Multimodal Systems for Human Authentication using Fusion of Dorsal Hand, Palm and Finger Veins

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Abstract

Multimodal biometric systems have been widely used to achieve high recognition accuracy. This paper presents a comparison between three multimodal biometric systems used to authenticate human by fusion of palm dorsal hand and finger veins which used alternately. We developed an image analysis technique to extract region of interest (ROI) from palm dorsal hand and finger veins image. After extracting ROI we design a sequence of preprocessing steps to improve palm, dorsal hand and finger veins images using Homomorphic, Median filter, Wiener filter and Contrast Limited Adaptive Histogram Equalization (CLAHE) to enhance vein image. Our smart systems are based on the following algorithms, namely; principal component analysis (PCA) algorithm for feature extraction and k-Nearest Neighbors (K-NN) classifier for matching operation. The database chosen was the CASIA Multi-Spectral Palm print Image Database V1.0,Bosphorus Hand Vein Database and the Shandong University Machine Learning and Applications - Homologous Multi-modal Traits (SDUMLA-HMT). The achieved results for the fusion biometric traits were Correct Recognition Rate (CRR) finger and dorsal hand veins is 96.8%., palm and dorsal hand veins is 97.6%, palm and finger veins is 97.9%

Keywords: *Biometric systems, pattern recognition, intelligent computing, image processing, machine learning.*

1. Introduction

Biometric authentication is a process of identifying a person using physiological or behavioral features. Physiological features are Iris, DNA, hand, finger print and face behavioral features are voice, signature, password, keystroke etc. Among all the authentication techniques present, biometrics is considered as the most reliable authenticators since they are unique to every individual and hard to get. The technology of Vein Patterns (VP) as a type of biometric authentication was first intended in 1992.VP is the network of blood carriers below a person's skin layers. VP structure distinct and distinguishable patterns across various people and they remain the same irrespective of age. The patterns of blood veins are unique to each person, even among twins. There are internal and external biometric systems. External include face, Iris, finger print based systems. Palm vein, finger vein, dorsal veins structure the internal biometric frameworks. Veins are intra-skin elements, consequently this feature makes the frameworks exceptionally secure, and they are not influenced by state of the external skin [1].Generally, biometric system works in two modes namely :(i) verification mode in which biometrics can be used to verify a person's identity and (ii) identification mode in which biometrics can be used to determine a person's identity, even without that individual's information [2].

Hand vein technology works by identifying the vein patterns (palm, dorsal hand and finger veins) in an individual's hand. When a user's hand is held over a scanner, a near-infrared light maps the location of the veins. The red blood cells present in the veins absorb the rays and show up on the map as black lines, whereas the remaining hand structure shows up as white. This vein pattern is then verified against a preregistered pattern to authenticate the individual [3].

Biometric authentication can be classified into unimodal and multimodal biometric systems. Unimodal systems that use single biometric trait for recognition purposes; and suffers a several practical problems like non-universality, noisy sensor data, intra-class variation, restricted degree of freedom, unacceptable error rate, failure-to-enroll and spoof attacks. So, the performance of single biometric system needs to be improved. The techniques of multimodal biometric system can offer a feasible method to solve the problems coming from unimodal biometric system. Multimodal biometric system makes use of different biometric traits simultaneously to authenticate a person's identity. Robustness and high security of authentication can be achieved by using the multimodal biometric systems [4].

The rest of the paper is organized as follows. We briefly explain our methodology of the fusion of palm hand and finger vein system in section 2.Section 3 presents the explanation of the process of biometric system. The discussion of results is introduced in section6.Finally; conclusions and future work are presented in section 4.

2. Proposed Methodology

In our study, we present a proposed intelligent paradigm to authenticate personal based on fusion of palm, dorsal hand and finger veins used alternately to authenticate user. The proposed multi-modal biometric system consists of several different submodules, each of them providing its own functionality. There are three sensor modules for palm finger and dorsal hand veins acquisition used alternately to capture the biometric data. In the feature extraction modules, the acquired data is processed to extract a set of features. In the matcher modules, the extracted features are compared against the stored templates, providing a matching score. These last modules encapsulate the decision making modules, which can operate either in verification or identification mode. Moreover, there is the system database module, which stores the biometric templates of the enrolled users.Figure1 shows the methodology of the authentication model using fusion of palm and dorsal hand veins biometrics as example of the methodologies used.

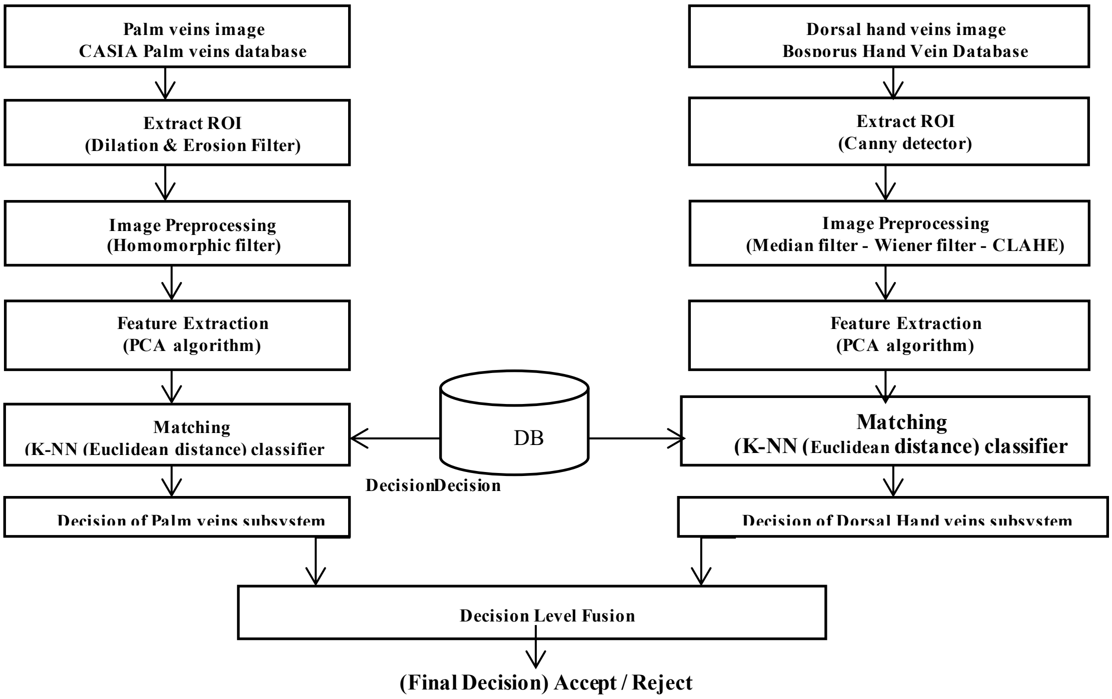


Figure 1The methodology of the authentication model using palm and hand veins biometrics

3. Process of Biometric System

In this section we describe the recognition process of palm, hand and finger veins characteristics. The process of biometric system involves: image acquisition, extract ROI, preprocessing, feature extraction, matching, decision of each trait and fusion decision.

3.1. Image Acquisition System

A) Palm Veins Database

The experiment reported in this paper for the palm vein authentication is CASIA Multi-Spectral Palm print Image Database V1.0 (CASIA database) [5]. This CASIA database has been acquired using a contactless imaging device and have images from 100 users. Six images were acquired from each user and these images were acquired in two different data acquisition sessions (three images in each session) with a minimum interval of one month. Since our work is focused on palm vein identification and the vascular details are typically observed in the NIR illumination, only the images that were acquired under 850 nm and 950 nm wavelength illuminations from CASIA database were utilized in the following experiments.

B) Dorsal Hand Veins Database

The experiments reported in this paper for the hand vein authentication the Bosphorus Hand Vein Database [6] is designed for research on biometry based dorsal vein patterns of the hand. The hand vein data is capture using NIR imaging innovation with a monochrome NIR CCD camera (WAT-902H2 ULTIMATE) equipped with an infrared lens. The back of the hand is illuminated by two IR light sources. The images have 300×240 pixel size with a gray-scale resolution of 8-bit. Every subject experienced four imaging sessions that comprised of the left hand under normal condition (N), after having carried a bag weighing 3 kg. for one minute (B), after having squeezed an elastic ball repetitively for one minute (A), after having cooled the hand by holding an ice pack on the surface of the back of the hand (I). We used the images taken under normal conditions (N: Normal). There are overall 600 images of 100 subjects distributed as: Three right-hand images and three left-hand images subject under normal conditions (N).

C) Finger Veins Database

In our study, we used the SDUMLA-HMT Database [7].This database involves a multimodal data (finger vein, face, finger print, iris and gait) from 106 persons. The first free public access database is SDUMLA-HMT. Every field includes his/her code as ring, middle and index finger of two hands. The collection of 6 fingers is duplicated 6 times to get 6 finger vein images. Therefore, finger vein database contains 3,816 images.

3.2.Extract ROI

A) ROI of Palm Veins

To detect ROI we used Morphological operations to extract useful structural information from palm veins images. Morphological operations are applied on binary images and affecting the form, structure or shape of an object. They are used in pre or post processing (filtering, thinning, and pruning) or used for smoothing, edge detection or extraction of other features. Morphological operations offers a variety of image transformation to eliminate dark (bright) regions from binary images .The two principal morphological operations are dilation and erosion [8].Dilation allows objects to expand, thus potentially filling in small holes and connecting disjoint objects. Erosion shrinks objects by etching away (eroding) their boundaries. These operations can be customized for an application by the proper selection of the structuring element, which determines exactly how the objects will be dilated or eroded [9]. The proposed algorithm of ROI extraction of hand vein image includes 5 tasks, as show in figure 2.

1. Convert image to binary
2. Estimates the area of the palm in binary image then apply a 201*201 square mask that could perfectly cover the whole region of palm.
3. After then apply the dilatation filter again to get one point that is the middle point of the hand.
4. Then apply the erosion filter on the same square mask, this time to get exact square placed at same point where the region of interest is placed in actual image
5. Then find xmin, ymin, length, and width of this square to crop ROI from original image.

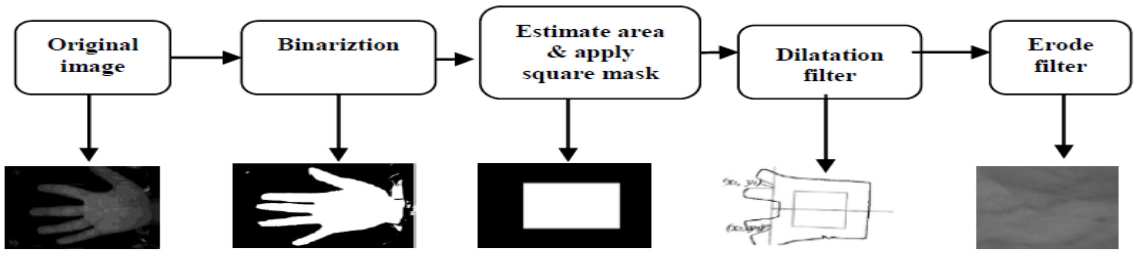


Figure2.The steps to detect ROI of palm veins

B) ROI of Dorsal Hand Veins

To detect ROI we used canny edge detector (CED) to extract useful structural information from hand veins images. The edge detection is an important process in many of the image processing algorithms. Significant property of the edge detection is the detection of the specific edges along with the great orientation of the object in the image [10]. The proposed algorithm of ROI extraction of hand vein image includes 5 tasks, as show in figure 3.

1. Convert image to binary.
2. Boundaries from the binary image are detected by canny operator.
3. Valleys of hand between index and middle fingers and between little and ring fingers are detected.
4. A geometrical technique is investigated to draw the line connecting the two keys points determined in the previous step and the line perpendicular to it.
5. A sub-image is detected and extracted as the ROI of hand vein image.

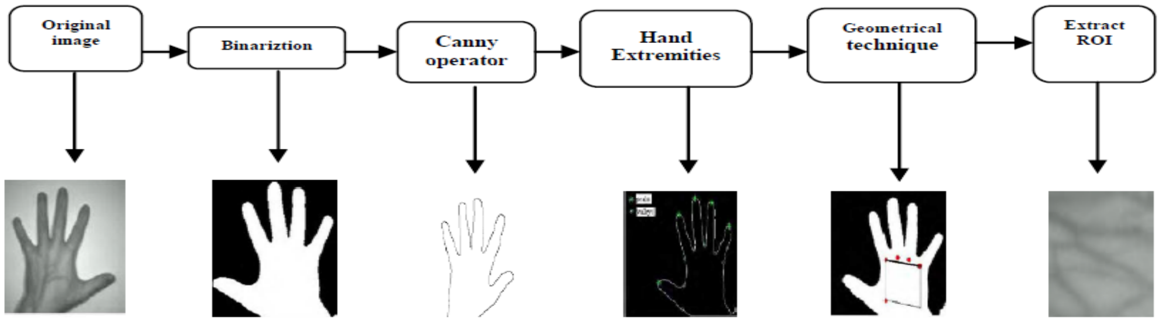


Fig. 3. The steps to detect ROI of dorsal hand veins

C) ROI of Finger Veins

In this section, we produce a proposed intelligent paradigm to authenticate personal based on finger veins. This paradigm is used to enhance the accuracy of finger vein authentication. Figure 4 shows the methodology of the authentication model using finger veins biometrics. The main characteristics of our model are;

1. Using the Shandong University Machine Learning and Applications - Homologous Multi-modal Traits (SDUMLA-HMT) Database image which has been capture under a NIR infrared radiation.
2. To detect ROI we used canny detector to extract useful structural information from finger veins images.
3. Using Median, Wiener and CLAHE filter to improve finger vein image.
4. Using PCA method for feature extraction.
5. Using K-NN classifier, matching was done between SDUMLA-HMTFV Database image and the extracted finger vein image.

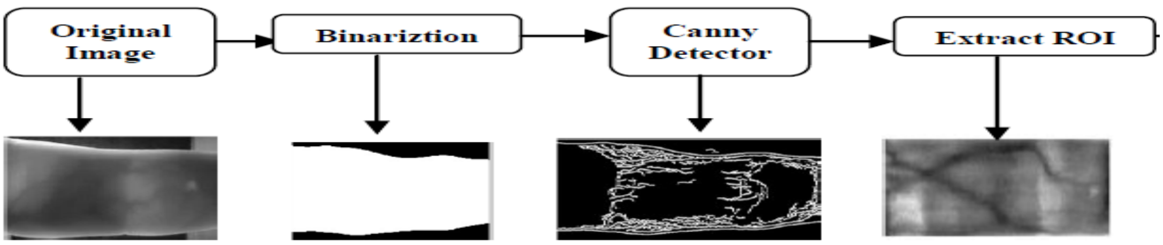


Figure 4. The steps to detect ROI of dorsal hand veins

3.3. Image preprocessing

A) Preprocessing of Dorsal Hand Veins

In this process, a number of preprocessing techniques are typically required for the purpose of reducing the effect of noise and enhancing the targeted hand veins. The proposed algorithm of preprocessing hand vein image includes the following steps done as show in figure 5.

1. The median filter 5*5 is applied to the original hand vein image for denoising.
2. 2D Wiener filter "Gaussian white noise" 3*3 is applied to remove the effect of high level frequency noise.
3. Applied Contrast Limited Adaptive Histogram Equalization (CLAHE) filter to enhance hand vein image.

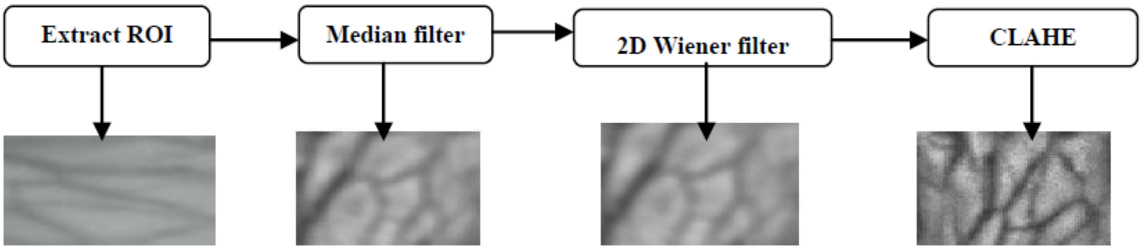


Figure 5. The steps of preprocessing of dorsal hand veins

B) Preprocessing of Palm Veins

Homomorphic filtering is a generalized technique for image enhancement and/or correction. It simultaneously normalizes the brightness across an image and increases contrast. Homomorphic filter is a nonlinear enhancement method. Homomorphic filter simultaneously normalizes the brightness across an image and increases contrast. The function of homomorphic filter is likely to decrease the low frequency and increase the high frequency. In general, an image can be regarded as a two-dimensional function of the form I(x, y), whose value at spatial coordinates (x, y) is a positive scalar quantity whose physical meaning is determined by the source of the image. The Homomorphic filtering can be summarized in steps show following:

1. An image I (x, y) can be expressed as the product of illumination and reflectance components:

$$I(x, y) = L(x, y)\, R(x, y) \qquad (1)$$

whereL(x, y) and R(x, y) stand for the illumination and reflectance components

2. Because the Fourier transform of the product of two functions is not separable, we define

$$Z(x, y) = \ln I(x, y) = \ln L(x, y) + \ln R(x, y) \qquad (2)$$

where F{.} is the operator for the 2D discrete Fourier transform

3. Doing the Fourier transform, as

$$S(u, v) = H(u, v)\, Z(u, v)$$
$$= H(u, v)\, I(u, v) + H(u, v)\, R(u, v) \qquad (3)$$

where H is a high-pass filter given by:

$$H(u, v) = \frac{1}{1+\left[\!\left[\frac{D_0}{D(u,v)}\right]\!\right]^{2n}} \qquad (4)$$

where D_0 is the cutoff amplitude in wavelet domain, n is the order of filter and D(u, v) is the amplitude at location (u, v):

$$D(u, v) = \sqrt{\left(u+\frac{M}{2}\right)^2+\left(v+\frac{N}{2}\right)^2} \qquad (5)$$

where M * N is the size of image.

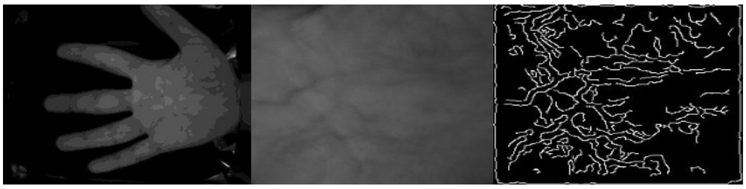
4. Taking inverse Fourier transform of S (u, v) brings the result back into natural log domain

$$S(x,y) = F^{-1}\{S(u,v)\}$$
$$\{H(u,v)\, I(u,v)\} + F^{-1}\{H(u,v)\, R(u,v)\} \qquad (6)$$

5. So the output image can be expressed by the function [11]

$$g(x,y) = \text{antilog}[S(x,y)] = e^{s}(s(x,y)) \quad (7)$$

Figure 6 show the result of applied algorithm (a) the original image (b) the result of extract region of interest (ROI) then (c) the result of applied preprocessing step to enhance the image quality.



(a) (b) (c)

Figure6. show of image enhancement: (a) The original image (b) Extraction of ROI (c) Extraction of Palm vein pattern

C) Preprocessing of Palm Veins

In this process, a number of preprocessing techniques are typically required for the purpose of reducing the effect of noise and enhancing the targeted finger veins. The proposed algorithm of preprocessing finger vein image includes the following steps done as show in figure 7.

1. Apply the median filter to reduce the black noise between vein pattern lines
2. Apply the wiener filter to remove effect of high frequency noises.
3. Apply the CLAHE filter to enhance contrast of vein image.

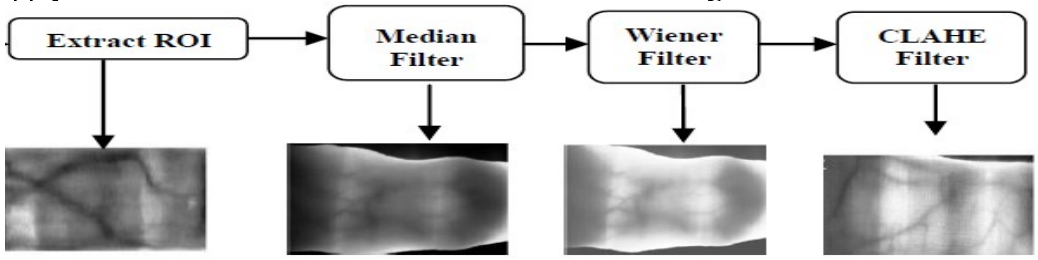


Figure 7. The steps of preprocessing of finger veins

3.4. Feature Extraction

Feature extraction plays an important role in palm vein recognition because the performance of feature matching is greatly influenced by its output. We use principal component analysis (PCA) algorithm to extract features from image [12].This algorithm using for extracting features from palm vein images. PCA is applied to generate vector of features that represent the highest detailed variant information. A matching process is then applied to find the best match from the data base to recognize and authenticate the person. It is one of the most widely implemented tools for dimensionality reduction or data exploration used in a variety of scientific and engineering disciplines. It transforms a number of possibly correlated variables into a smaller number of new variables, known as principal components. Since a digital image can be regarded as a two – or more – dimensional function of pixel values and represented as a 2D or 3D data array, PCA can be performed on such an m x n matrix [13].

The algorithm:

1. Assume data matrix is B of size m x n. Compute mean μ_i for each dimension.
2. Subtract the mean from each column to get A
3. Compute covariance matrix C of size n x n which $C = A^T A$

4. Calculate the eigenvalues and eigenvectors (E, V) of the ^{T}covariance matrix C
5. Project the data step by step onto the principle components $v_1^{\rightarrow}$, $v_2^{\rightarrow}$…etc.
6. Select n eigenvectors that correspond to the largest n eigenvalues to be the new basis.

4. Matching

In our technique, we use the K-NN classifier. The nearest neighbor classifier works depended on a simple nonparametric decision. Every query image Iq is inspected depended on the distance of its features from the features of other images in the database. The nearest neighbor is the image which has the minimum distance from the query image in the feature space. The distance between two features can be compute depended on one of the distance functions such as, city block distance d1, and Euclidean distance d2 or cosine distance dcos [14].

$$d_1(x,y) = \sum_{i=1}^{N} |x_i - y_i| \quad (8)$$

$$d_2(x,y) = \sqrt{\sum_{\vec{v_1},\vec{v_2} i=1}^{N} |(x_i - y_i)^2|} \quad (9)$$

$$d_{cos}(x,y) = 1 - \frac{\vec{x}.\vec{y}}{|x|.|y|} \quad (10)$$

K nearest neighbor algorithm utilizes K nearest samples to the query image. Every one of these samples belongs to a known class Ci. The query image Iq is arranged to the class CM which has the most of events among the K samples. The presentation of the KNN classifiers highly related to value of the k, the number of the samples and their topological distribution over the feature space.

5. Fusion decision

The fusion methodology adopted at the decision level is a post-classification method, and it follows the AND rule; i.e., it is sufficient that all biometric traits are recognized as genuine to lead to a positive final decision. This serial matching approach gives the possibility of acquiring all the traits to determine if a user is genuine or an impostor. From a numeric value (generally normalized between 0 and 1) that represents the confidence of the matching, each decision module is given two possible different outputs {YES, NO}, depending on the comparison of that value with some predefined thresholds that divide the interval [0,1] .A decision module outputs the YES value if the obtained score is the interval [1, 1] and the user is recognized as one of the enrolled users (in identification mode) or their claimed identity has been confirmed (in verification mode). The output value NO is produced if the obtained score is one of intervals [0, 1] or [1, 0] or [0, 0] and the user is rejected as if they were impostors.

6. Results and discussion

In this section we describe the result of each system independently and the result of fusion of two traits. Palm and dorsal hand vein recognition includes training and recognition phases. In training phase, features of the training samples are calculated and stored in a database template. In the recognition phase, features of the input vein are determined and then matched by using K-NN matching classifier. After this, these features are compared with the stored template to obtain the recognition result. We do our experiment by divided the database to 5 Cases as table 1 shows:

Table 1. Data base for 5 cases

Case No.	Training	Testing
1	One image for every person (100 images)	Five images for every person (500 images)
2	Two images for every person (200 images)	Four images for every person (400 images)
3	Three images for every person (300 images)	Three images for every person (300 images)
4	Four images for every person (400 images)	Two images for every person (200 images)
5	Five images for every person (500 images)	One image for every person (100 images)

By applying the PCA algorithm with K-NN (Euclidean distance) the accomplished result for dorsal hand veins was CRR is 91.2 %, finger veins is 94.6%, palm veins is 95.20%, fusion of finger and dorsal hand veins is 96.8%., fusion of palm and dorsal hand veins is 97.6%, fusion of palm and finger veins is 97.9%.Testing result of every case showed in table 2 and figure 8. We have two potential results, the first result is where the user that is unauthorized which means that his/her template is not found in the database, and the other result is the user is authorized, i.e. a template similar to his/her is found in the database. Based on this experiment, it was suggested that recognition based on authentication by fusing the palm and dorsal hand veins, performs better than conventional recognition technique. Hence this method can be successfully used for recognition.

Table 2. The testing results for each case

Case No.	CRR					
	Palm	Dorsal hand	Finger	Palm +Dorsal Hand	Palm +Finger	Finger +Dorsal Hand
1	94	89	93	96.5	96.8	95
2	94	90	94	96.6	97.25	96.3
3	95	92	95	97.8	97.8	97.2
4	96	92	95	98.3	98. 66	97.2
5	97	93	96	99	98. 8	98.5

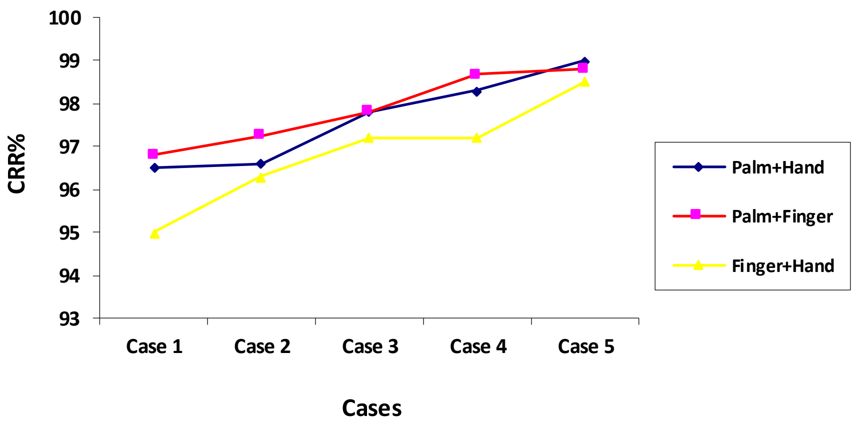


Figure 8. Result of cases

7. Conclusion and Future Work

In this paper, we have developed a new practical and intelligent technique for biometric recognition based on fusion of palm, dorsal hand and finger veins used alternately to authenticate user. The technique consists of the following steps: Image acquisition, determining the region of interest and pre-processing, extracting the finger vein pattern features and recognition. We proposed an original method based on the principal component analysis (PCA) algorithm to extract features and using K-NN (Euclidean distance) matching classifier in matching. In this paper, a complete biometric system based fusion of palm, dorsal hand and finger veins has been developed. The experimental results show that fusion of finger and dorsal hand veins is 96.8%., fusion of palm and dorsal hand veins is 97.6%, fusion of palm and finger veins is 97.9%.Hence the fusion of palm and finger method can be successfully used for recognition better than other fusion.

In our opinion, this developed improvement increases the usefulness and usability of this efficient technique, especially as regards its application in all security tasks and domains. Future work may involve applying additional/ alternative pattern recognition algorithms or turning it into a multimodal system where other additional biometrics traits are considered and making the system more invariant to illumination conditions.

References

[1] KulkarniSumit ,PanditManali:Biometric Recognition System based on Dorsal Hand Veins. International Journal of Innovative Research in Science, Engineering and Technology(IJIRSET), Vol. 5, Issue 9, September (2016),pp. 18899-18905.
[2] MenariaLaxmi, Jain Kalpana: A Survey on Biometric Template Protection. International Journal of Scientific Research in Computer Science, Engineering and Information Technology (IJSRCSEIT),Vol. 2 ,Issue 2,(2017)pp.995-999.
[3] B.Shruthi.M, MohnaniPooja, Mallinath, R.Ashwin.G:Multimodal Biometric Authentication Combining Finger Vein and Finger Print. International Journal of Engineering Research and Development, Vol.7, No.10, July (2013), PP.43-54.
[4] Bharathi .S and Sudhakar.R:Biometric recognition using dorsal and palm vein images. International Journal of Advanced Engineering Technology, Vol. 7, No.2, June, (2016), pp.415-419.
[5] http://www. cbsr.ia.ac.cn/MS_Palmprintlast accessed on 2018
[6] http://bosphorus.ee.boun.edu.tr/hand/Home.aspx last accessed on 2018
[7] http://www.mla.sdu.edu.cn/sdumla-hmt
[8] Jankowski Mariusz:Erosion, dilation and related operators. 8th International Mathematica Symposium, Avignon, June (2006), pp. 1-10.
[9] Van. M. Droogenbroeck and Buckley. M: Morphological erosions and openings: Fast algorithms based on anchors. Journal of Mathematical Imaging and Vision,(2005), pp1-35.
[10] L. Amruta.Kabade ,G. V. Sangam:Canny edge detection algorithm. International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE) Volume 5, Issue 5, May (2016), pp.1292-1295.
[11] Liu Wenli, He Peng, Li Hui, Yu Hongbo:Improvement on the Algorithm of Homomorphic Filtering. International Conference on Electrical and Computer Engineering Advances in Biomedical Engineering, vol.11, (2012), pp120-124.
[12] HalkoNathan, MartinssonPer-Gunnar, ShkolniskyYoel and TygertMark:An algorithm for the principal component analysis of large data sets.Siam journal on scientific computing, vol. 33, No. 5, October (2011), pp.1-12.
[13] HladnikAleš, "Image Compression and Face Recognition: Two Image Processing Applications of Principal Component Analysis", International Circular of Graphic Education and Research, No. 6, (2013).
[14] N.MuhammadMansor,YaacobSazali, MuthusamyHariharan, NishaShafriza, Hi-fi S. J.,MohdL. Mohd,MuhammadN. Rejab,KuMohdY. Ku Ibrahim,H.AddzrullSyam, Ahmad Jamaluddin ,KadriJunohAhmad:" PCA- Based Feature Extraction and k-NN algorithm for Early Jaundice Detection", International Journal of Soft Computing And Software Engineering (JSCSE),Vol.1,No.1,(2011),pp25-29.