), the Personalized Best Bit Maps (PBBM) and the Local Directional Code (LDC) are come under this method [18, 22]. A. Perez Vega et al. proposed a finger vein pattern based personal identification with Personalized Best Bit Map

(PBBM) segmentation method. It uses binarization for image pre-processing and matching as a classifier [34]. C. Liu et al. proposed an efficient finger vein feature extraction algorithm based on random forest training and regression with efficient local binary pattern. It is robust to finger misalignment when integrated with a vein pattern matching. In ELBP method, interpolation is performed to identify the gray values of the diagonal pixels and the neighborhood pixels are tabulated to design the circular chain [35].

B. Dimensionality Reduction-Based Methods

Subspace learning method transforms a high dimensional space data into a lower dimensional space [7]. Manifold Learning, Principal Component Analysis (PCA), Two Dimensional Principal Component Analysis (2DPCA), Linear Discriminate Analysis (LDA). Training process is required for this method to learn the transformation matrix. Whenever the new user enrolled, then the transformation matrix needs to learn. For matching process, classifiers are used in this method [3]. J. Yang et al. studied the problem of recognition and localization of finger vein and presented an effective segmentation and feature extraction method with the help of nearest neighbor classifier. In this paper the author proposed inter-phalangeal joint prior to remove the uninformative vein imaginary [8]. Z. Liu et al. proposed a manifold leaning classifier for finger vein recognition with the use of principal component analysis feature extraction method. This system works effectively on noise reduction [9].

F. Guan et al. proposed the robust finger vein recognition system with two dimensional linear discriminate analysis for feature extraction with dimensionality reduction. This literature also compare the two direction weighted (2D) 2LDA and ((W2D) 2LDA) based on image pre-processing and proved that two direction weighted provides the better results [10]. S. Damavandinejadmonfared et al. highlighted a new Kernel Entropy Component Analysis (KECA) and compared this algorithm with Principal component analysis (PCA) to define the most appropriate finger vein recognition system. This system uses Euclidian distance calculation as a classifier [11].

C. Minutiae-Based Methods

The end or fork point of the ridge lines is defined as minutiae point for finger vein. Minutiae points are used in finger vein recognition and this method is already used in fingerprint techniques [37]. This is one of the important methods of feature extraction and the minutiae point refers to the terminal point and the bifurcation point of blood vessels [27, 38]. P. Preethy et al. presented the minutiae based finger vein feature extraction which includes the end points and bifurcation point extraction from the skeletal patterns of vein with spurious minutiae removal to improve the identification accuracy [28]. The minutiae based recognition provides the unsatisfactory results because the minutiae in the vein are limited and it is difficult to perform.

D. Vein Pattern-Based Methods

In vein pattern- based method, the vein point is detected. This can be done by analyzing the current point and the surrounding point relationships. Vein pattern-based approach classified into the following three categories.

1) Cross- Sectional Profile-Based Method

This method includes Repeated Line Tracking, Modified Repeated Line Tracking, Region Growth and Maximum Curvature. In this method, vein points have lower gray value than any other profile. Repeated line tracking is tracing a line in a vein pattern and this can be repeated for specified number of times until the feature is extracted. Naoto Miura et al. proposed this tracking with randomly varied vein points for the unclear image and showed the Equal Error Rate was 0.145% [12]. Bhagyashree Bersa et al. described the line tracking algorithm with random start positions and the author introduced different phases for feature extraction to obtain higher matching score which includes image acquisition, pre-processing, image normalization and post-processing [13].

T. Liu et al. proposed the robust Modified Repeated Line Tracking (MRLT) algorithm for finger vein image segmentation and the proposed algorithm reduces the computational cost and noise by selecting the initial point from the skeleton image and the parameters are revised in accordance with the width of the skeleton image. The process of parameter revising is reducing the significant evaluation [12]. In maximum curvature method, the centre lines of veins are emphasized and Naoto Miura et al. proposed the local maximum curvature approach for conventional method with 0.0009% Equal Error Rate [15].

In region growth method, the decision parameter in vein pattern extraction is based on the growing time. Q. Guo et al. proposed a finger region extraction algorithm in accordance with the characteristics of edge of the finger image that can efficiently extract the finger region from the noisy background [16]. L. Yang et al. proposed an anatomy based analysis algorithm for finger vein feature extraction and an integration matching approach in which the vein network calibration is used. In this system, vein features are extracted from orientation map guided curvature by using cross-sectional method [17].

2) Neighborhood Region-Based Method

Wide line detector and Gabor are employed as a neighbourhood region. In Wide line detector, the neighbours have the higher gray value when the current pixel was labelled as vein point. B. Huang et al. presented the effective finger vein authentication method based on Wide line detector with pattern normalization [26]. Gabor filters are linear filters and it gives the highest response at points and edges. Lu et al. described an efficient local descriptor called

as histogram of competitive Gabor response for feature extraction. Competitive Gabor response is a combination of competitive Gabor magnitude and the competitive Gabor orientation [29].

3) Whole Image-Based Method

In this method, vein images viewed as three-dimensional geometric shape and Mean curvature is the representative for this method. W. Song et al. proposed a Mean curvature based finger vein verification system with 0.25% of Equal Error Rate value [30].

IV. COMPARATIVE ANALYSIS

The Comparison Analysis of various finger vein recognition techniques are shown in Table 2.The summary of various feature extraction methods, different databases and equal error rate(EER) or recognition rate are shown. It is clear that the dimensionality reduction based method achieved the highest finger vein recognition rate but it is not suitable for large scale databases. Minutiae based extraction provided the moderate result for recognition. Finger vein pattern-based method presents the efficient result for different databases and achieved robust pattern extraction and Equal Error Rate (EER).

Table 2. Comparison Analysis of various finger vein recognition Techniques

Author	Group	Technique	Database	EER/RR (%)
Lee et al. [18]	Local-binary based	LBP	240 fingers x 10 images	EER=0.21
Rosdi B A et al. [19]	Local-binary based	LLBP	204 fingers x 10 images	EER=3.845
Meng X J et al. [20]	Local-binary based	LDC	136 fingers x 30 images	EER=1.02
Yang G P et al. [21]	Local-binary based	PWM	136 fingers x 20 images	EER=0.41
Yang G P et al. [22]	Local-binary based	PBBM	106 fingers x 14 images	EER=0.38
Liu Z et al. [9]	Dimensionality reduction based	Manifold learning	328 fingers x 70 images	RR=97.8 EER=0.8
Wu J D et al. [23]	Dimensionality reduction based	LDA	10 fingers x 10 images	RR=98
Wu J D et al. [24]	Dimensionality reduction based	PCA	10 fingers x 10 images	RR=99
Yang G P et al. [25]	Dimensionality reduction based	$(2D)^2PCA$	80 fingers x 18 images	RR=99.17
Preethi P et al. [28]	Minutiae based	Spurious minutiae removal	106 fingers x 6 images	N/A
Miura N et al. [12]	Vein-pattern based	Repeated line tracking	678 fingers x 2 images	EER=0.145
Miura N et al. [15]	Vein-pattern based	Maximum curvature	678 fingers x 2 images	EER=0.0009
Liu T et al. [14]	Vein-pattern based	Modified repeated line tracking	200 images	N/A
Huang B et al. [26]	Vein-pattern based	Wide line detector	50,700 images	EER=0.87
Song W et al. [31]	Vein-pattern based	Mean curvature	320 fingers x 5 images	EER=0.25
Kumar A et al. [29]	Vein-pattern based	Gabor	312 fingers x 6 or 12 images	EER=0.65
Qin H F et al. [36]	Vein pattern based	Region growth	125 fingers x 9 images	EER=0.0369

V. CONCLUSION AND FUTURE SCOPE

In this paper, we analyze the numerous finger vein feature extraction methods for biometric recognition or authentication. It presents the various extraction techniques and their groups, equal error rate and recognition rate for different databases. Different methods provide different level of security and accuracy, robustness. The comparative analysis of this paper presents the overall performance of existing system.

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