

Principal Component Analysis of Thermal Dorsal Hand Vein Pattern Architecture

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Abstract: The quest of providing more secure identification system has lead to rise in developing biometric systems. Biometrics such as face, fingerprint and iris have been developed extensively for human identification purpose and also to provide authentic input to many security systems in the past few decades. Dorsal hand vein pattern is an emerging biometric which is unique to every individual. In this study principal component analysis is used to obtain Eigen vein patterns which are low dimensional representation of vein pattern features. The extraction of the vein patterns was obtained by morphological techniques. Noise reduction filters are used to enhance the vein patterns. Principle component analysis is able to reduce the 2-dimensional image database into 1-dimensional Eigen vectors and able to identify all the dorsal hand pattern images.

Keywords: Dorsal hand vein patterns, enhancement, morphological techniques, noise reduction, principal component analysis

INTRODUCTION

Personal identification systems are gaining lot of demand due to increased threats and attacks from the terrorists. These can be prevented by tightening the security at important places. The traditional methods make use of smart cards or personal identification numbers etc to identify a person. However these methods have limited security and are unreliable. Over the past years various biometric systems have been developed to overcome these disadvantages (Jain *et al.*, 2004). Biometrics is the science of identifying a person using its physiological or behavioral features. These features range from physical traits like fingerprints, faces, iris etc to represent the signature or personal behavior of a human being. Compared to traditional methods biometric features are much harder for intruders to copy or forge and it has one more advantage that it is very rare for them to be lost. Hence for identification systems making use of biometric features offer a much more secure and reliable performance. Each of these biometric features has its strengths and weaknesses. Anatomically aside from surgical intervention the shape of the vascular patterns in the back of the hand is distinct from each other and it remains stable over a long period (Chih-Lung and Kuo-Chin, 2004). In addition as the blood vessels are hidden underneath the skin and are invisible to the human eye, vein patterns are much harder for intruders to copy as compared to other biometric features (Tanaka and Kubo, 2004). All these special properties of hand vein patterns make it a potentially good biometric to offer more secure and reliable features for personal verification (Badawi,

2006). Biometrics is a science for uniquely recognizing humans based upon one or more intrinsic physical or behavioral traits. Biometrics is used as a form of identity access management, access control and identifying individuals in groups under surveillance. Biometrics can be divided in two main classes that are physical and behavioral. Physical are related to the shape of the body like fingerprint, face recognition, DNA, palm print, hand geometry and iris of the eye. Behavioral are related to behavior of a person like voice, gait etc. The biometrics should have the certain characteristics like each person should have the said characteristic, it should distinguish individual from another, should be resistive to ageing, easy to acquire, should be accurate, robust and should have acceptability. A biometric which possesses more number of characteristics is treated as a good bio-metric (Ratha *et al.*, 2001; Sonka *et al.*, 1998).

A biometric system can operate in two modes, one is Verification and Identification. Verification is the one to one comparison of a captured biometric with a stored template to verify that the individual is who he claims to be. Can be done in conjunction with a smart card, user ID number etc. Identification is a one to many comparison of the captured biometric against a biometric data base in attempt to identify an unknown individual. The identification only succeeds in identifying the individual if the comparison of the biometric sample to a template in the data base falls within a previously set threshold. Before the Verification or Identification an individual should enroll his information in the system to store it as template for subsequent uses. During the identification process, the Query image is matched with the set of



Fig. 1: Thermal dorsal hand vein image

templates available as data base with the help of some image processing algorithm. During this signature recognition, lot of comparisons need to be with every template in the database. Principal Component Analysis (PCA) is a way of identifying patterns in data and expressing the data in such a way to highlight their similarities and differences. The purpose of PCA is to reduce the large dimensionality of the data space to smaller intrinsic dimensionality of feature space, which are needed to describe the data economically (Dagher *et al.*, 2007). In this study principal component analysis performed for the database, their Eigen vein patterns are extracted and weights are obtained for the training set. These weights are compared with the weights of the query image to be tested.

MATERIALS AND METHODS

Veins are hidden underneath the skin and are invisible to the naked eye and other visual inspection systems. However human superficial veins have higher temperature than the surrounding tissue. Based on this fact, the vein pattern in the back of the hand can be captured using a thermal camera. In this study NEC Thermal tracer is utilized to acquire thermal images of the back of the hand. The images collected from different people in a normal office environment between 20-25°C. This study was conducted at Research and consultancy center of VNR Vignana jyothi institute of Engg and Tech., during February 2011. One image of hand vein dorsal is shown in Fig. 1.

Methodology: The steps involved in the proposed study are given in Fig. 2. The input hand Vein pattern thermal images are cropped to extract the region of interest. The cropped images are grouped as training set and normalization is carried out (Im *et al.*, 2000; Shi *et al.*, 2007). On the training set principle component analysis is performed to correct the intensity inequalities due to variations in the ambient conditions. Eigen vein patterns are extracted from the training set and weights are obtained as feature vector. For the Query image to be verified from the database is filtered first and

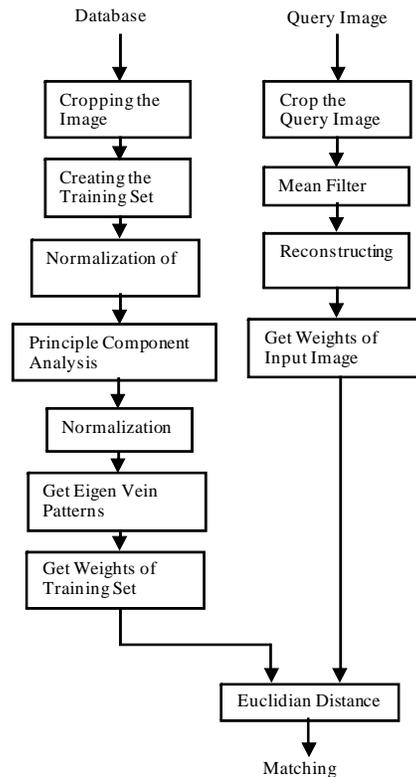


Fig. 2: Steps involved in the work

reconstructed from the weights of the training set. Weights of the Query image obtained and matching is performed by using Euclidian distance.

Preprocessing: In preprocessing the hand vein pattern images are cropped to the required region of interest training set. Weights of the Query image obtained and matching is performed by using Euclidean distance. where, vein look prominent. The portions of fingers are removed and to adjust the intensities uniformly normalization has been carried out. The collected data base is converted into training set.

Principal Component Analysis (PCA): Principal Component Analysis (PCA) is applied on the vein patterns to obtain 'Eigen vein' features. These features are projected onto a vein space. The steps involved in PCA are described in Fig. 2.

Mathematical steps for PCA:

- The first step is to obtain a set S with M vein pattern images. In our example $M = 4$ as shown at the beginning.

- Each image is transformed into a vector of size N and placed into the set given in Eq. (1).

$$S = \zeta_1, \zeta_2, \zeta_3 \dots \zeta_M \dots \quad (1)$$

After set is obtained, the mean image Ψ is obtained.

- Then the difference Φ between the input image and the mean image is computed as given in Eq. (2).

$$\Phi_i = \zeta_i \Psi \quad (2)$$

- Next a set of M ortho normal vectors, u_n , are obtained, which best describes the distribution of the data. The k^{th} vector, u_k , is chosen such that the Eigen value λ_k shown in Eq. (3) is a maximum:

$$\lambda_k = \frac{1}{M} \sum_{n=1}^M (u_k^T \Phi_n)^2 \quad (3)$$

Subject to Eq. (4):

$$u_l^T u_k = \delta_{lk} = \begin{cases} 1 & \text{if } l = k \\ 0 & \text{otherwise} \end{cases} \quad (4)$$

where, u_k and λ_k are the eigenvectors and Eigen values of the covariance matrix C.

- The covariance matrix C obtained using the Eq. (5):

$$C = \frac{1}{M} \sum_{n=1}^M \Phi_n \Phi_n^T = AA^T \quad (5)$$

where, $A = [\Phi_1, \Phi_2, \Phi_3, \dots, \Phi_n]$

- The eigenvectors, v_i, u_i are found
- Eigen vector matrix of the training set is calculated using Eq. (6):

$$L_{mn} = \Phi_m^T \Phi_n \quad (6)$$

Recognition procedure:

- A new vein pattern is transformed into its Eigen vein components. First we compare our input image with our mean image and multiply their difference with each eigenvector of the L matrix. Each value would represent a weight given in Eq. (7) and would be saved on a vector Ω , given in Eq. (8):

$$\omega_k = u_k^T (\zeta - \Psi) \quad (7)$$

$$\Omega^T = [\omega_1, \omega_2, \omega_3, \dots, \omega_M] \quad (8)$$

- We now determine which vein pattern class provides the best description for the input image. This is done by minimizing the Euclidean distance using Eq. (9):

$$\epsilon_k = \|\Omega - \Omega_k\|^2 \quad (9)$$

- The input vein pattern is considered to belong to a class if ϵ_k is bellowing an established threshold θ_ϵ . Then the vein pattern image is considered to be a known vein pattern. If the difference is above the given threshold, but bellow a second threshold, the image can be determined as a unknown vein pattern. If the input image is above these two thresholds, the image is determined NOT to be a vein pattern.
- If the image is found to be an unknown vein pattern we could decide whether or not we want to add the image to our training set for future recognitions. We would have to repeat steps 1 trough 7 to incorporate this new vein pattern image.

RESULTS AND DISCUSSION

The hand pattern images are cropped and normalized to form the training set. It is shown in Fig. 3. The Eigen pattern images are shown in Fig. 4. The reconstructed images for each Query image are shown in Fig. 5, 6, 7 and 8. The plots of weights of each Query is shown in Fig. 9, 10, 11, 12, 13, 14, 15 and 16. False acceptance rate and false rejection rate are two parameters considered as evaluation parameters.

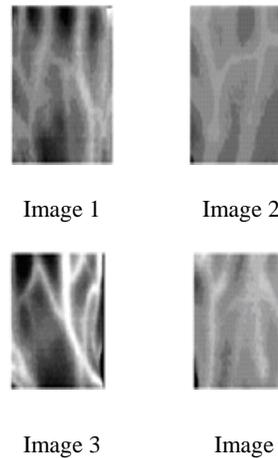


Fig. 3: Training set

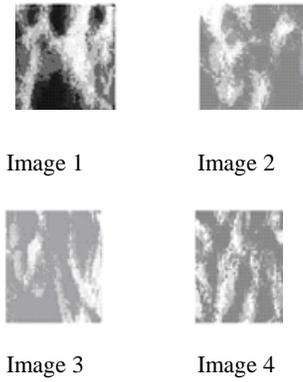


Fig. 4: Eigen vein pattern images

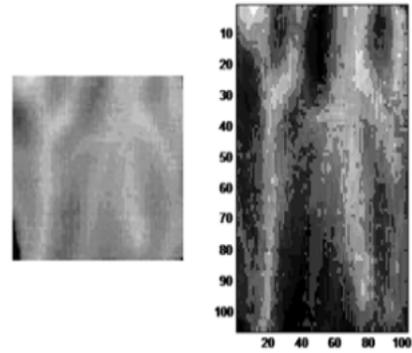


Fig. 8: Input image 4 and its reconstructed image

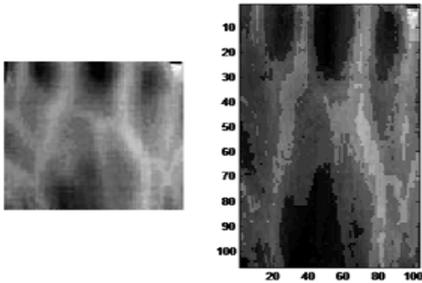


Fig. 5: Input image 1 and its reconstructed image

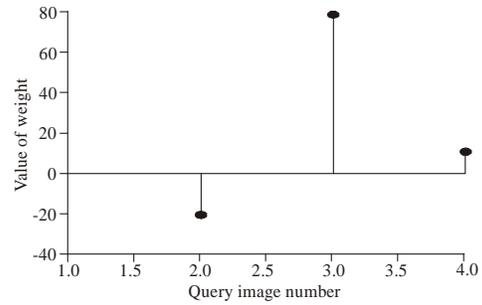


Fig. 9: Input image versus weight of input face

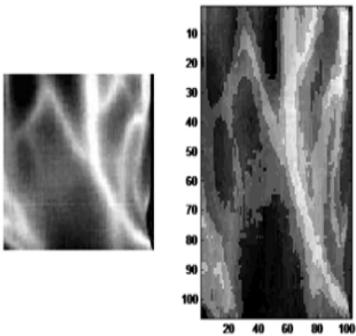


Fig. 6: Input image 2 and its reconstructed image

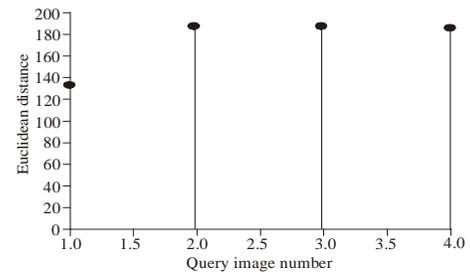


Fig. 10: Input image versus euclidean distance between weight of input image and weights of training set

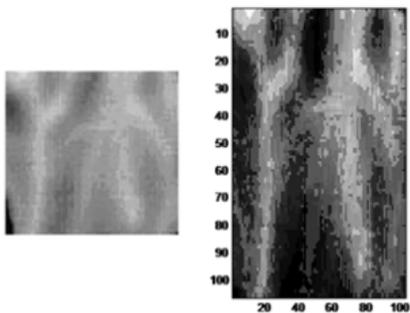


Fig. 7: Input image 3 and its reconstructed image

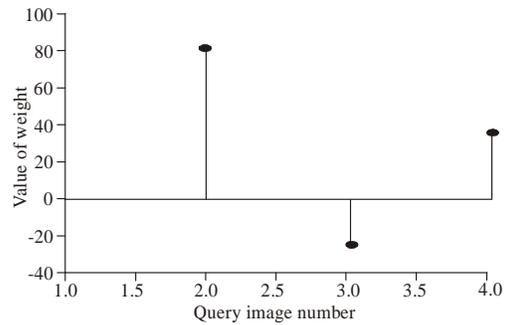


Fig. 11: Input image versus weight of input face

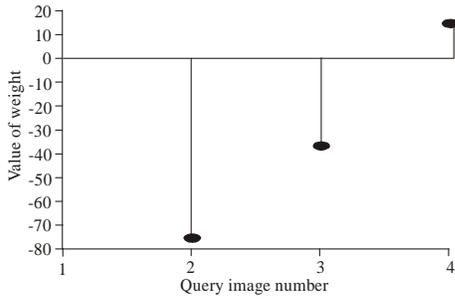


Fig. 12: Input image versus euclidean distance between weight of input image and weights of training set

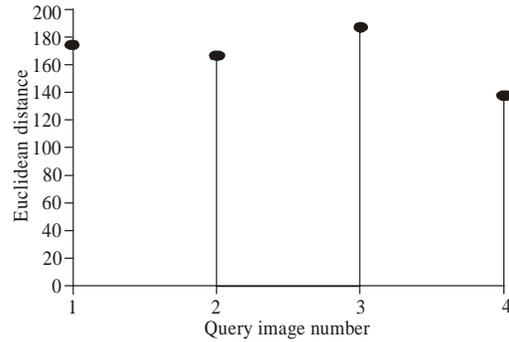


Fig. 15: Input image versus weight of input phase

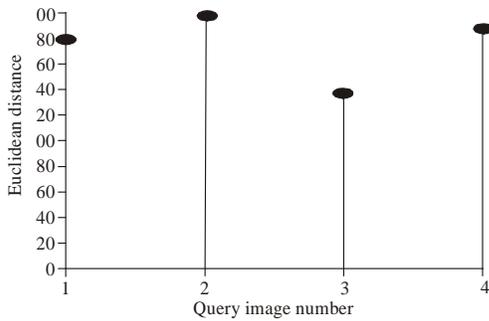


Fig. 13: Input image versus weight of input phase

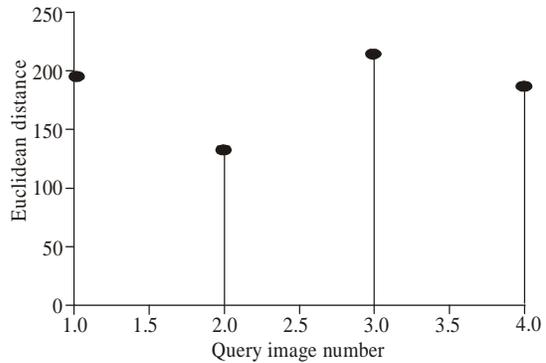


Fig. 16: Input image versus euclidean distance between weight of input image and weights of training set

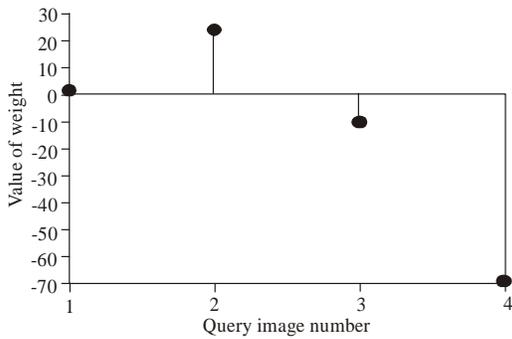


Fig. 14: Input image versus euclidean distance between weight of input image and weights of training set

Table 1: Euclidean distances of images and training set

S. No.	Image in database	Image not in database	Euclidean maximum distance	Euclidean minimum distance
1	1	-	182.3091	138.4036
2	-	1	171.4209	154.7666
3	2	-	205.0328	135.0768
4	-	2	206.6520	163.5061
5	3	-	190.8079	134.0292
6	-	3	191.9126	164.9585
7	4	-	171.8887	126.2710
8	-	4	166.2598	148.4661

Table 2: False acceptance rate and false rejection rate

Acceptance rate	100%
False acceptance rate	0%
False rejection rate	0%

False rejection rate: False rejection rate refers to the total number of authorized persons not getting access to the system over the total number of people attempting to get the system.

False acceptance rate: False acceptance rate refers to the total number of unauthorized persons getting access to the system over the total number of people attempting to the system.

Table 1 gives the Euclidean distances of images and training set and Table 2 gives the false acceptance rate and false rejection rates.

CONCLUSION

Cropping the images has highlighted the vein patterns. The normalization of the training set has corrected the undesirable differences in the intensity levels. The normalization of Eigen vectors has minimized the differences in magnitudes of Eigen vectors. Principle component analysis is able to reduce the 2-dimensional image database into 1-dimensional Eigen vector because

of the principle component analysis allows the database represented in terms of the differences and similarities between them. And also the proposed method is able to identify all the images with 100% acceptance rate.

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