A Review: Personal Identification based on Palm Vein Infrared Pattern

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***Abstract*—Palm vein recognition is the latest biometrics technique used and researches currently. This method achieved high performance in identification due to the complexity of vein pattern on the palm. This studies proposed a review of overall process of vein recognition and vein recognition techniques. In particular, this studies is systematically described in three parts which is vein image acquisition and preprocessing, feature extraction and decision matching. According to the available work, various approaches for different kind of features extractions, palm vein segmentation and overall process will be discussed in this paper.**

***Index Terms*— Biometric Traits; Palm Vein; Preprocessing; Feature Extraction.**

I. INTRODUCTION

In this world of digital impersonation, security system has getting more attention to the society. Many ideas have been proposed and it can be categorized into traditional method and biometric method. However, traditional method such as keys, passwords and Personal Identification Number (PIN) cannot fulfill and satisfy for high secure and high security. Hence, biometrics method is popular and take full advantage on establish identification.

Biometrics methods such as facial, finger print, and voice are the popular identification system in the society. However, most of them have their own limitation. For example, there were 2% of population claim that they cannot use their own finger print for recognition on extract high quality finger print on manual workers. Eye recognition system is not suitable for the user. Hence, vein recognition system able to design in contactless biometrics identification.

Palm vein recognition stand out among all the biometric system because of great level of recognition accuracy. Vein pattern has its own uniqueness and distinctive. The complexity of vein pattern of the palm make the recognition more secure and protect against all spoof attacks. Even identical twins have their own different palm vein patterns. Besides from that, vein is lies underneath the skin. Naked eyes are unable to observe and forged by the people. Vein pattern is also stable over period of time which make vein database can be used for a long period. In vein recognition system, contactless design has been introduced which brings to no contamination on the sensor and produced no hygiene issues.

The rest of the paper will briefly discussed on the overall process of the palm vein recognition system. A description of the method that proposed by other researchers for palm vein and other vein recognition system will also discussed in the following sections. Figure 1 will shows the overall process flow chart of the palm vein recognition system.

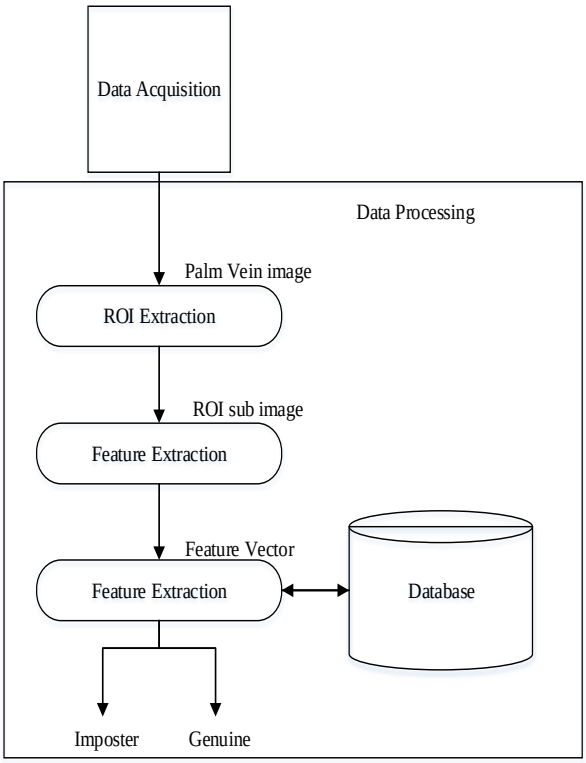

Figure 1: Process flow of the palm vein recognition system [1]

II. METHODS

A. Image Acquisitions

In order to obtain the palm vein pattern, some palm vein pattern authentication principle must be followed. Palm vein image are normally taken in the near infrared light. This is because natural light image are unable to obtain the discriminative information in the palm vein image which make the recognition is not possible. Hence, palm vein image that capture in near infrared light make palm pattern extraction possible on recognition stage. Wavelength of 760nm is the minimum wavelength of the near infrared light to obtain the palm pattern. This is because the light can penetrate through the human tissue in that wavelength. Therefore, image processing will be very easy to recognize the superficial veins and deep veins.

Palm vein image can be acquired by using either own capturing device or online database. There was some research done by using their own database with their own design capturing device. A paper that publish by Wang Jian-Gang,

et.al on Fusion of Palm print and Palm Vein Images for Person Recognition Based on "Laplacianpalm" [2] has develop their own IR camera to acquire either palm print and vein image. The IR radiation wavelength emitted to the palm is under then range of 3000 to 12000nm. But the issue will be occur to the images that need to be registered and verified to make sure it is usable images. In this work, "A novel biometric system based on palm vein image" [3] a digital noise reduction NIR charge-coupled device (CCD) camera is used. This camera can capture the NIR image on about 1100nm. Besides from that, near IR illumination (LEDs) is add on around the camera. The purpose of adding LEDs is to reduce the effect of surrounding light, that LEDs will acts as an infrared filter for the image. Figure 2 shows that the basic principal of Near Infrared camera on capturing the palm vein image.

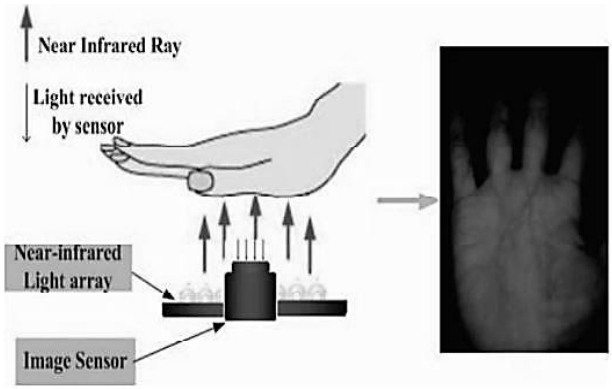

Figure 2: Basic principal of near infrared camera on capturing palm vein image [1]

Palm vein image can also be obtained by using the online database. There are several popular online database used on research which is PolyU, PUT and CASIA database [4, 5, 6]. 250 participants has involved in PolyU multispectral palm vein images. It contains 6000 images from 500 different palms with left hand and right hand. The clipped ROI image also provided for every images. In CASIA database, 100 volunteers has involved with 7200 images. Each sample contain six palm images capture in the same time with six different wavelength spectrum which are 460nm, 630nm, 700nm, 850nm, 940nm and white light. In capturing the palm vein images, volunteers are allow to do some degree of variations of hand postures. For PUT vein database, it consist of 2400 images which half of the images contain palmar vein images and another half contains wrist vein patterns. Data was collected by 50 volunteers which has a 100 different patterns for palm and wrist regions.

B. Preprocessing

Zhou and Kumar [7] has introduced the ROI extraction which is suitable for contactless palm vein recognition. ROI extraction have to be normalized first that would make the system is invariant to those axis changes. Two Web points is generated in between the index finger and middle and between the ring finger and little finger. Binarization will be adopted to differentiate the palm and the background region. Central position or center image is estimate from the boundary of palm. This approach is stated that is similar to this paper work [8]. Finally, the ROI images extraction will be scaled in a fixed size adopted with histogram equalization by achieving an enhanced image. This method are normally employed by most of the researchers either palm vein or palm print recognition [9]. Figure 3 below shows the example of ROI extraction on palm vein in one sampler.

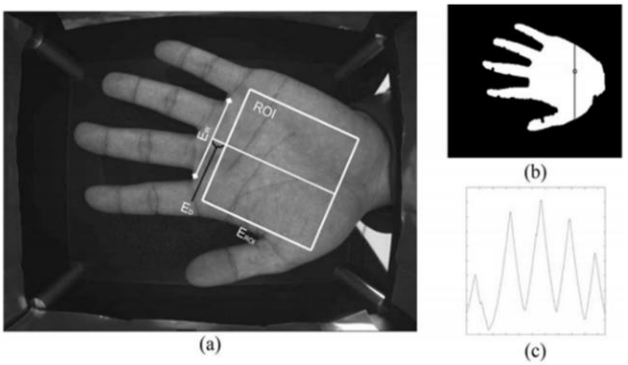

Figure 1: Palm vein ROI extraction [7]

In this research paper [10], the author has do some modified on the pre-processing. This is because a lot of issues is address on palm vein image. Image in Near Infrared image are generally show in not uniform illumination and also darker with low contrast mode. This make difficulties on extracting the palm vein pattern in contact free recognition systems. Entire palm region including five fingers are extracted as the ROI for the next processing stage. OTSU threshold is the fixed threshold which normally adopted after ROI segmentation because simple and fast.

Radian Distance Function (RDF) has been used on the work that was published by Rahul & Cherian et al [11]. In the beginning OTSU method was used to extract hand contours from grayscale palm vein image. RDF will be function as set the peak and valley points as a reference point and contour point. Finally, final palm vein ROI will be obtained by using scaling and rotation normalization for the scaling, rotational and translational problems.

In this paper [12], Competitive Hand Valley Detection (CHVD) has been used to determine the ROI of the palm. CHVD is an algorithm which can identify the palm region by determine the valley point of the palm. The pixel will generate and draw a line once the valley point is located in each gap between the finger [13].

C. Vein Pattern Feature Extraction

Recently, studies of palm veins have focused more on the palm vein extraction. It can be categories into four which is the geometry based method, statistical based methods, local invariant feature based methods and subspace methods.

a. Vein Pattern Feature Extraction

Geometry based method are the methods which typically use vascular structure information. The palm vein pattern are extracted using spatial methods such as Gabor filter, vector grams of maximal intra-neighbor difference, repeated line tracking, and maximum curvature points. These type of methods makes problems in extraction, representation and matching. It produces information loss on tiny and blurred pixels which occurred on low quality image. Hence, those methods are sensitive to scaling, rotation and translational problems. It also cause poor distinguishing ability [14].

Gabor filter has been adopted in the feature extraction stage [3]. This method is useful in 2D image due to its variation to 2D spatial position. In addition, it also advantage against near infrared images which cause brightness and contrast problem

on the images [15]. By using this method, Gabor filter able to extract the edge information of the images. It able to achieved high performance in either frequency or space domains. This method has been tried to apply on other recognition techniques [16]. Different type of Gabor filter also been proposed to identify which Gabor filter is suitable for palm vein recognition [17].

For other methods, Miura et al. [18] proposed the palm vein extraction by using repeated line tracking algorithm. This method able to locate the vein patterns from the low quality images. The tracking lines will based on the dark line detection that will move along the line or by pixel. Once there was no dark line detected, the tracking operation will automatically start at another position. In the end, the dark lines will keep on repeating to recover the vein patterns. Miura et al. [19] proposed another techniques local maximum curvature on extract vein patterns. Maximum curvature points will be found from four direction and finally will be calculate using the weighted sum of the all points.

Kang and Deng [20] use the maximal intra neighbor difference (MIND) on extracting palm vein patterns. MIND image will obtained once the neighbor information vein extracted. This MIND image will be processes by histogram modification. By compare the weighted sum of MIND image and mean image, the vein pattern images will be obtained. Key parameters can be set according to the user to improve results. The performance for geometry based method shown in the Table 1 below.

Table 1
Performance on Geometry Based Method for Vein Recognition System

Reference	Methodology	Database	Performance / Equal Error Rate %
J. C.Lee [3]	Using 2D Gabor filter on extracting the filter palm vein image, employed Hamming distance on measure similarity of two VeinCodes.	Own Database	99.18% 0.44%
W. Y.Han and J. C.Lee [17]	Using different type Gabor filter and measure Hamming distance	Own Database	Single Gabor 0.70% Multi Gabor 0.55% Adaptive Gabor 0.65%
W. X.Kang and F.Q.Deng [20]	Calculate and extract vein pattern using maximum intra-neighbour vector difference	Own Database	93.5%

b. Statistical Based Method

Statistical based method is the method typically use various statistical data in the image such as Local Binary Pattern (LBP), Local Derivative Pattern (LDP), Local Tetra Pattern (LTrP) and Local Directional Texture Pattern (LDTP). However, the use of these method is effected on axis or scale change which is the reason on using block-based strategies on feature extraction.

Local Binary Pattern (LBP) has been proposed on facial recognition, finger recognition and palm print recognition. This method is the method that compare the gray level neighborhood pixel values. The original operator 3x3 neighborhood that consists of 8 pixels in between a middle pixel. Local Binary Pattern (LBP) is a good texture encoder which can characterize the variance of spatial structure of an image [21].

By using Directional Features from Local Binary Pattern [22], the works shows that the computed palm vein features are represented as binary series therefore this can be computed efficiently by binary operation. The proposed method employs the directional information of vein patterns and take the advantage of multi-resolution analysis bringing by the LBP. Existing study on directional features are effective extracting vein patterns either in texture based or structure based methods. It developed a new LBP descriptors by extract more directional information for palm vein representation [22].

From this work [14], mutual foreground fusion with LBP for palm vein identification has been proposed. In this experiments, LBP match was match with the mutual foregrounds (MF) of vein image. This method extracted features only in grayscale image which exclude and eliminate the background pixels. The performance is better compared with LBP method is used only.

Local Derivative Pattern (LDP) have large order texture descriptor. The feature extracted are always stored in histograms with the decimal values of the image. In order to obtain the LDP descriptor, own suitable parameter have to be set or adjust. In this paper [23], the best operator of size 236x236 with veins of 2 to 10 pixel thick is set. The output histogram will generated by the LDP once all the characteristics and features is obtained. All value of LDP is stored in a histogram from the pixel values of 0 to 255. It results four grades according to the four directional features [24].

Local Directional Texture Pattern (LDTP) is a local feature descriptor which can encode contrast and directional information of texture vein patterns. LDTP is a local feature descriptor especially for contactless palm vein recognition [11, 25]. The input image will represents in 7 binary code. In order to generate LDTP, edge response of neighborhood using mask techniques. It helps to gather all information in the 8 directions. By using Kirsch masks, it help to reveal vein pattern structure and robust against noise. While for this work [11], Mutual Foreground-Local Directional Texture Pattern (MF-LDTP) is used for palm vein recognition. Palm vein pattern is extracts directional using LDTP texture descriptor first and finally it will multiply foreground information with LDTP feature to obtain MF-LDTP which is similar to the MF-LBP methods used.

Local Tetra Pattern (LTrP) uses four direction on the texture descriptor which created more information on the image. It has the highest order descriptor compared to those method above. This method are able to solve the irregularities vein pattern of the sampler. [26]. LTrP will obtain the local texture by using the middle gray pixel.is Thirteen binary patterns is represent in one image and those image will be combined together and become a single image. Table 2 will shows the evaluation on every technique used on palm vein

recognition.

Table 2
Performance for Statistical Based Method for Palm Vein Recognition System

Reference	Methodology	Database	Performance / Equal Error Rate %
T. Ojala, M.Pietikainen, and T.Maenpaa [21]	Vein Recognition based on directional information derived from local binary pattern, employed matching by score level fusion.	PolyU	0.13% (palm vein) 0.0012% (palm print and palm vein)
W.Kang and Q.Wu [14]	Palm Vein Extraction using improved mutual foreground Local Binary Pattern (LBP), employed with Support Vector Machine (SVM).	CASIA	0.267%
W.Lu, M.Li and L.Zhang [22]	Multi-scale Local Binary Pattern (LBP) and Local Derivative Pattern (LDP)used for vein extraction and matching by similarity measure	CASIA	0.004% LBP 0.0009% LDP
L. Mirmohamadsadeghi et.al [23]	Local Derivative Pattern (LDP) as feature extraction and matching by Histogram Intersection	CASIA	0.01% 98.3%
F.akhbar, Wirayudha et.al [24]	Using improved foreground based Local Directional Texture Pattern (LDTP) and match by using Chi-square dissimilarity test	CASIA	95% 0.05%
R.Rivera, R.Castillo and O.Chae [25]	Employed Local Tetra Pattern (LTrP) and matching by Cosine Similarity Measure	PUT	0%

c. Local Invariant Featured Based Method

Local invariant feature based methods are the methods extract image features which exists as a point. This methods are not sensitive to rotation, scale and axis changes. This method are mostly used for the contactless design system. However, due to the loss of useful feature information, binarization will not been used in preprocessing stage [27]. Some research have directly extracted invariant features from the vein image without any preprocessing process.

Gurunathan V et.al [28] is use SURF invariant method on multimodal palm vein and palm print recognition system. The work tested the algorithm with rotated sample and the method shows it able to match correctly although the sample image has been rotated. In this paper, feature level fusion is applied by fusion with palm print feature extraction and palm vein feature extraction. This methods have their own key point identifier and descriptor.

SIFT also has been proposed in this paper [27]. Key point of SIFT are located in the gradient of the image [29]. Difference of Gaussian (DoG) used as the descriptor which has the difference plane of Gaussian layer. Descriptor is created to read the key points which can understand by the algorithm [30]. In this paper [10], RootSIFT has been developed by replacing Euclidean distance with the Hellinger kernel function. Euclidean distance is used to maintain invariant features which normalized to a Euclidean unit vector.

In this paper [31], SIFT and ORB score level fusion is used for palm vein pattern extraction. SIFT are able to extract blob feature while for ORB are able to extract corner feature. SIFT points are placed in the image and ORB feature points are placed along the vein pattern which means that two features have different features point placement. Score level fusion by using min-rule has the highest identification rate compared to others. The below Table 3 shows the Equal Error Rate for all local invariant feature based method.

Table 3
Performance of Local Invariant Featured Based Method for Palm Vein Recognition

Reference	Methodology	Database	Performance/ Equal Error Rate %
P.-O Ladoux, C. Rosenberger, and B. Dorizzi [27]	Speeded Up Robust Features (SURF) algorithm and feature level fusion using Sum Rule. Matching by using sum of absolute difference (SAD) distance measure.	PUT and PolyU	1.19%
W. Kang, Y. Liu, Q. Wu and X. Yue [10]	Scale Invariant Feature Transform (SIFT) and improved RootSIFT on feature extraction, matching by using Hellinger Kernel.	CASIA and Own database	0.996% CASIA 3.112% own database
P.-O Ladoux, C. Rosenberger, and B. Dorizzi [27]	Apply Scale Invariant Feature Transform (SIFT) and matching with Euclidean Distance	Own database	0.14%
X. Yan, F.Deng and W. Kang [31]	Score level fusion with SIFT and ORB, matching using bidirectional matching	CASIA	0.36%

d. Subspace Method

Subspace method is a method which take subspace as a features without prior knowledge. This method are always adopt both artificial intelligence and machine learning for classification. This method are always used to reduce or simplify the data structure between two groups of variables. The most popular method used on feature reduction is Principal Component Analysis (PCA), Independent Component Analysis (ICA), and Linear Discriminative Analysis (LDA).

Some of the paper stated that PCA is capable to reduce the dimension size but still maintain the important feature in the picture [12, 32]. However, ICA can describe image features more efficiently compare to PCA [33]. ICA can describe image features on the high order. LDA are often uses as a feature reduction which able to extract the discriminative

features with low dimension [34, 35]. This type of method are very powerful because it can project the palm vein image into subspace built from training data. By improving this method, some new subspace method has also been proposed in palm vein recognition such as Partial Least Square [36], two dimensional Fisher Linear discriminant (2DFLD) [1] and Radon Transform [7, 37]. Table below shows the performance for subspace method in palm vein recognition.

Table 4
Subspace Method on Palm Vein Recognition

Reference	Methodology	Database	Performance / Equal Error Rate %
J. Xu[1]	Extract vein using two dimensional Fisher Linear discriminant (2DFLD) and matching by Euclidean distance matrix	Own database	8.92% 99.29%
Y. Zhou and A. Kumar [7]	Feature extraction and matching using Neighbourhood Matching Radon Transform (NMRT) and Hessian phase from palm vein image	CASIA PolyU	0.51 NMRT 1.44 Hessian 0.004 NMRT 0.43 Hessian
D. Y. Perwira [12]	Feature extraction using Principal Component Analysis (PCA) and classification using Probabilistic Neural Network	CASIA	84%
S. Elnasir and S. M. Shamsuddin [34]	Palm vein recognition based on Linear Discriminative Analysis (LDA) and classify using Nearest Neighbour Classifier	PolyU	99.5% 0%
S. Elnasir and S. M. Shamsuddin [35]	Feature Extraction based on 2D Discrete Wavelet Transform and Linear Discriminative Analysis (LDA) and matching using cosine distance	PolyU	99.74% 0%
J. Xu [36]	Feature Extraction using Partial Least Square and matching using Euclidean Distance	CASIA	98.7% 1.33%
Y. Zhou, Y. Liu, et. al [37]	Feature Extraction using Gaussian Radon Transform and match using principal oriented features	PolyU CASIA	0.09% PolyU 0.67% CASIA

D. Feature Matching

Depending on feature extraction used, several feature matching method were used to evaluate the method or work done. Matching method can be categories into two which is the geometry and featured based method. Geometry-based matching is the techniques which use to compare points and line features on the vein patterns. Point matching are used to calculate the distance between two points. Normally, the method used like interesting point detector [38], distance metric like Cosine Similarity Distance [39], Hamming Distance [17], and Euclidean Distance [10, 40]. Vein pattern are always shows in line structure which could be obtain more information by using line-based method. Hence, researches has found out that vein pattern like principal line features has high authentication rate compared to others [41].

Feature based matching are able to works on either appearance or texture based methods. PCA, LDA and ICA are one of the subspace method which normally adopted with Euclidean distances on matching scores [42, 43]. For other distance measures like chi square distances were applied [44, 45, 46]. Feature based method perform better than geometry based method on low quality images.

High resolution images normally used in geometry based matching due to the points and coordinates of the geometrical features.

Besides from that, machine learning like neural network [12], Support Vector Machine (SVM) [47] and Hidden Markov Models (HMM) [48] were also used before by the researchers. SVM is based on the Structural Risk Minimization (SRM) principle to classifier the data [49]. It has high classification characteristics by minimizing the boundary or draw the boundary lines based on their characteristics.

III. FUTURE WORKS

Among all these method, palm vein recognition has been applied successfully on access control in many organizations. However, these still have unsolved issue although there was so many method that proposed by researchers [34, 35]. An accurate palm vein reading is still an issue occur to palm vein recognition. Although Fujitsu Labs have proved to be highly discriminative reach almost lowest FAR [50]. However, there was not any paper proved that this system can be apply on other database. Hence, most of the research are target and aim on the lower EER percentage. In this work stated that usage of wavelet transform in the higher decomposition levels for palm vein recognition system can be investigate [35].

In addition, most of the research are also target on contactless palm vein recognition system. This is because contactless design system is suitable for the real world scenario. In contactless design system, it produce issues such as non-uniform illumination and affine transformation which is not suitable for some methods. Besides than that, contactless design will also occur scale change, axis change which will affect the accuracy on the system.

Combination or multimodal biometrics system is also worth exploring and suggest for the recognition system. There was some research shows that combination biometrics system can cover up the disadvantage each other that will also improve the performance on the recognition system. Fusion strategy are always adopted and it shows that this method are suitable for this multimodal biometrics system.

IV. CONCLUSION

Biometrics refers to the recognition based on individual behaviors and traits. Vein recognition system is the most popular among all the biometrics system on making access to the system. Vein recognition system is highly secure because the vein pattern is complex and it is underneath the skin which make the intruders unable to access the information. Hence, several methods and techniques was proposed on this vein recognition research. However, there are still have unsolved issue on this research such as the accuracy and the contactless design issues. It bring to the future work or the gap that

researchers can focus on research on those topic to solve those issues.

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REFERENCES

[1] Xu, J. An online biometric identification system based on two dimensional fisher linear discriminant. (2015) 774–778.
[2] Wang, J.-G., Yau, W.-Y. & Suwandy, A. Fusion of palmprint and palm vein images for person recognition based on Laplacianpalm'' Feature. Int. Conf. Signal Process. Proceedings, ICSP 2015–Janua, (2015) 2407–2410.
[3] Lee, J. C. A novel biometric system based on palm vein image. Pattern Recognit. Lett. 33, (2012) 1520–1528.
[4] Palmprint, C. M. & Database, I. Note on CASIA Multi-Spectral Palmprint Database. 1–4
[5] PolyU multispectral palmprint database. Available at: http://www.comp.polyu.edu.hk/~biometrics/%0AMultispectralPalmprint/MSP.htm.
[6] PUT vein database. Available at: http://biometrics.put.poznan.pl/vein-dataset.
[7] Zhou, Y. & Kumar, A. Human identification using palm-vein images. IEEE Trans. Inf. Forensics Secur. 6, (2011) 1259–1274.
[8] Hao, Y., Sun, Z., Tan, T. & Ren, C. Multispectral palm image fusion for accurate contact-free palmprint recognition. in 2008 15th IEEE International Conference on Image Processing (IEEE, 2008) 281–284.
[9] Zhang, Y.-B., Li, Q., You, J. & Bhattacharya, P. Palm vein extraction and matching for personal authentication. in International Conference on Advances in Visual Information Systems (Springer, 2007) 154–164.
[10] Kang, W., Liu, Y., Wu, Q. & Yue, X. Contact-free palm-vein recognition based on local invariant features. 9, (2014).
[11] Rahul, R. C. & Cherian, M. A novel MF-LDTP approach for contactless palm vein recognition. (2015) 793–798.
[12] Perwira, D. Y. Personal Palm Vein Identification Using Principal Component Analysis and Probabilistic Neural Network. (2014) 24–27.
[13] Michael, G. K. O., Connie, T. & Teoh, A. B. J. Touch-less palm print biometrics: Novel design and implementation. Image Vis. Comput. 26, (2008) 1551–1560.
[14] Kang, W. & Wu, Q. Contactless palm vein recognition using a mutual foreground-based local binary pattern. IEEE Trans. Inf. Forensics Secur. 9, (2014) 1974–1985.
[15] Zhang, D., Kong, W.-K., You, J. & Wong, M. Online palmprint identification. IEEE Trans. Pattern Anal. Mach. Intell. 25, (2003) 1041–1050.
[16] Daugman, J. G. High confidence visual recognition of persons by a test of statistical independence. IEEE Trans. Pattern Anal. Mach. Intell. 15, (1993) 1148–1161.
[17] Han, W. Y. & Lee, J. C. Palm vein recognition using adaptive Gabor filter. Expert Syst. Appl. 39, (2012) 13225–13234.
[18] Miura, N., Nagasaka, A. & Miyatake, T. Feature extraction of finger-vein patterns based on repeated line tracking and its application to personal identification. Mach. Vis. Appl. 15, (2004) 194–203.
[19] Miura, N., Nagasaka, A. & Miyatake, T. Extraction of finger-vein patterns using maximum curvature points in image profiles. IEICE Trans. Inf. Syst. 90, (2007) 1185–1194.
[20] Kang, W. X. & Deng, F. Q. Vein image enhancement and segmentation based on maximal intra-neighbor difference. Acta Opt Sin 29, (2009) 1830–1837.
[21] Ojala, T., Pietikainen, M. & Maenpaa, T. Multiresolution gray-scale and rotation invariant texture classification with local binary patterns. IEEE Trans. Pattern Anal. Mach. Intell. 24, (2002) 971–987.
[22] Lu, W., Li, M. & Zhang, L. Palm vein recognition using directional features derived from local binary patterns. 9, (2016) 87–98.
[23] Mirmohamadsadeghi, L. & Drygajlo, A. Palm vein recognition with local binary patterns and local derivative patterns. 2011 Int. Jt. Conf. Biometrics, IJCB 2011 (2011).
[24] Akbar, A. F., Wirayudha, T. A. B. & Sulistiyo, M. D. Palm vein biometric identification system using local derivative pattern. 2016 4th Int. Conf. Inf. Commun. Technol. 4, (2016) 1–6.
[25] Rivera, A. R., Castillo, J. R. & Chae, O. Local directional texture pattern image descriptor. Pattern Recognit. Lett. 51, (2015) 94–100.
[26] Saxena, J., Tec, K., Travieso, C. M. & Alonso-hernández, B. Palm Vein Recognition using Local Teetra Patterns. (2015) 151–156.
[27] Ladoux, P.-O., Rosenberger, C. &Dorizzi, B. Palm vein verification system based on SIFT matching. in International Conference on Biometrics (Springer, 2009) 1290–1298.
[28] Gurunathan, V., Sathiyapriya, T. &Sudhakar, R. Multimodal biometric recognition system using SURF algorithm. 2016 10th Int. Conf. Intell. Syst. Control (2016) 1–5.
[29] Mikolajczyk, K. &Schmid, C. A performance evaluation of local descriptors. IEEE Trans. Pattern Anal. Mach. Intell. 27, (2005) 1615–1630.
[30] Lowe, D. G. Distinctive image features from scale-invariant keypoints. Int. J. Comput. Vis. 60, (2004) 91–110.
[31] Yan, X., Deng, F. &Kang, W. Palm vein recognition based on multi-algorithm and score-level fusion. Proc. - 2014 7th Int. Symp. Comput. Intell. Des. Isc. 2014 1, (2015) 441–444.
[32] Bayoumi, S. et al. PCA-based palm vein authentication system. 2013 Int. Conf. Inf. Sci. Appl. ICISA 2013 (2013).
[33] Liu, J., Cui, J., Xue, D. & Jia, X. Palm-dorsa vein recognition based on independent principle component analysis. 2011 Int. Conf. Image Anal. Signal Process. 660–664 (2011).
[34] Elnasir, S. & Shamsuddin, S. M. Proposed scheme for palm vein recognition based on Linear Discrimination Analysis and nearest neighbour classifier. Proc. - 2014 Int. Symp. Biometrics Secur. Technol. ISBAST 2014 (2015) 67–72.
[35] Elnasir, S. & Shamsuddin, S. M. Palm vein recognition based on 2D-discrete wavelet transform and linear discrimination analysis. Int. J. Adv. Soft Comput. its Appl. 6, (2014) 43–59.
[36] Xu, J. Palm vein identification based on partial least square. 1, (2015) 575–579.
[37] Zhou, Y. et al. Palm-vein classification based on principal orientation features. PLoS One 9, (2014) 1–12.
[38] You, J., Li, W. & Zhang, D. Hierarchical palmprint identification via multiple feature extraction. Pattern Recognit. 35, (2002) 847–859.
[39] Manmohan et al. Palm vein recognition using local tetra patterns. IWOBI 2015 - 2015 Int. Work Conf. Bio-Inspired Intell. Intell. Syst. Biodivers. Conserv. Proc. (2015) 151–156.
[40] Ladoux, P. O., Rosenberger, C. & Dorizzi, B. Palm vein verification system based on SIFT matching. Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics) 5558 LNCS, (2009) 1290–1298.
[41] Huang, D.-S., Jia, W. & Zhang, D. Palmprint verification based on principal lines. Pattern Recognit. 41, (2008) 1316–1328.
[42] Lu, G.-M., Wang, K.-Q. & Zhang, D. Wavelet based independent component analysis for palmprint identification. in Machine Learning and Cybernetics, 2004. Proceedings of 2004 International Conference on 6, (IEEE, 2004) 3547–3550.
[43] Lu, G., Zhang, D. & Wang, K. Palmprint recognition using eigenpalms features. Pattern Recognit. Lett. 24, (2003) 1463–1467.
[44] Wu, X., Wang, K. & Zhang, D. A novel approach of palm-line extraction. in Image and Graphics (ICIG'04), Third International Conference on 230–233 (IEEE, 2004).
[45] Wu, X., Wang, K. & Zhang, D. Palmprint recognition using directional line energy feature. in Pattern Recognition, 2004. ICPR 2004. Proceedings of the 17th International Conference on 4, (IEEE, 2004) 475–478.
[46] Wu, X., Zhang, D. & Wang, K. Fisherpalms based palmprint recognition. Pattern Recognit. Lett. 24, (2003) 2829–2838.
[47] Zhou, X., Peng, Y. & Yang, M. Palmprint recognition using wavelet and support vector machines. in Pacific Rim International Conference on Artificial Intelligence (Springer, 2006) 385–393.
[48] Wu, X., Wang, K. & Zhang, D. in Biometric Authentication (Springer, 2004) 775–781.
[49] Michael, G., Connie, T., Teoh, A., Connie, T. & Teoh, A. A contactless biometric system using palm print and palm vein features. Image (Rochester, N.Y.) (2011).
[50] Watanabe, M. & Endoh, T. Palm vein authentication technology and its applications. Proc. (2005) 4–5.