Analysis of Different Techniques for Finger-Vein Feature Extraction

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***Abstract*—– 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. This study proposes an analysis of different techniques for finger-vein feature extraction. The fundamental principle, various feature extraction techniques and performance evaluation metrics are extensively analyzed. Most of the existing work is systematically described and compared in three parts, i.e., finger-vein image acquisition, pre-processing and feature extraction. According to the available work in literatures and commercial utilization experiences, finger vein biometrics ensures higher performance and spoofing resistance. It has reached an unparallel level of security, efficiency and reliable choice of high precision among the biometrics techniques.**

***Keywords*- personal identification and authentication, feature extraction, finger-vein biometrics.**

I. Introduction

Personal identification technology is used in a wide range of systems for functions such as area access control, logins for PCs, bank ATM systems, surveillance, driver identification, e-commerce systems and many more. Biometric techniques for identifying individuals are attracting attention because conventional techniques such as keys, passwords, and PIN numbers carry the risks of being stolen, lost, or forgotten. There has been considerable research in biometrics [1];[2] over the last two decades. The list of physiological and behavioural biometric characteristics that has to date been developed and implemented is long and includes the face [3];[4], iris[5];[6], fingerprint [7], palm print [8], hand shape [9], voice [10], signature [11], and gait [12]. 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 [13], 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 [14]. To this end, many researchers have sought to improve reliability and frustrate spoofers 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. Finger–vein features hold the following merits:

Anti-counterfeit: Finger veins staying underneath the skin make vein pattern duplication impossible in practice.

Active liveness: Vein information disappears with biological tissues losing liveness, which makes artificial veins unavailable in application.

User friendliness: Finger–vein images can be captured noninvasively without the contagion and unpleasant sensations [15]

The rest of this paper is organized as follows. The fundamental principle for finger-vein biometrics is briefly introduced in Section II, various techniques are addressed in Section III, and performance evaluation is included in section IV. Finally, concluding remarks are given in Section V.

II. Fundamental Principle for Finger-Vein Biometrics

At their most basic level, biometric technologies are pattern recognition systems that use image acquisition devices, such as scanners or cameras for finger-vein image acquisition. The characteristics of the acquired samples considered the most distinctive between users and the most stable for each user are extracted and encoded into a biometric reference or template that is a mathematical representation of a person‘s biometric feature. These templates are stored in a database or on a smart card or other token. Then that template is used for comparison when recognition is warranted. Biometric systems are automated by hardware and software, allowing for fast, real-time decision making in identification situations.

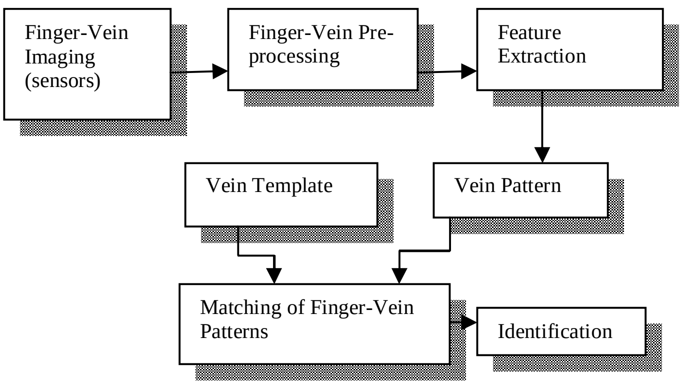

Fig.1 Human Identification Process Using Finger-Vein Biometrics

Most of the existing work is systematically described and compared in three parts

- Finger-vein image acquisition
- Pre-processing and
- Feature extraction

FINGER-VEIN IMAGE ACQUISITION:

The image acquisition system comprises of a light source, a digital camera/scanner. The input image is a colour/gray scale image of the finger-veins. In this proposed system, a special imaging device is used to obtain the infrared image of the finger. An infrared light irradiates the backside 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. Fig. 2 shows a prototype imaging device. It is 7 cm (wide) × 6 cm (long) × 4 cm (high) and has a 1/3-inch CCD camera. The device is constructed of inexpensive parts. As haemoglobin in the blood absorbs the infrared light, the pattern of veins in the palm side of the finger are captured as shadows. Moreover, the transmittance of infrared light varies with the thickness of the finger. Since this varies from place to place, the infrared image contains irregular shading. Fig. 3 is an example of the captured image. This image is gray scale, 240 × 180 pixels in size, with 8 bits per pixel.

Fig.2 Imaging Device

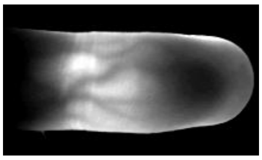

Fig.3 Acquired Finger Vein Image

PRE-PROCESSING

The next stage is image pre-processing module. Image pre-processing relates to the preparation of an image for later analysis and use. Image may need improvement to reduce noise; other may need to simplified, enhanced, altered, segmented, filtered, etc. The role of the pre-processing module is to prepare the image for feature extraction.

FEATURE EXTRACTION

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. Various techniques are implemented for robust extraction of finger-vein features.

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III. TECHNIQUES FOR FINGER-VEIN FEATURE EXTRACTION

Finger-vein pattern forecast one of mainstream identification technology in the current and future trends. Personal authentication using finger vein images has received considerable attention during the last 10 years and some approaches have been proposed in the literature : Montesinos P, Alquier L (1996); Maio D, Maltoni D (1997); HooverA, Kouznetsova V, Goldbaum M (2000); Walter T, Klein J, Massin P, Zana F (2000);Naoto Miura, Akio Nagasaka, Takafumi Miyatake (2002); Naoto Miura, Akio Nagasaka, Takafumi Miyatake(2005); Tanaya Guha and Q. M. Jonathan Wu(2006); Z. Lian, Z. Rui and C. B. Yu (2008);Li Xueyan and Guo Shuxu(2008); A.Ushapriya, M.Subramani (2011); Eui Chul Lee , Hyunwoo Jung and Daeyeoul Kim (2011); Azadeh Noori Hoshyar, Riza Sulaiman and Afsaneh Noori Houshyar 2011; Ajay Kumar and Yingbo Zhou (2012); Ying Yang, Gongping Yang and Shibing Wang (2012); M. Vlachos, E. Dermatas (2013). The current available approaches for finger vein recognition are all based on texture or feature extraction of one single infrared image of finger vein. A detailed description of these approaches is beyond the scope of this paper. However, a summary of these approaches with the typical references can be seen in table I

TABLE I
Methods for Personal Authentication using Finger Vein Recognition

Name	**Method**	**Year**	**Reference**
Montesinos P et al.	Connection of emphasized edge lines	1996	Montesinos P, Alquier L (1996) [16]
Maio D et al.	Ridge line following for minutiae detection in gray scale images	1997	Maio D, Maltoni D (1997) [17]
HooverA, Kouznetsova V et al.	Matched-filter method	2000	HooverA, Kouznetsova V, Goldbaum M (2000) [19]
Walter T et al.	Mathematical morphology	2000	Walter T, Klein J, Massin P, Zana F (2000) [20]
Naoto Miura et al.	Repeated line tracking	2002	Naoto Miura, Akio Nagasaka, Takafumi Miyatake (2002) [24]
Naoto Miura et al.	Maximum curvature	2005	Naoto Miura, Akio Nagasaka, Takafumi Miyatake(2005) [25]
Z.Zhang et al.	Curvelets	2006	Tanaya Guha and Q. M. Jonathan Wu(2006) [27]

Z. Lian et al.	Curvelets	2008	Z. Lian, Z. Rui and C. B. Yu (2008) [23]
Li. Xueyan et al.	Moment invariants(tracking based, transform based, matched filter method, thresholding method)	2008	Li Xueyan and Guo Shuxu(2008) [26]
A.Ushapriya et al.	Radon transform and Principal component analysis algorithms	2011	A.Ushapriya, M.Subramani(2011) [28]
Eui Chul Lee et al.	Modified Gaussian high-pass filter through binarization, local binary pattern (LBP), and local derivative pattern (LDP) methods	2011	Eui Chul Lee , Hyunwoo Jung and Daeyeoul Kim(2011) [30]
Azadeh Noori Hoshyar et al.	Gradient-based thresholding using morphological operation and Maximum Curvature Points in Image Profiles	2011	Azadeh Noori Hoshyar, Riza Sulaiman, Afsaneh Noori Houshyar(2011) [31]
Ajay kumar et al.	Gabor filter	2012	Ajay Kumar and Yingbo Zhou(2012) [32]
Ying Yang et al.	local binary pattern (LBP)	2012	Ying Yang, Gongping Yang, Shibing Wang(2012) [29]
M. Vlachos et al.	A Region Growing Method Based on Statistical Attributes of Infrared Images	2013	M. Vlachos, E. Dermatas (2013) [33]

IV. PERFORMANCE EVALUATION

To quantitatively evaluate the accuracy of finger-vein feature extraction techniques, various performance evaluation metrics are usually considered. As illustrated in Table 2 performance evaluation of various feature extraction techniques are presented.

Database: For each technique, database must be prepared in advance for feature extraction. Size of database depends upon the number of participants and samples of each participant. A representative database should contain samples collected from males, females and different races [34], adults and children in diverse ages, etc. It is necessary to note that for each participant atleast two sample vein images are required to be captured[35], one is used for enrolment and the other is used as query image for testing algorithm's performance.

Performance Evaluation Metrics:
Following performance evaluation metrics are used for biometric systems:

1) False Accept Rate or False Match Rate (FAR or FMR): The probability that the system incorrectly matches the input pattern to a non-matching template in the database. It measures the percent of invalid inputs which are incorrectly accepted. In case of similarity scale, if the person is imposter in real, but the matching score is higher than the threshold, and then he is treated as genuine that increases the FAR and hence performance also depends upon the selection of threshold value.

2) False Reject Rate or False Non-Match Rate (FRR or FNMR): The probability that the system fails to detect a match between the input pattern and a matching template in the database. It measures the percent of valid inputs which are incorrectly rejected.

3) Receiver Operating Characteristic or Relative Operating Characteristic (ROC): The ROC plot is a visual characterization of the trade-off between the FAR and the FRR. In general, the matching algorithm performs a decision based on a threshold which determines how close to a template the input needs to be for it to be considered a match. If the threshold is reduced, there will be fewer false non-matches but more false accepts. Correspondingly, a higher threshold will reduce the FAR but increase the FRR. A common variation is the Detection error trade-off (DET), which is obtained using normal deviate scales on both axes. This more linear graph illuminates the differences for higher performances (rarer errors).

4) Equal Error Rate or Crossover Error Rate (EER or CER): The rates at which both accept and reject errors are equal. The value of the EER can be easily obtained from the ROC curve. The EER is a quick way to compare the accuracy of devices with different ROC curves. In general, the device with the lowest EER is most accurate.

5) Failure to Enrol Rate (FTE or FER): The rate at which attempts to create a template from an input is unsuccessful. This is most commonly caused by low quality inputs.

6) Failure to Capture Rate (FTC): Within automatic systems, the probability that the system fails to detect a biometric input when presented correctly.

7) Template Capacity: The maximum number of sets of data which can be stored in the system.

8) Response Time: In practical applications, Response Time must be taken into account. It is jointly determined by two factors viz, computational complexity of vein recognition algorithm and capability of processing platform including the adopted software, performance of CPU, memory size, etc

TABLE II
Performance Evaluation of Various Finger-Vein Feature Extraction Techniques.

Finger-vein Feature Extraction Techniques	**No. of images**	**Performance Evaluation Metrics**
Conventional Methods [16]-[17],[19]-[20]	678	EER=2.36%, Mismatch Ratio=4.62%
Repeated Line Tracking [24]	678	EER=0.145%, ROC=6.54%, Response Time=460ms, Mismatch Ratio=4.56%, Recognition Accuracy=77.94%
Maximum Curvature [25]	678	EER=0.0009%,ROC=2.20%, Mismatch Ratio=2.83%, Recognition Accuracy=73.49%
Matched Filter [19]	678	Mismatch Ratio=4.62%, ROC=1.88%, Recognition Accuracy=86.67%
Curvelets [27]	—	Average Recognition Accuracy=90.44%, RR[Rejection Rate]=1.2
Radon transform and Principal component analysis algorithm [28]	100	FAR=0.008, FRR=0.0
Gradient-based thresholding using morphological operation and Maximum Curvature Points in Image Profiles [31]	7	Recognition Accuracy=93-95%, VAF(Variance Accounted For)=95%[training] and 93%[testing]
Modified Gaussian high-pass filter through binarization, local binary pattern (LBP), and local derivative pattern (LDP) methods [30]	2400	EER=0.13; EER For LDP=0.89, LBP=1.53, BINARISATION=2.32, Processing Time for LDP=112.5ms, LBP=44.7ms, BINARISATION=30.6ms
Even Gabor with Morphological methods [32]	6264	ROC=0.43%, Recognition Accuracy=93.49%
A Region Growing Method Based on Statistical Attributes of Infrared Images [classical] [33]	10	Mean Sensitivity=0.711, Mean Specificity=0.978, Mean Accuracy=0.919
A Region Growing Method Based on Statistical Attributes of Infrared Images [improved] [33]	10	Mean Sensitivity=0.836, Mean Specificity=0.972, Mean Accuracy=0.942, Recognition Speed=100ms/person, FAR=5X, Recognition Accuracy=94.2%

V. CONCLUSIONS

This study presents an analysis of different techniques of finger-vein feature extraction for biometric authentication and identification. It presents the fundamental principle, various feature extraction techniques and performance evaluation metrics. According to the available work in literatures and commercial utilization experiences, different Finger-vein Feature Extraction Techniques offer different levels of performance, spoofing resistance, robustness, security and accuracy.

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