A Review on Finger Vein Recognition Matching Techniques

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Abstract : In today's society with the rapid growth in the field of computer and network technology, the identity verification is a critical key problem. Thus, the requirement for a better and more reliable approach for identity authentication becomes more significant. Since it is difficult to mislay, forge or share biometric identifiers, biometric recognition is more efficient and reliable than traditional passwords or PINs. Finger vein recognition technique has become the most preferred and novelist biometric method due to its low device constraint, low forgery risk, stability, aliveness detection and high anti counterfeit. A finger vein recognition consists of four main steps which include image acquisition, preprocessing, feature extraction, and matching. The matching technique is most crucial step of recognition to decide whether an input image is genuine or an imposter for one enrolled image, in which matching score is generated. A matching score measures the similarity between the enrolled template and the input image. This paper presents a detailed review on FVR matching algorithms. Matching stage plays a vital role as only this stage involves analysing the recognition performance which is the main criteria to measure the effectiveness of an algorithm. This paper presents the most recent research advancements in the recognition performance of FVR. Various matching algorithms reviewed in this paper have the potential to enhance the recognition performance in a broad sense.

***Index Terms* - Biometric Recognition, Finger vein, Matching, Recognition performance.**

I. Introduction

Rapid developments of science and information technology lead to a major security issue that needs an immediate solution. Due to the growing demand of user-friendly and stringent personal identification, biometric authentication has become a booming research area for decades. The design of efficient biometric authentication systems is nowadays a challenging and pertinent task for both the scientific and the industrial communities.

Conventional approaches such as keys, passwords, and PIN numbers carry the risks of being stolen, forged, lost, or forgotten [1]. Hence, it gives rise to an efficient technique of identity recognition against digital impersonation based on biological features. Biometric recognition is proved more reliable and secure than the traditional hedges against identity theft such as passwords and PINs. It utilizes inherent physiological features and behavioral characteristics of an individual. Examples of physiological features are face, fingerprint, iris, vein, etc. Some examples of behavioral characteristics are like handwriting, voice, signature, etc. [2]. However, these conventional biometric techniques have their limitations regarding performance, accuracy and convenience. Hand-based biometrics commonly include fingerprint recognition, finger knuckle print recognition, and palm print recognition. However, all of these are vulnerable to forgery since the features are external to human bodies.

Out of these biometric techniques, finger vein biometric has drawn much attention and gaining popularity. The finger vein recognition system is more efficient and reliable and can solve many difficulties faced by conventional biometrics techniques. From the security and convenience point of view, the finger-vein is a promising biometric pattern as the vein pattern is defined as the vast network of blood vessels underneath the skin of a particular part of a human body. Veins features are unique, robust, stable and largely hidden patterns. In addition, vein patterns are not easily observed, damaged, or changed. Unlike facial features or fingerprints, though, it's much more difficult to forge finger vein patterns, or even distort them in attempts to fool a biometric security system. Additionally, individuals can't photograph finger veins and, unlike fingerprints, they can't be left on surfaces.

Compared with other biometric traits, the finger-vein is more advantageous because of these advantages as listed: a) Internal characteristic i.e., it is hard to copy or forge finger vein, and very little external factor can damage finger vein. b) The non-invasive and contactless capture of finger-veins are more convenient and hygienic for the user, and thus, it is more acceptable. c) Living body identification i.e., only vein in living finger can be captured [3]. Because of its uniqueness, stability, high accuracy, response timing and high resistance to criminal tampering, vein pattern offers a more reliable trait for a secure biometric authentication system. Regardless of advantages, there are some challenges that need to be overcome to achieve high accuracy and recognition performance. The main challenges are poor lighting, recognition rate and misalignment [4].

A typical finger vein recognition system consists of four main stages which comprises image acquisition, image preprocessing, feature extraction, and *matching*. Matching is the most important stage in finger vein recognition. After features are extracted from the vein image, the matching stage measures the similarity or dissimilarity between the features of input finger vein image and the previously enrolled ones in the database [5]. The main objective of this study is to analyze the most recent matching/classification techniques applied in finger vein recognition. It is observed that finger vein recognition is a challenging task because of low image contrast, uneven-illumination and temperature variations. Finger vein identification systems are also vulnerable to spoof attacks. However, accuracy of the personal verification system is the most serious issue to consider. Therefore, fast, reliable and more efficient matching techniques are still required for FVR. The main challenge in biometric system is to enhance the recognition performance in terms of both accuracy and efficiency [6]. An acceptable level of recognition performance has not yet been achieved. In this paper, the most advanced matching techniques and algorithms utilized in finger vein recognition will be reviewed.

II. FINGER VEIN RECOGNITION: MATCHING PHASE

The matching technique is the last step of finger vein recognition to decide whether an input image is genuine or an imposter for one enrolled image based on a threshold match score, by comparing the currently extracted features against the stored templates to generate a matching score [7]. A matching score measures the likeness between the enrolled template and the input finger vein image. The threshold match score is important. If the score exceeds the threshold score, it is not considered a fit. The system automatically flags the suspicious activity and generates management reports if the probe image is an imposter.

The cleansed and enhanced user data is stored in the feature template, which is stored in a database for later retrieval. This template is then used for matching in the future. Recognition or matching process takes place after features have been extracted from the vein image [8]. During verification/matching phase, a biometric sensor captures the biometric trait for which it was designed. An algorithm analyses the trait and then a matcher compares the trait to an existing template in the enrolment database to determine whether the new trait is genuine or an imposter as shown in Figure 1. The matching stage consists of two steps: a) Comparison/Classification – The new biometric data is compared with the stored template. b) Decision Making – The system decides whether the new data is a match or a non-match based on a threshold match score. Template matching is performed in this stage.

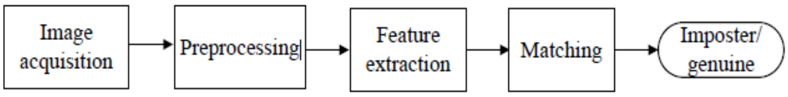

Figure 1. Block diagram of finger vein recognition

Matching is the method of comparing two or more feature vectors and determining the amount of difference or the distance in features between the feature vectors. The higher its value, the higher is the chance that the feature vectors belong to different classes. It is a method of checking the efficiency of the system, by ensuring that there is no ambiguity among the feature vectors of different classes and there is sufficient distance to reduce the chances of false acceptance or false rejection.

Matching stage plays a vital role in finger vein recognition as only this stage involves analyzing the recognition performance which is the main criteria to measure the effectiveness of an algorithm. The false rejection of the genuine image should be avoided as much as possible. Two types of finger vein matching techniques are used [7], i.e., distance-based matching and classifier-based matching as shown in Figure 2. Conventional finger vein recognition approach uses the *distance-based* matching technique, while by machine learning techniques finger vein recognition can employ *classifier-based* matching technique. Accuracy rate of almost all the machine learning finger vein algorithms is close to 100%. In most FVR techniques, machine learning classifier-based methods were employed during the matching stage of FVR to improve the recognition performance of the template matching.

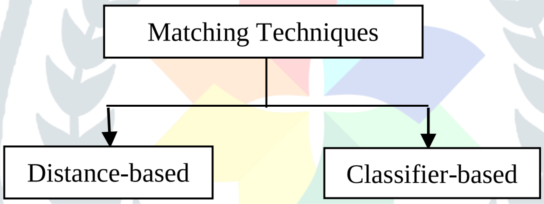

Figure 2. Types of finger vein matching techniques

Extensive feature dimensions can cause huge computation and the memory cost of the classifier training and classification. Thus, to make the finger vein recognition system more practical in real life, the system should have a high recognition rate and high recognition speed. This can be achieved with a more robust and stringent finger vein recognition matching algorithm. The performance parameter for finger vein is Equal Error Rate (EER) which is calculated using different matching algorithms [9]. *Equal Error Rate* is where false acceptance and false rejection rates are equal, and since the rates have an inverse relationship, the lower the Equal Error Rate the better the biometric security system is working.

Recent years, finger vein recognition has attracted a great attention due to its high accuracy, response timing, contact-less and non-intrusive technology and achieved some promising recognition performance. Some of the finger vein recognition systems require longer processing time. Even though its performance is appreciable, the long processing time makes the system impractical in real life applications. Therefore, more efficient and accurate matching algorithms need to be applied in order to reduce the processing time and eventually attain high accuracy and recognition rate.

III. A REVIEW ON RECENT MATCHING ALGORITHMS

The most recent research advancements in the matching techniques and algorithms applied in the finger vein recognition are reviewed in order to overcome the weaknesses of the previous methods to develop a more robust, efficient, highly accurate and powerful finger vein-based identification or verification system. Template matching is performed between a processed input image and a stored template image in this phase. Thus, closer the normalized distance between the processed image and template image proves that two feature vectors are more related [10]. Some matching algorithms (e.g. the mismatch ratio) are sensitive to the image translation and rotation, meanwhile, the distribution information of the vein vessel network is neglected. The mismatch ratio is used to quantify the differences of two patterns.

Sujani G[11] et al., makes the use of SIFT algorithm as a matching technique of finger vein recognition. A sift algorithm is used to detect the number of key points for each of the image of finger-vein and calculate the total number of key points for all the 6 fingers of the person i.e., index, middle and ring finger of both hands. It has been found that the finger will provide maximum number robust feature of points for the matching algorithm. The centre reference of each and every sub-region is the points which matches for the features selected. Fingers are compared with the highest number of sift points which leads to a result that the index finger is best suited to give more precise results.

In [12], matching method includes histogram statistics and histogram comparison. The histogram matching belongs to a sample of statistics. Bhattacharyya distance conversion combined with the weighted method of statistics is applied to compare the similarity of two statistical samples. The Bhattacharyya distance measures the distribution of two discrete probability. The closer to zero the value calculated by the Bhattacharyya distance is, the greater the similarity shared by the two compared histograms is. The average recognition proposed by this research reaches 97%.

Another method of Matching of Finger-Vein patterns is introduced by Chenguang Liu which is based on integrating random forest regression with a vein pattern matching technique which is robust to finger misalignment [13]. In this paper, the author has developed a vein pattern matching method to calculate the matching score. Instead of matching the two patterns directly, which may suffer from finger misalignment, the image size of one of the two patterns is extended and the other one is slided on the extended pattern. At each step of sliding, a matching score is calculated according to the likelihood function and the best score among all matches is selected as the matching score of the two vein patterns.

Q Chen, L Yang[14] et al. highlighted the problem of the image deformation and proposed a deformable finger vein recognition framework consisting of the improved vein PCA-SIFT feature and bidirectional deformable spatial pyramid matching (B-DSPM). In bidirectional matching of two images, the pixel correspondences from the first image to the second one, and these from the second image to the first one are both given by DSPM. Based on two kinds of correspondences, two matching scores are computed, and the minor one is used in recognition. So, this method is efficient to overcome all kinds of image deformations.

In [15], author has proposed an integration matching strategy in which, the vein backbone is used in vein network calibration to overcome large-scale finger displacements. The similarity of two calibrated vein networks is measured by the proposed elastic matching and further recomputed by integrating the overlap degree of corresponding vein backbones. Elastic matching is robust against small-scale vein deformation.

Lin Y [16] et al. proposed a new matching method based on potential energy for finger-vein recognition. This method first extracts the finger vein skeleton feature, and then uses a weighted potential energy vector of skeleton image to represent the skeleton feature, and finally evaluate the similarity by calculating the Hausdorff distance of potential energy eigenvectors to classify. The smaller the value of this distance, the greater the probability of the two samples come from the same finger. This technique spends less time than the method based on template matching and obtain higher accuracy rate than the method based on minutiae matching.

In [17], the author proposed a new matching algorithm which is based on the observation that regular deformation, which corresponds to a posture change, can only exist in genuine vein patterns. It incorporates optimized matching to generate pixel-based 2D displacements that correspond to deformations. The pixel-based displacements are obtained by considering the matching process as a pixel-based optimization process based on dense local features. The texture of uniformity extracted from the displacement fields is taken as the final matching score to discriminate between genuine and imposter matching. Regions of the same displacement values in genuine matching tend to be larger in terms of area covered than in imposter matching. This method has shown that deformation information is discriminative.

H Zheng[18] et al., highlighted the impact of different meteorological factors such as temperature, humidity, atmospheric pressure, and wind on the performance and accuracy of the recognition system. Such factors can significantly affect the matching score, which is directly related to system performance, and temperature difference is the one that has the most significant impact on it. The author has proposed two methods, dynamic template selection and threshold adjustment, to reduce such impact from temperature and to improve the accuracy for the recognition system. The mean matching score for all the difference of the meteorological factors is computed and linear regression is conducted on them.

In [19], a new superpixel-based finger vein recognition method is presented. Two types of effective superpixels are developed, i.e. stable superpixel and discriminative superpixel to represent finger vein image and these superpixels play different roles in matching stage. In the matching stage, the superpixels are compared at the same location as the two types of superpixels in template. When the two images are homologous, the matching score of stable superpixels will be greater than the score of heterologous images. Then, the two types of superpixels are combined utilizing a reversible weight-based fusion method in score level.

In [20], a finger vein recognition algorithm based on an improved Zernike moment is proposed to describe the global characteristics of the image, which will improve the accuracy of the recognition algorithm. The Zernike moment features of the image and a combination matching algorithm of template matching and Hu moment matching, are used to realize the accurate identification of the finger vein. The results indicate that this algorithm can greatly reduce the influence of image rotation, translation, and noise in the recognition process. The recognition rate achieved using the improved Zernike algorithm is 98.89%.

C Hsia [21], proposed a method in which multi-image quality assessments (MQA) are applied to conduct a second stage verification to double check the result of feature point matching. A feature point based method with a MQA voting strategy allows an efficient feature points matching using a robust feature and rigorous verification using the MQA process. Multiple MQA methods are used to increase flexibility and robustness of the recognition algorithm.

In [22], Convolutional Neural Network (CNN) based finger vein recognition system is proposed. In the matching stage, for each testing sample generated earlier, the trained CNN returns a probability value for all the available classes/fingers. The maximum probability value determines the most similar finger to the testing sample [23]. For a given testing sample, if the matching probability value returned by the network is less than 50% for its comparisons with any trained class, then that test image is classified as "not-identified" in the database. This method significantly reduces the training and testing time, and also enhances the recognition accuracy.

IV. Performance Comparison Of Various Matching Techniques

The matching stage is of paramount importance as it can significantly influence the performance of a finger vein recognition system. Extensive feature dimensions can cause huge computation and the memory cost of the classifier. Thus, to make the finger vein recognition system more practical, the system should have a high recognition rate, high accuracy and high recognition speed.

The matching has two types of error results to achieve high accuracy, which are false rejection rate (FRR) and false acceptance rate (FAR). False rejection rate claims a genuine pair as imposter, and the false acceptance claims an imposter pair as genuine. Hence, the system efficiency is computed by the equal error rate (EER) [10]. The EER is defined as the error rate when the false rejection rate (FRR) equals the false acceptance rate (FAR). The threshold is used to make a decision on the matching algorithm. If the threshold is reduced, FAR is increased and FRR is decreased, and vice-versa. Always, low FAR and high FRR would ensure that any unauthorized user will not be permitted to access [26]. The lower the EER, the higher the accuracy.

Table 1 demonstrates the performance comparison of the recent research advancements in the matching techniques of the finger vein recognition system along with their Equal Error Rate (EER) or Recognition Rate (RR). From Table 1, we can observe clearly that some matching methods, for example, Random Forest Regression [13], Elastic Matching [15] and Pixel-based optimized matching [17] report promising performance. These methods are robust to noise, image deformations and misalignment. Most of the recent finger vein recognition matching techniques show remarkable performance in terms of accuracy and equal error rate. Accuracy rate of almost all the recent finger vein matching algorithms is close to 100%. The machine learning method i.e., CNN [22] has advantages in being robust to noise and solve the complex pattern recognition problems achieving high accuracy and low EER.

Table 1. Performance Comparison of Different Matching Methods based on EER/RR

S.No	Matching Methods	Database	EER/RR
1.	SIFT [11]	106 images	EER=1.086%
2.	Histogram Matching, Bhattacharyya distance [12]	SDU	RR=97%
3.	Random Forest Regression [13]	MMCBNU	EER=0.35% RR=99.65%
4.	Bidirectional Deformable Spatial Pyramid Matching (B-DSPM) [14]	HKPU	EER=0.70% RR=99.41%
5.	Elastic Matching [15]	HKPU	EER=0.38% RR=99.68%
6.	Potential Energy Vector, Hausdorff distance [16]	600 images	EER=0.97%
7.	Pixel-based optimized matching [17]	HKPU	EER=0.0053%
8.	Dynamic template selection and Threshold adjustment [18]	Not Reported	EER=0.124%
9.	Super-pixel Context Feature (SPCF) [19]	HKPU	EER=0.0075% RR=97.65%
10.	Improved Zernike Moment, Template & Hu Moment Matching [20]	360 images	RR=98.89%
11.	Multi-image quality assessments (MQA) [21]	FVUSM	EER=0.13%
12.	CNN [22]	SDU	EER=0.079% RR=99.53%

V. CONCLUSION

Finger-vein recognition, enlisting the uniqueness of living recognition, is a high security biometric authentication technology. In modern era, finger-vein recognition technology has become increasingly popular. Basically, the finger-vein recognition process involves finger-vein image acquisition, feature extraction and recognition. The recognition algorithm is the key research issue in that the accuracy and recognition performance of finger vein recognition system mainly depends on this matching algorithm. In this paper, a systematic and detailed review is presented for the recent development of most advanced matching techniques/algorithms utilized in finger vein recognition to overcome the weaknesses of the previous methods in order to develop a more powerful and robust finger vein-based identification or verification system. The paper presents the most recent research developments of the key matching techniques available for finger vein recognition and provides details for methods being reviewed along with their error rates.

In addition, a performance comparison has been made among various recently developed matching techniques in which the recognition performances of various matching methods were compared. These compared methods are robust to noise, image deformations and finger misalignment. Recognition rate of almost all the reviewed finger vein matching algorithms is close to 100%. Recent advancements in matching techniques of finger vein recognition have resulted in increased accuracy and reliability and reduced cost. The key advantages of this technology are high degree of privacy and anti-spoofing capabilities. The research should emphasize more on creating and utilizing novel machine learning solutions to challenging finger vein problems which can significantly influence the recognition performance of a finger vein recognition system and to achieve a high accuracy and recognition rate of the finger vein recognition in near future.

REFERENCES

[1] S. Gupta and L. Singh. 2017. A Study on New Biometric Approaches. IEEE International Conference on Computing and Communication Technologies for Smart Nation (IC3TSN): 306 – 310.

[2] T. Sabhanayagam. 2018. A Comprehensive Survey on Various Biometric Systems. International Journal of Applied Engineering Research, 13(5): 2276-2297.

[3] M. Jadhav and P. M. RavaleNerkar. 2015. Survey on Finger Vein Biometric Authentication System. IJCA Proceedings on National Conference on Emerging Trends in Advanced Communication Technologies NCETACT, 3: 14-17.

[4] RamaPrabha R. and V. K. David. 2015. Finger Vein Recognition Using Computational Intelligence Techniques. (IJCSIT) International Journal of Computer Science and Information Technologies, 6(4): 4024-4028.

[5] E. Ting, M.Z. Ibrahim. 2017. A Review of Finger Vein Recognition System. Journal of Telecommunication, Electronic and Computer Engineering, 10(1): 167-171.

[6] R. Dev and R. Khanam. 2017. Review on Finger Vein Feature Extraction Methods. IEEE International Conference on Computing, Communication and Automation (ICCCA): 1209-1213.

[7] K. Shaheed, H. Liu, G. Yang, I. Qureshi, J. Gou, Y. Yin. 2018. A Systematic Review of Finger Vein Recognition Techniques. Information, 9: 213.

[8] S. B. Kutemate and R. U. Shekokar. 2015. Secure and Reliable Human Identification Based on Finger-Vein Patterns. International Journal of Engineering Research & Technology (IJERT), 4(3): 978-980.

[9] L. Yang, G. Yang, Y. Yin, L. Zhou. 2014. A Survey of Finger Vein Recognition. Chinese Conference on Biometric Recognition, 8833: 234-243.

[10] K. A. Akintoye, M. S. M. Rahim and A. H. Abdullah. 2018. Challenges of Finger Vein Recognition System: A Theoretical Perspective. International Journal of Emerging Technology and Advanced Engineering, 8(2): 196-204.

[11] Sujani. G and S. Reddy. 2017. A Hierarchical finger selection method for finger vein recognition using SIFT. IEEE International Conference on Smart Technologies for Smart Nation.

[12] C. Chiu, T. Liu, W. Lu, W. Chen and J. Chou. 2018. A micro-control capture images technology for the finger vein recognition based on adaptive image segmentation. Microsystem Technologies, Springer, 24(10):4165–4178.

[13] C. Liu and Y. Kim. 2016. An efficient finger-vein extraction algorithm based on random forest regression with efficient local binary patterns. IEEE International Conference on Image Processing (ICIP).

[14] Q. Chen, L. Yang, G. Yang, Y. Yin and X. Meng. 2017. DFVR- Deformable finger vein recognition. IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP).

[15] L. Yang, G. Yang, Y. Yin. 2017. Finger Vein Recognition with Anatomy Structure Analysis. IEEE Transactions on Circuits and Systems for Video Technology, 28(8): 1892 - 1905.

[16] L. You, H. Li and J. Wang. 2015. Finger-vein Recognition Algorithm Based on Potential Energy Theory. IEEE 16th International Conference on Communication Technology (ICCT).

[17] X. Meng, X. Xi, G. Yang and Y. Yin. 2017. Finger vein recognition based on deformation information. Science China Information Sciences, Springer.

[18] H. Zheng, Q. Xu_, Y. Ye and W. Li. 2017. Effects of meteorological factors on finger vein recognition. IEEE International Conference on Identity, Security and Behavior Analysis (ISBA).

[19] L. Zhou, G. Yang, Y. Yin, L. Yang and K. Wang. 2016. Finger Vein Recognition Based on Stable and Discriminative Superpixels. International Journal of Pattern Recognition and Artificial Intelligence, 30(6).

[20] J. Li, Y. Hu, Y. Zhang and Z. Zhao. 2017. Finger-Vein Recognition Based on Improved Zernike Moment. Chinese Automation Congress (CAC), IEEE.

[21] C. Hsia. 2018. New Verification Strategy for Finger-Vein Recognition System. IEEE Sensors Journal, 18(2):790 – 797.

[22] R. Das, E. Piciucco, E. Maiorana and P. Campisi. 2018. Convolutional Neural Network for Finger-Vein-based Biometric Identification. IEEE Transactions on Information Forensics and Security, 14(2): 360 – 373.

[23] W. Liu, W. Li1, L. Sun, L. Zhang and P. Chen. 2017. Finger Vein Recognition Based on Deep Learning. IEEE Conference on Industrial Electronics and Applications (ICIEA): 205-210.

[24] N. Ortiz, R. D. Hernández, R. Jimenez, M. Mauledeoux and O. Avilés. 2018. Survey of Biometric Pattern Recognition via Machine Learning Techniques. Contemporary Engineering Sciences, 11(34): 1677 – 1694.

[25] Umesh, H. Sehrawat, V. Siwach. 2017. Analysis of Finger Vein Based in Recognition. International Journal of Advanced Research in Computer Science, 8(5): 1818-1823.

[26] Y. Ye, H. Zheng, L. Ni, S. Liu and W. Li. 2016. A Study on the Individuality of Finger Vein Based on Statistical Analysis. International Conference on Biometrics (ICB).

[27] H. Qin and M. A. E. Yacoubi. 2018. Deep Representation for Finger-vein Image Quality Assessment. IEEE Transactions on Circuits and Systems for Video Technology, 28(8): 1677 – 1693.