Person Identification Based on Palm and Hand Geometry

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(Thesis submitted in partial fulfillment of requirements for BS Degree in Computer and Information Sciences)

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بسم الله الرحمن الرحيم

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Supervisor's Name: **Fayyaz A. Afsar**

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Dedication

Dedicated to my God, Beloved Family and Teachers

Acknowledgement

During my four-year study at PIEAS, I received an incredible amount of support and encouragement, both technical and moral, from Faculty and Colleagues.

First and foremost praises and thanks to ALLMIGHTY ALLAH who bestowed upon us all blessings, intelligence and faculty of searching and learning.

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Abstract

The development of accurate and reliable security systems is a matter of wide interest and in this scientific society, biometrics are regarded as an extremely effective automatic mechanism for person identification and verification. Among biometric technologies, hand information based identification and verification systems are regarded as a simple, low cost and accurate approach, being able to support real-time person identification.

In this thesis, a new multimodal biometric system using feature level fusion of hand features (i.e. hand shape, hand geometry and palm print texture features) is described. Both the palmprint and hand-shape features are proposed to be extracted from a single hand image acquired using a simple flatbed scanner. These features are then examined for their individual and combined performances. Two databases of hand images (DB1 of 500 images and DB2 of 1100 images) are used to validate the performance of the proposed system. Features are extracted by applying the techniques such as Principle Component Analysis, Hand geometry feature extraction using image processing, and wavelet transform and then these features are integrated to obtain a fusion matrix. PCA is used to extract the hand shape global features. To extract the hand geometry features, a technique of hand geometry feature extraction using image processing is applied. Using this technique sixteen features (i.e. four finger length, eight finger width, palm length, palm width, palm area and hand length) of hand geometry are extracted. Texture features are extracted by applying wavelet transform on palm prints (ROI).

Following two types of features are extracted as texture features of the palmprints.

(i) The percentage of energy corresponding to the approximation, horizontal, vertical, and diagonal details.

(ii) Energy of autocorrelation functions of the wavelet coefficients.

The similarity of two feature vector is measured by using Euclidean distance as similarity measure. Accuracy of the proposed system using DB1 (PIEAS Hand Database 1) and DB2 (PIEAS Hand Database 2) are 96.4% and 94% respectively.

Chapter 1- Introduction

In recent years, biometric technology is one of the newest research topics in the Information Technology field. It finds its applications for accurate person identification or verification in security systems such as electronic fund transfer, online shopping, e-commence, e-banking, access control, immigration, attendance control, and law enforcement etc. Although conventional tackles including password, physical key and smart card in security systems are widely applied but high level security standard and requirements in our sophisticated society still cannot be satisfied because these tools are subject to easy loss, duplication and low accuracy. In current Internet-based applications, the password is the most common tool to identify a person however its reliability is very limited.

Traditionally, two major approaches for person identification have been in use [1]:

(i) Token Based- approaches establish the identity of a person on the basis of possession of a token, such as an ID card or a driver's license.

(ii) Knowledge based- approaches rely on the possession of certain information e.g. a password by the subject in making an identification decision.

Advantages of these approaches are simplicity, ease if use, and low system integration cost. The important draw backs of these approaches are as follows:

(i) Possessions (e.g. ID card) can be lost, stolen or easily duplicated.

(ii) Knowledge (e.g. password) can be forgotten.

(iii) Both possessions and knowledge can be shared or stolen.

Using physiological or behavioral characteristics, or biometric, provides a solution to the conventional problems and presents more secure and more reliable authentication systems.

The human hands are used to grasp, throw, and make tools but today it has another use, a media to verify identity. The physical dimensions of a human hand contain information that is capable of authenticating the identity of an individual. This information has been popularly known as palm contents or hand geometry.

1.1 Biometrics

Biometrics is the science and technology of measuring and analyzing biological data. In information technology, biometrics refers to technologies that measure and analyze human body characteristics, such as fingerprints, eye retinas and irises, voice patterns, facial patterns and hand measurements, for authentication purposes.

Currently, almost all systems involve an identity authentication process before a user can access the requested services; such as, online transactions, entrance to a secured vault, logging into a computer system, accessing laptops, secure access to buildings, etc. Therefore, authentication has become the core of any secure system. Biometric technologies increasingly are being used by government agencies and private industry to verify a person's identity, secure the nation's borders (as possible), and to restrict access to secure sites including buildings and computer networks. Biometric systems provide the solution to ensure that the rendered services are accessed only by a legitimate user and no one else. Biometric Systems identify users based on behavioral or physiological characteristics.

Enterprise-wide network security infrastructures, secure electronic banking, investing and other financial transactions, retail sales, law enforcement, and health and social services are already benefiting from these technologies. A range of new applications can be found in such miscellaneous environments as hilarity parks, banks, and other financial organizations, business enterprises and administration networks, passport programs and driver licenses, universities and physical access to multiple facilities (night clubs).

1.1.1 Evaluation of Biometrics and Biometric System

Any human physiological and/or behavioral characteristic can be used as a biometric identifier for person identification as long as it satisfies the following requirements:

a. **Universality**

   Universality points out the ratio of people possessing a particular biometric so each person should have the Biometrics.

b. **Distinctiveness**

   Which means that any two person should be "sufficiently different" in terms of their biometric identifiers.

c. **Permanence**

Permanence implies the stability of a biometric. Which means that the characteristics should be invariant with time.

d. Collectability

Which means that the characteristics should be measured quantitatively. If the data collection process is too complex or requires high cost input devices, the collectability of that biometric is low.

Other issues to be considered in a practical biometric system include:

a. Performance

It refers to the achievable recognition accuracy and speed, the resources required, as well as the operational and environmental conditions that may affect the accuracy and speed. It is measured by two rates:

(i) False Acceptance Rate (FAR)

(ii) False Rejection Rate (FRR)

Reducing FAR (FRR) means increasing FRR (FAR). Equal Error Rate (EER) or crossover rate also implies precision. A system with 1% EER or crossover rate means that this system has 1% FRR and 1% FAR [14].

b. Acceptability

To what extend people are willing to accept and use the biometric system as part of their daily lives.

c. Degree of intrusiveness

How much co-operation is required from the user to collect the biometric sample.

d. Circumvention

Which means how easy it is to fool the system by fraudulent techniques i.e. degree of vulnerability to fraud.

e. Long-term system support

DB management, re-enrollment, template updating, etc

A practical biometric system should have acceptable recognition accuracy and speed with reasonable resource requirements, user friendly, accepted by the intended population, reliable and sufficiently robust to various fraudulent methods.

1.1.2 Biometric Technologies

A large number of biometric features are available for use in person identification and verification and it can be broadly categorized as:

a. Physiological Biometrics

A physiological biometric are congenital and are physically associated with a subject e.g. face hand, fingerprints etc.

b. Behavioral Biometrics

A behavioral biometric is a unique feature of a person's behavior on the basis of which he can be identified e.g. signatures, voice prints etc.

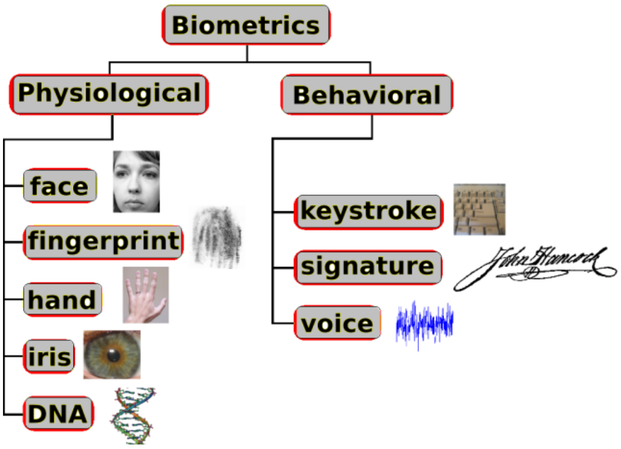


Figure 1-1 Different Biometrics

A brief introduction to the most common biometrics is provided below.

i. **DNA:** Deoxyribo Nucleic Acid (DNA) is recognized as an ultimate unique code for one's individuality, except for the fact that identical twins have identical DNA patterns. It is, however, the most reliable biometrics. DNA based person recognition requires extensive testing and advanced technology, due to this fact it is not the most cost efficient Biometric, but it is regarded as the most reliable biometric technology.

ii. **Ear Recognition:** The shape of the ear and the structure of the cartilaginous tissue of the pinna are considered to be distinctive to each individual. The ear recognition approaches are based on matching the distance of salient points on the pinna from a landmark location on the ear.

iii. **Face Recognition:** Face recognition systems identify an individual by analyzing the unique shape, pattern and positioning of facial features. The face is one of the most acceptable biometrics because it is one of the most common methods of recognition. The method of acquiring face images is not very complex but it is very challenging to develop face recognition techniques because of the effects of aging, facial expressions, slight variations in the imaging environment, and variations in the pose of the face with respect to the camera. The attraction of this biometric system is that it is able to operate 'hands-free', limiting the amount of man-machine interaction. However, this biometric system is highly unreliable and expensive. For example, it may be not able distinguish twins or triplets, not recognize the client after a haircut, and not recognize a individual who changes from wearing and not wearing glasses.

iv. **Facial, hand, and hand vein infrared thermograms:** The pattern of heat radiated by the human body is a feature of each individual body and can be captured by an infrared camera in an unremarkable way much like a regular photograph. The technology could be used for hidden recognition and could distinguish between identical twins. A thermogram-based system is non-contact and not disturbing but sensing challenges in uncontrolled environments, such as, room heaters and vehicle exhaust pipes, may drastically affect the image acquisition phase. A related technology using near infrared imaging is used to scan the hand or hand vein structure. Infrared sensors are expensive which inhibit the widespread use of thermograms.

v. **Gait:** Gait is the peculiar way one walks and is a complex biometric. Gait is not supposed to be very distinctive, but is sufficiently characteristic to allow verification in some low-security applications. Gait is a behavioral biometric and may not stay invariant, especially over a large period of time, due to large fluctuations of body weight, major shift in the body weight, major injuries involving joints or brain, or due to inebriety. Acquisition of gait is similar to acquiring facial pictures and hence it may be an acceptable biometric technology.

vi. **Palmprint and Hand Geometry:** Hand recognition technology is currently one of the most deployed biometrics disciplines world wide. Some features related to a human hand are somewhat invariant and peculiar to an individual. Hand geometry is based on the fact that almost every person’s hand shape is different and it does not (after a certain age) significantly change. Hand shape contains two types of information i.e. geometrical features and internal contents of hand. The image acquisition system requires cooperation of the subject and captures images of the palm flatly placed on a panel with outstretched fingers. Due to its limited distinctiveness, hand geometry-based systems are typically used for verification and do not scale well for identification applications.

vii. **Fingerprint Identification:** Fingerprint identification is the most commonly recognized and most widely applied form of Biometric technology. Fingerprint identification is based upon the fact that a person's fingerprint is completely unique to the individual. A fingerprint is made of a series of ridges and creases on the surface of the finger. Current fingerprint systems utilize minutiae and singular points as the features. Fingerprint has high performance, uniqueness and user acceptance. However, some people’s fingerprints are not easy to be clearly captured. Fingerprint identification systems are preferred because of their compact size.

viii. **Iris:** Biometrics which analyzes the complex and unique characteristics of the eye can be divided into two different fields: iris biometrics and retina biometrics. It is the colored ring of tissue that surrounds the pupil of the eye. Iris recognition is based on visible features, i.e. rings, furrows, freckles and the corona. Features and their location are used to form the Iris codes, which is the digital template. It is widely regarded as the most safe, accurate biometrics technology. An iris image is typically captured using a non-contact imaging process. Capturing an iris image involves cooperation from the user, both to register the image of iris in the central imaging area and to ensure that the iris is at a predetermined distance from the focal plane of the camera.

ix. **Retinal scan:** The retina is the layer of blood vessels at the back of the eye. The blood vessel pattern in the retina is the feature for retinal recognition technology. The retinal vasculature is rich in structure and is supposed to be a characteristic of each individual and each eye. It is claimed to be the most secure biometric since it is not easy to change or replicate the retinal vasculature. The image capture requires a user’s eye to be aligned with the camera target. The image acquisition involves cooperation of the subject, requires contact with the eyepiece, and a conscious effort on the part of the user. All these factors adversely affect public acceptability of retinal biometrics. The primary advantage of the time domain representation of the retinal signature is computational efficiency.

x. **Signature Recognition:** The way a person signs his name is known to be a characteristic of that individual. The user sings his signature on a digitized graphics tablet. Signature aspects, such as speed, stroke order, stroke count and pin pressure is analyzed. Although signatures require contact and effort with the writing instrument, they seem to be acceptable in many government, legal, and commercial transactions as a method of verification. Signatures are a behavioral biometric that change over a period of time and are influenced by physical and emotional conditions of the signatories. Signatures of some people vary a lot even successive impressions of their signature are significantly different. Furthermore, professional forgers can reproduce signatures to fool the unskilled eye.

xi. **Voice Verification:** Voice verification is the science of verifying a person's identity on the basis of their voice characteristics. Voice recognition is not the same as speech recognition, it is speaker recognition. It is different from speech recognition because the technology does not recognize the spoken word itself. Rather, it recognizes the speaker of the words by analyzing unique speech characteristics, such as the frequency between phonetics. It is considered both physiological and behavioral characteristic. This biometric is popular and low-cost, but less accurate and sometimes lengthy enrollment.

xii. **Other Technologies:** Other technologies such as keystrokes, body odor, lip shape etc. are also under investigation for person identification.

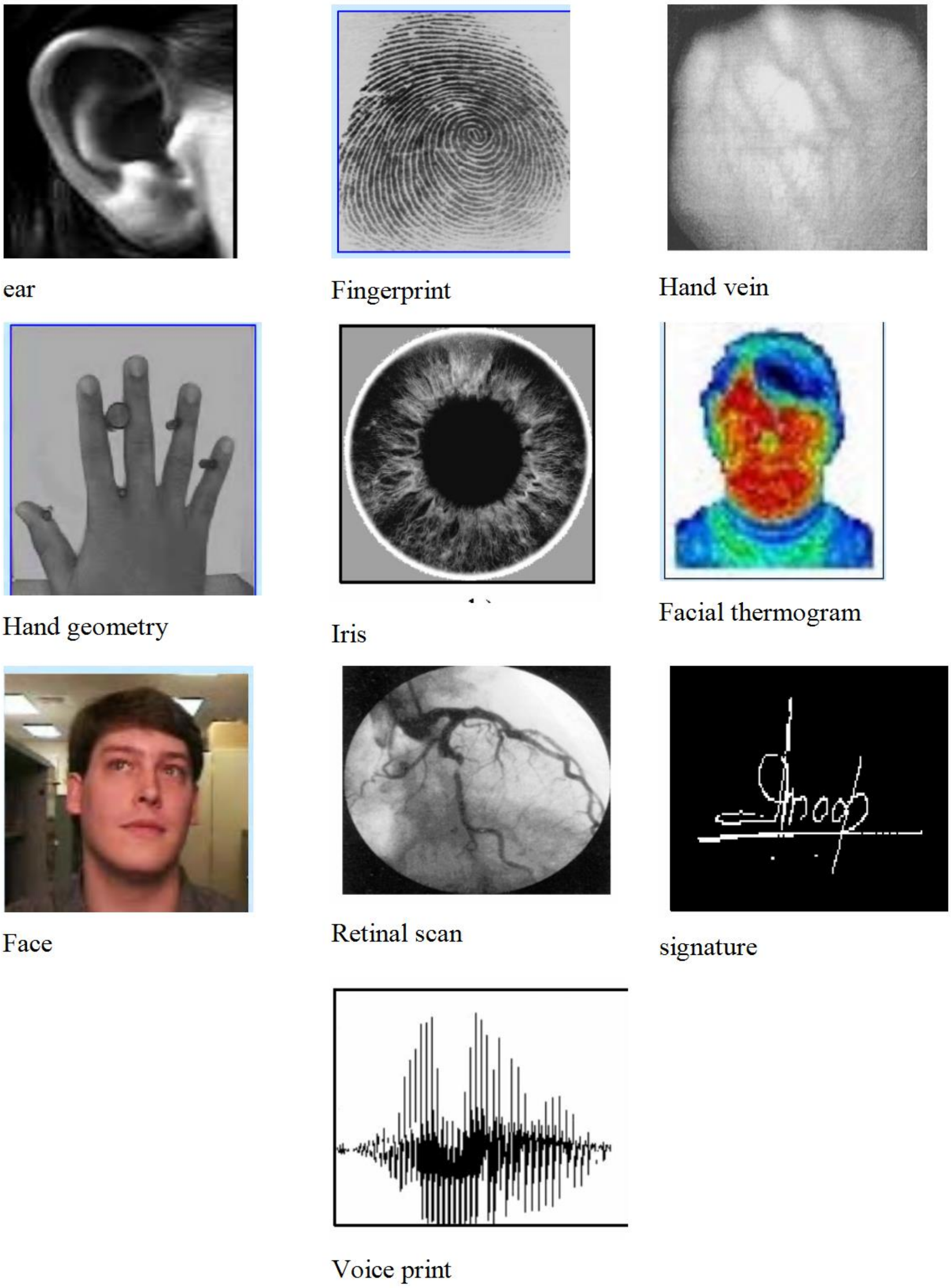


Figure 1-2 Different Biometric Technologies

Comparison of Biometric Technologies:

The comparisons of different biometric identifiers are described in Table 1.1. It shows that palm and hand geometry biometrics is suitable for low and medium security purposes. The major advantage of this biometric is the high collectability which means that it requires simple data acquirement system i.e. a simple flat document scanner is sufficient. High collectability and low cost makes it much more attractive to the clients.

Table 1-1 Comparisons of Biometric Technologies: High, Medium, and Low are Denoted by H, M, and L, Respectively

Biometric Identifier	Universality	Distinctiveness	Permanence	Collectability	Performance	Acceptability	Circumvention
DNA	H	H	H	L	H	L	L
Ear	M	M	H	M	M	H	M
Face	H	L	M	H	L	H	M
Facial Thermogram	H	H	L	H	M	H	L
Fingerprint	M	H	H	M	H	M	M
Gait	M	L	L	H	L	H	M
Palm and Hand Geometry	M	M	M	H	M	M	M
Hand Vein	M	M	M	M	M	M	L
Iris	H	H	H	M	H	L	L
Retina	H	H	M	L	H	L	L
Signature	L	L	L	H	L	H	H
Voice	M	L	L	M	L	H	H

A comparison with different biometric is summarized in table below.

Table 1-2 Comparison with Different Biometrics and Algorithms

Biometrics	Algorithm	FRR (%)	FAR (%)	No. Individuals	No. Images
Hand Shape.	Deformable matching [17].	3.5	2	53	353
Finger Crease Profile.	Correlation function [18].	0.19	0.07	206	206
Palm Print.	Line matching [19].	0.1	0.1	100	100
Palm Print.	Decision-based NN [20].	1.0	1.0	32	64
Palm Print.	GLVQ algorithm [21].	2.7	2.4	10	200
Palm Print plus Palm Shape	GLVQ algorithm [21].	1.3	1.25	10	200

1.1.3 Applications of Biometric Systems

There are many applications of biometric systems and all of them can be categorized into three main fields:

(i) **Commercial**: computer network login, access digital information, sensitive facilities, ATM, credit card, cellular phone, PDA, medical records, attendance applications, etc.

(ii) **Government:** national ID, passport, driver's license, welfare claims, border control, social security, etc.

(iii) **Forensic**: terrorist identification, parenthood determination, missing children, criminal investigation, dead body identification, etc.

1.2 System Architecture and Operations

A typical biometric system for person identification consists of four main parts: Data Acquisition, Preprocessing, Feature Extraction, and Pattern Matching. The functions of each part are described as follows:

(i) **Data Acquisition:** In this part, biometric data is collected such as an iris' image, voice and signature motion. It is an important part in the whole process. If the image is **c**ontaminated by noise or is blur, the overall performance of the system will be affected.

(ii) **Pre-processing**: pre-processing is an important step in biometric recognitions. It serves several purposes including segmentation, noise reduction, rotational normalization and translation normalization etc.

(iii) **Feature Extraction**: In this step of biometric based person recognition systems stable and unique features are extracted by applying feature extraction techniques.

(iv) **Identification/Verification**: After feature extraction, pattern matching techniques are used to classify the features and to make a final decision whether two features belonged to the same person or not.

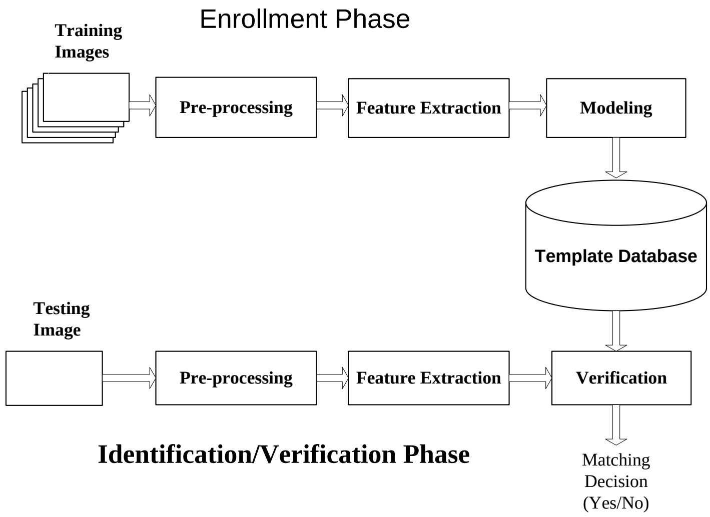


Figure 1-3 The Modules of Biometric-Based Verification Systems

1.3 Hand Geometry and Palm print Anatomy

The physical dimensions of a human hand contain information that is capable to authenticate the identity of an individual. This information is popularly known as palm or hand geometry.

Hand geometry, as the name suggests, refers to the geometric structure of the hand. Hand geometry provides for a good general purpose biometric, with acceptable performance characteristics and relative ease of deployment coupled to a low learning curve for users. There exists useful information within the geometry of an individual hand. Since each human hand is unique, finger length, width, thickness, curvatures and relative location of these features distinguish one human being from others [**4**].

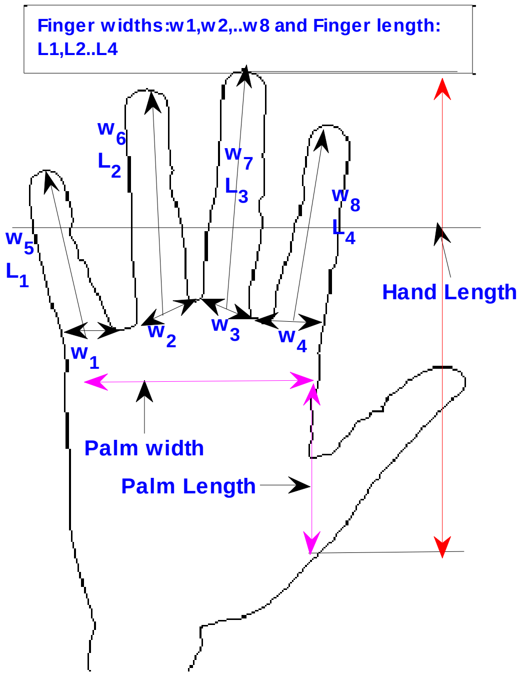


Figure 1-4 Hand Geometry Features

Palm is the inner surface of a hand between the wrist and the fingers. It contains interior content of a hand shape. These features are: Area of palm; palm Length and principal lines on the palm, creases and wrinkles. In particular, the lines on a person's hand are unique to every individual; even our own two hands are never quite alike. For example, there are three principal lines caused by flexing hand and wrist, which are named as heart line, head line and life line, respectively [2]. The location and form of these principal lines in a palm are very important physical features for identifying an individual because they vary slowly from time to time. Due to the stability of these feature lines, they can be regarded as reliable and stable features to distinguish a person from others [7].

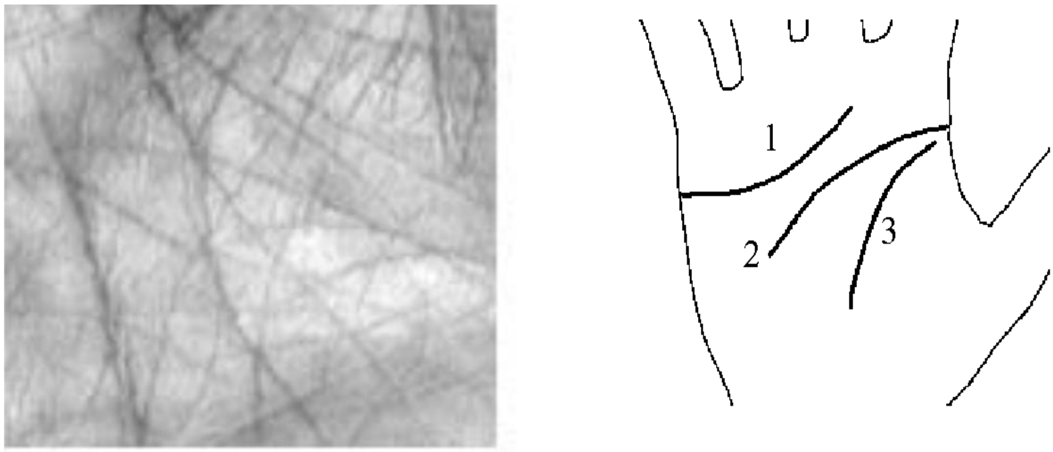


Figure 1-5 Sample Palm Print and Principal Lines of Palm Print

1.4 Literature Survey

In addition to hand geometry features, there are many other methodologies that have been used in literature for hand based person identification and verification i.e. shape analysis, palm print texture analysis etc. Shape analysis is a conventional method for object identification, has been extensively employed in the field of object recognition by various researchers on different shapes. So by considering human hand as an object of definite rigid shape, extract its boundary and shape parameters as recognition features, often normalized and invariant to various geometric changes such as translation, rotation and scale. Shape analysis includes geometric moments, invariant geometric moments, Zernike moments, Fourier descriptors, Principal Component Analysis and wavelet analysis.

1.5 Organization of this Thesis

This thesis is organized as follows: Chapter 1 provides an introduction to biometric technologies. Chapter 2 describes the data acquisition step of a biometric recognition system. System Architecture is described in Chapter 3. Chapter 4 explains new hand biometric feature extraction techniques for extracting hand shape, palm print texture and hand geometry features. The feature integration and feature reduction processes is explained in chapter 5 and Chapter 6 discusses the experimental results of identification system. Finally, conclusions and suggestions for further research are made in Chapter 7.

Summary

Reliability in the person authentication is key to the security in the networked society. Many physiological characteristics of humans, i.e. biometrics, are typically time invariant, easy to acquire, and unique for every individual. That is why Biometrics are considered to be more reliable and robust and is becoming the global standard for person identification especially for access control. Palm prints and hand geometry biometric features that are widely used in the world because of their high collectability and low cost. A Typical biometric identification system consists of a data acquisition module, a pre-processing module, a feature extraction module and a matching module. The performance of a biometric system is quantized in terms of False Acceptance Rate and False Rejection Rates, which are described graphically in the form of the ROC Curve. This project is aimed at exploring the techniques used for palmprint and hand geometry based person identification.

Chapter 2- Data Acquisition

In order to assess the performance of the proposed system, two different databases have been for experiments namely PIEAS Hand Database 1 (DB1) and PIEAS Hand Database 2 (DB2). Details of these two datasets are given below.

DB1 that is used for experiments consists of 500 right hand images from 50 individuals, 10 images from each individual. All images of DB1 are captured using a simple flatbed document scanner (Camera Model: Hp scanjet 5590). It has no pegs to control the hand alignment. To ensure proper hand alignment a transparent sheet with five pegs on it is placed on the scanner. These five pegs on the platform serve as control points for the placement of hands. Using pegs makes sure that the fingers don't touch each other and most of the part of the hand touches the imaging sheet containing the pegs. These pegs also reduce the time requirement of image pre-processing for hand alignment. The arrangement of pegs is:

(i) **Peg No. 1** -It is the peg located between little finger and ring finger. It controls the alignment of little finger.

(ii) **Peg No.2** –It is the peg located between ring finger and middle finger. It controls the alignment of the middle finger.

(iii) **Peg No.3** –It is the peg located between index finger and middle finger and it controls the alignment of both the fingers.

(iv) **Peg No.4** –this peg is also between index finger and middle finger but it is below and small in size as compared to peg No. 4. It controls the hand up and down movement.

(v) **Peg No. 5** –The peg No. 5 control the alignment of thumb.

The second database called DB2 consists of 1100 right hand images from 110 individuals, 10 images from each individual. It is used for experiments to see the performance of the system on large datasets. All images of DB2 are captured using the same flatbed document scanner (Camera Model: Hp scanjet 5590) as was used for making PIEAS Hand Database 1 and same arrangements are done for controlling the hand alignment.

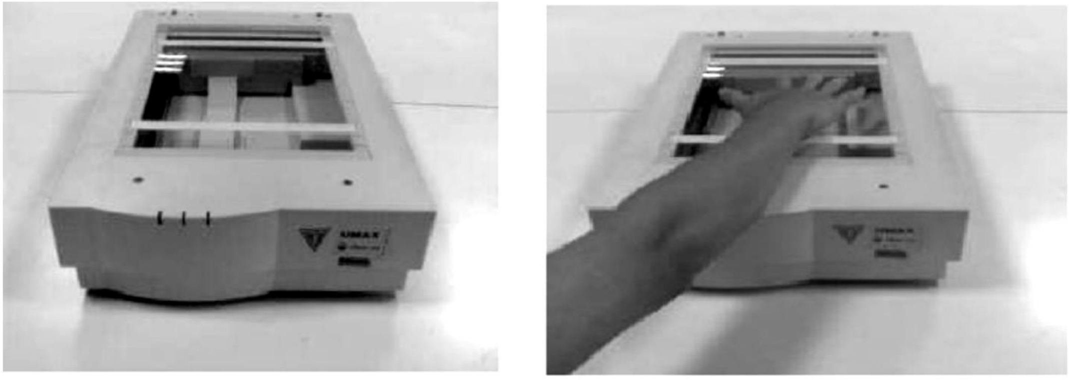


Figure 2-1 Input Device for Data Acquisition

A sample hand image from DB1 is shown in figure below.

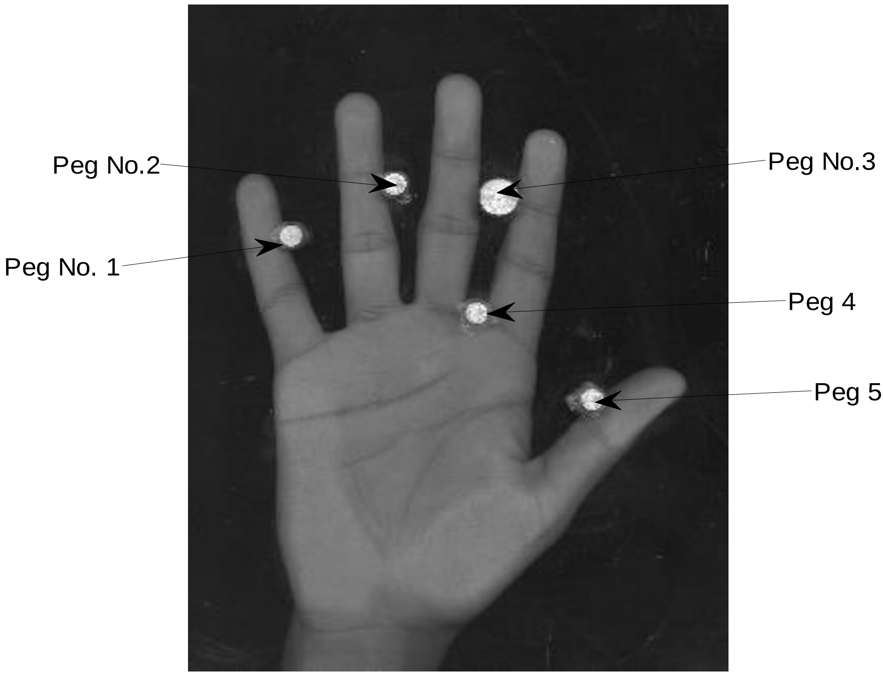


Figure 2-2 Sample Hand image of the database

All the images of PIEAS Hand database 1 (DB1) and PIEAS Hand database 2 (DB2) are of type JPEG and of size 1700 X 2340 and 1675 X 2307 respectively. The format of the file name is "(USER_ID). (SAMPLE).jpg". Where (USER_ID) is the ID of the user, (SAMPLE) is the sample number for the user (USER_ID) and jpg is the format of the image file. The disk size of each image is about 1Mb.

In DB1, 42 individuals are male and remaining 8 individuals are female. The age distribution of the subjects is

Below 30 years = 90%

Older than 50 years=2%

Between 30 and 50 years= 08%

In DB2, 85 individuals are male and remaining 25 individuals are female. The age distribution of the subjects is

Below 30 years = 81%

Older than 50 years=2%

Between 30 and 50 years= 17%

The images of Dataset 1 are collected in two weeks and it takes 10 seconds to acquire a single hand image. Similarly it took three weeks to collect the images of Dataset 2.

The PIEAS Hand database 1 is also updated after one year so that experiments of time dependency analysis of the identification system can be performed.

Chapter 3- System Architecture

A typical biometric system for person identification consists of three main parts: Image Processing, Feature Extraction and Classification. Conceptual biometric system architecture is shown below.

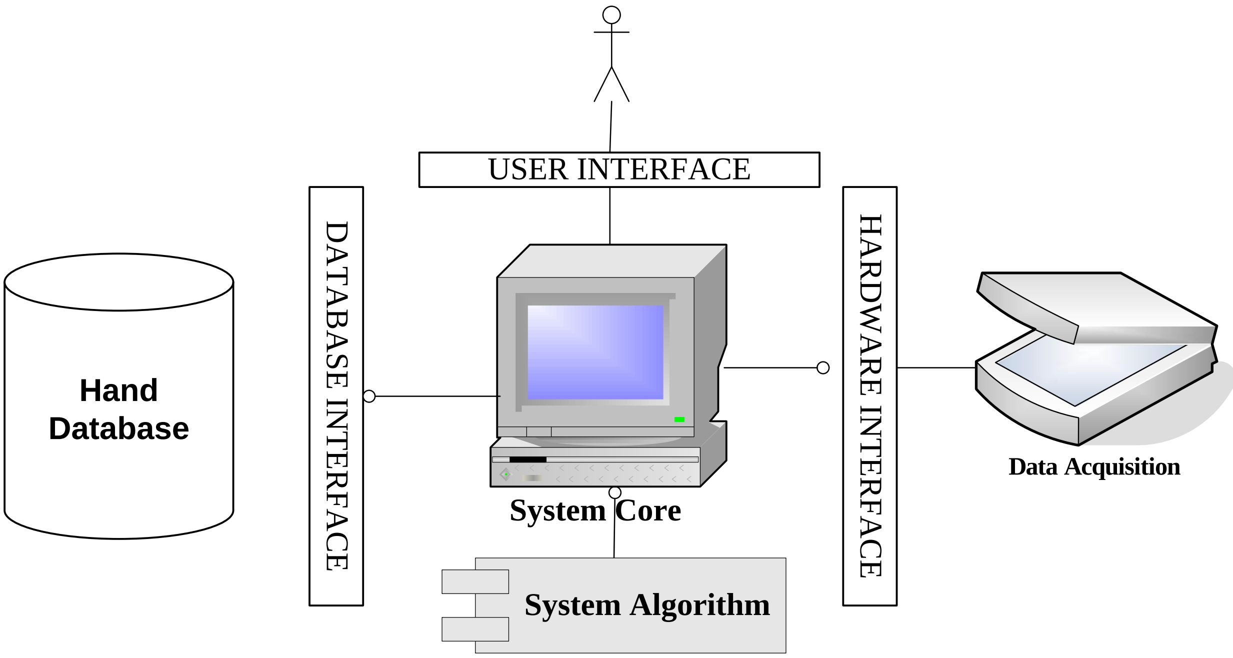


Figure 3-1 Architecture a Conceptual Biometric System

3.1 Image Pre-processing

Image pre-processing is an important step for many pattern recognition systems. In our proposed palm and hand geometry based identification system, five pre-processing steps are discussed in this chapter. These five image pre-processing steps are common and are performed before all proposed feature extraction techniques. These processes are image cropping, grayscale conversion, median filtering for noise reduction in images, binirization and removal of pegs as shown in figure 3-3.

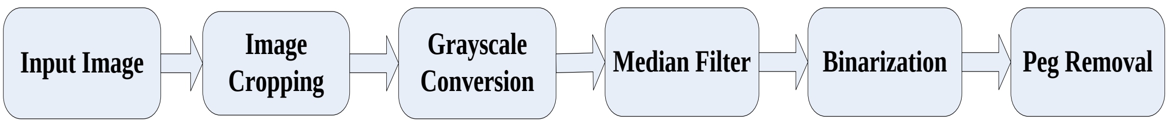


Figure 3-2 Image Processing Block Diagram

3.1.1 Image Cropping

The input color image is cropped to eliminate the undesired portion of the image as shown in figure 3-3(a, b). The input image is of size 1700X 2340 which is a very large size. To reduce the size, input image is cropped against a rectangle. There is also another advantage of image cropping that is noise reduction. Image cropping process also removes the noise associated with unwanted image portion. The rectangle against which the input image is cropped is defined such that its area is larger than any hand image in the database as shown in figure 3-3a so that no information is lost.

The defined rectangle is then placed over the input image for reduction of image size. The portion of the image outside the rectangle is cropped such that the cropped image contain the entire hand shape and no information is lost such as shown in figure 3-3b.

3.1.2 Grayscale conversion

The original input image is of type RGB, sometimes referred to as a "truecolor" image. The cropped RGB image is converted to a grayscale (256 gray levels) image. A sample grayscale image from the database used for experiments is shown in figure 3-3b.

3.1.3 Binary Thresholding

The grayscale images (8 bit per pixel image) are binarized (monochrome) to obtain the binary images (1 bit per pixel), applying a threshold.

Output image=input image>threshold

Where the threshold is calculated by means of the Otsu's method [15]. A sample binary image is shown in figure 3-3c.

3.1.4 Noise removal

It is necessary to remove the salt and pepper noise from binary images. Different techniques can be used to remove the noise from images. In our proposed system, median filter is used to remove the noise due to the fact that it can remove salt and pepper noise from an image without significantly reducing the sharpness of the image.

Median Filter:-

Median filtering is a nonlinear operation often used in image processing to reduce "salt and pepper" noise. The Median Filter calculates a median value of an M-by-N neighborhood and then replaces the central value of that M-by-N neighborhood with calculated median value. If the neighborhood has a center element, then median filter places the median value there, as illustrated in the following figure.

Table 3-1 M-by-N Neighborhood having Exact Centre

	Median value	

If the neighborhood does not have an exact center, the block has a bias toward the upper-left corner and places the median value there, as illustrated in the following figure.

Table 3-2 M-by-N Neighborhood having no Exact Centre

	Median value		

The median filter pads the edge of the input image so, pixels within [M/2 N/2] of the edges may appear distorted. Because the median value is less sensitive than the mean to extreme values, the Median Filter block can remove salt and pepper noise from an image without significantly reducing the sharpness of the image.

3.1.5 Peg Removal

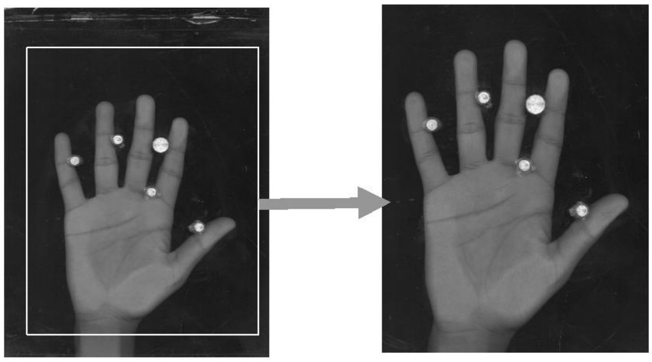
In order to obtain the pure hand image, pegs are removed. The image of the transparent sheet, containing the five pegs and placed over the scanner, is captured. This image is then pre-processed i.e. cropped and converted to grayscale such that its size and type is same as the hand images. We called this image as “Peg Template” and is used to remove the pegs from the hand images. The procedure of the peg removal is such that peg template lets say, $peg(i, j)$ is first negated and then multiplied with the binary hand image lets say, $I(i, j)$ as shown is equation 3.1.

The equation 3.1 removes the pegs from binary hand images by changing the peg pixels from white to black and unchanged the hand shape pixels. The binary image after the removal of pegs is shown in figure 3-3(d).

3.1.6 Edge Detection

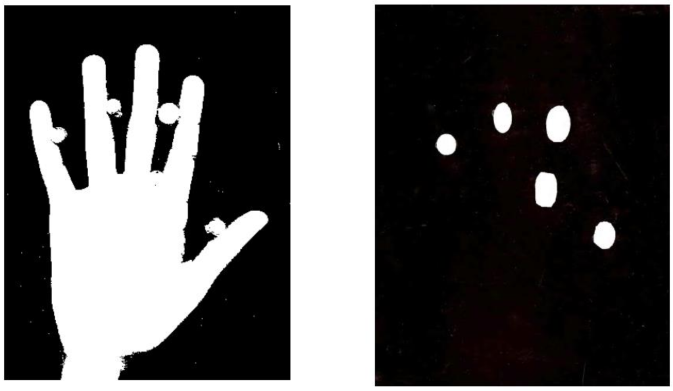
After the removal of pegs, next step of image pre-processing is the edge detection. In order to find the hand geometry features and palm print region of interest (ROI) edges of hand shapes are detected. There are many ways to perform edge detection. However, the most may be grouped into two categories, gradient (Roberts, Prewitt, Sobel) and Laplacian (Marrs-Hildreth). The gradient method detects the edges by looking for the maximum and minimum in the first derivative of the image. The Laplacian method searches for zero crossings in the second derivative of the image to find edges. In the proposed system, Sobel method is used for edge detection [15]. The Sobel method finds edges using the Sobel approximation to the derivative. It returns edges at those points where the gradient of the input image is maximum.

After image pre-processing, features of hand shape, hand geometry and palm prints are extracted by applying feature extraction techniques.



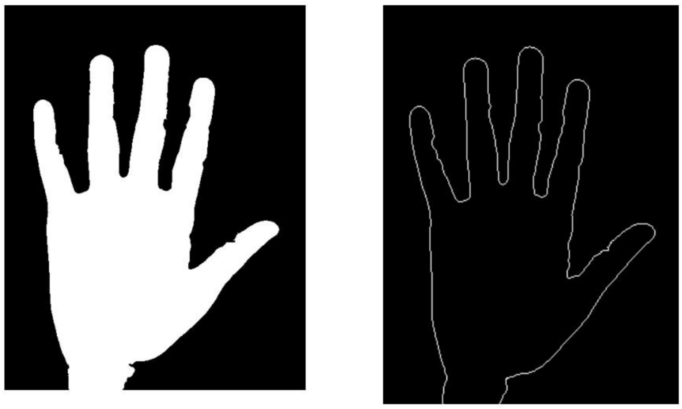
a-Grayscale image without cropping

b-Cropped image



c-Binary Image before peg removal

c-Peg template for peg removal



d-Binary Image after peg removal

e-Edge detection

Figure 3-3 Image Processing Steps

3.2 Feature Extraction

Feature extraction is considered to be the main and most imaportant module in a biometric system. In this module different types of biometric feature are extracted for classification. In our proposed system, three different techniques are implemented i.e.

Feature extraction using PCA, Hand geometry feature extraction using image processing and palm print feature extraction using wavelet transform. All these feature extraction techniques are explained in detail in next chapter.

3.3 Classification

In a typical biometric system classification is considered to be the last and decision making step because after that step some decisions (match/ no match) are made. In our proposed system the similarity of two feature vectors is measured by using Euclidean distance as similarity measure.

The similarity measure between f_1 (feature vector from the user) and f_2 (stored template) is used as the matching score and is computed as follows:

$$\omega_T = \frac{f_1 \cdot f_2}{|f_1||f_2|} ------(13)$$

If ω_T is less than threshold then the two images do not match otherwise a match is considered.

Performance Analysis

The performance of the system is measured in terms of accuracy and speed. The accuracy of the system is measured in terms of False Acceptance Rate (FAR) and False Rejection Rate (FRR). FAR is defined as the probability that an imposter is accepted as a genuine individual whereas FRR is the probability that a genuine individual is rejected as an imposter. There is also another accuracy measure called Equal Error Rate (EER) which is defined as the point at which the probability of false acceptance equals the probability of false rejection. The range of threshold that is used to measure the accuracy is from -1 to +1.

Chapter 4- Feature Extraction Approaches

Feature extraction is the most essential and main phase in pattern recognition. Meaningful features are needed to be extracted after the image pre-processing phase. In the proposed system three types of features have been extracted from a hand image i.e. global hand shape features, hand geometry features and features of palm prints. Principal Component Analysis is used to extract the global hand shape features, hand geometry features have been extracted using image processing techniques and wavelet transform is applied to extract the wavelet domain features of palm prints. The extracted features of three techniques are merged to enhance the accuracy of the verification and identification of system.

4.1 Hand Shape Recognition using Principal Component Analysis

Eigenspace projection examines images in a subspace. It is also known as Karhunen _ Loeve (KL) and Principal Component Analysis (PCA) [9]. PCA is a useful statistical technique that has found application in fields such as face recognition, hand shape recognition and image compression. In the proposed system PCA is used to extract hand shape features [16]. It is a common technique for finding patterns in data of high dimension. It projects images into a subspace such that the first orthogonal dimension of this subspace captures the greatest amount of variance among the images and the last dimension of this subspace captures the least amount of variance among the images. Once image are projected into subspace, a similarity measure is used for matching. Two methods of creating an eigenspace are examined, the original method and a method designed for high-resolution images know as the snapshot method.There are basically two methods for creating an eigenspace:

(i) Original method of eigenspace projection

(ii) Snapshot method

4.1.1 Original Method of Eigenspace Projection

There are basically three steps to identify images through eigenspace projection in original method. The first step is to create an eigenspace using the training images. The second step is to project the training images into the eigenspace created in the first step. In final step, test images are identified by projecting them into the eigenspace and then comparing them to the projected training images. The detail of three basic steps of original method for identifying images is.

Create Eigenspace

Eigenspace creation is the first step to identify images through eigenspace projection. In order to create an eigenspace each image is stored in a vector of size N.

(i) **Center data:** First of all each of the training images must be centered. It can be done by subtracting the mean image from each of the training images as shown in equation 2.

(ii) **Create a data matrix:** Data matrix is created by combining the centered images. The size of data matrix is NxP. Where P is the number of training images and each column is a single image.

(iii) **Create a covariance matrix**: For the creation of covariance matrix, data matrix is multiplied by its transpose.

(iv) **Compute eigenvalues and eigenvectors**: The eigenvalues and eigenvectors are computed for Ω using eigenvector decomposition.

where V is the set of eigenvectors and Λ is the set of eigenvalues.

(v) **Normalization of eigenvectors:** The eigenvectors are divided by their norm for normalizaton.

(vi) **Order eigenvectors:** Eigenvectors v_i are sorted according to their corresponding eigenvalues. And those eigenvectors selected which are associated with eigenvalues contain energy more than zero.

Project training Images

Once the eigenspace is created the entire centered training images are projected into it. To project an image, calculate the dot product of that image with each ordered eigenvector.

Identify test images

Each test image is centered as training images, and then these test images are projected onto the created eigenspace.

And

The projected test image is compared to every projected training image and the training image that is found to be the closest to the test image is used to identify the training image.

The original method leads to extremely large covariance matrices and the calculation of the covariance matrix and the eigenvectors is computationally demanding. Due to this drawback the second method (snapshot method) is used in our proposed system.

4.1.2 Snapshot Method

Snapshot method is also comprised of three steps and identify images through eigenspace projection. The first step is to create an eigenspace using the training images. In second step the training images are projected onto the eigenspace created in the first step. In the last step, the test images are identified by projecting them onto the eigenspace and then comparing them to the results of the second step. The description of these three basic steps is below.

Create Eigenspace

Eigenspace creation is the first step to identify images through eigenspace projection. In order to create an eigenspace each image is stored in a vector of size N.

(i) **Center data:** First of all each of the training images must be centered. It can be done by subtracting the mean image from each of the training images as shown in equation 2.

(ii) **Create a data matrix:** Data matrix is created by combining the centered images. The size of data matrix is NxP. Where P is the number of training images and each column is a single image.

(iii) **Create a covariance matrix**: For the creation of covariance matrix, data matrix is multiplied by its transpose.

(iv) **Compute eigenvalues and eigenvectors**: The eigenvalues and eigenvectors are computed for Ω' using eigenvector decomposition.

where V' is set of eigenvectors and Λ' is the set of eigenvalues.

(v) **Compute eigenvectors of** : Eigenvectors V of are computed by multiplying data matrix with V'.

(vi) **Normalization of eigenvectors:** The eigenvectors are divided by their norm for normalizaton.

(vii) **Order eigenvectors:** Eigenvectors ν_i are sorted according to their corresponding eigenvalues. And those eigenvectors selected which are associated with eigenvalues contain energy more than 98%. Using this threshold only 15 features are selected and remaining 235 features are discarded.

<u>Project training Images</u>

Once the eigenspace is created the entire centered training images are projected into it. To project an image, calculate the dot product of that image with each ordered eigenvector.

Identify test images

Each test image is centered as training images, and then these test images are projected onto the created eigenspace.

And

The projected test image is compared to every projected training image and the training image that is found to be the closest to the test image is used to identify the training image.

The similarity of two feature vector is measured by using Euclidean distance as a similarity measure which has been explained in chapter 2.

4.1.3 Experimental Results

In order to access the performance of identification system, two Datasets i.e. PIEAS Hand Database1, PIEAS Hand Database 2 are used for experimental results. The description of two datasets is given in chapter 2. The experimental results of DB1 and DB2 using Principle Component Analysis is shown below.

The datasets contain ten images from each individual. In order to perform experiments, first five images are used for training and the remaining five images are used for testing. The false acceptance and false rejection rates are shown in figures 4-1 and 4-2 below. The optimal threshold value is obtained by plotting the FAR and FRR against threshold levels from minus 1 to plus 1.

Using PIEAS hand dataset 1 and applying PCA for feature extraction the system can operate at **94.5** % accuracy rate and the optimum threshold value that is calculated is about **0.68** as shown in figure 4-1.

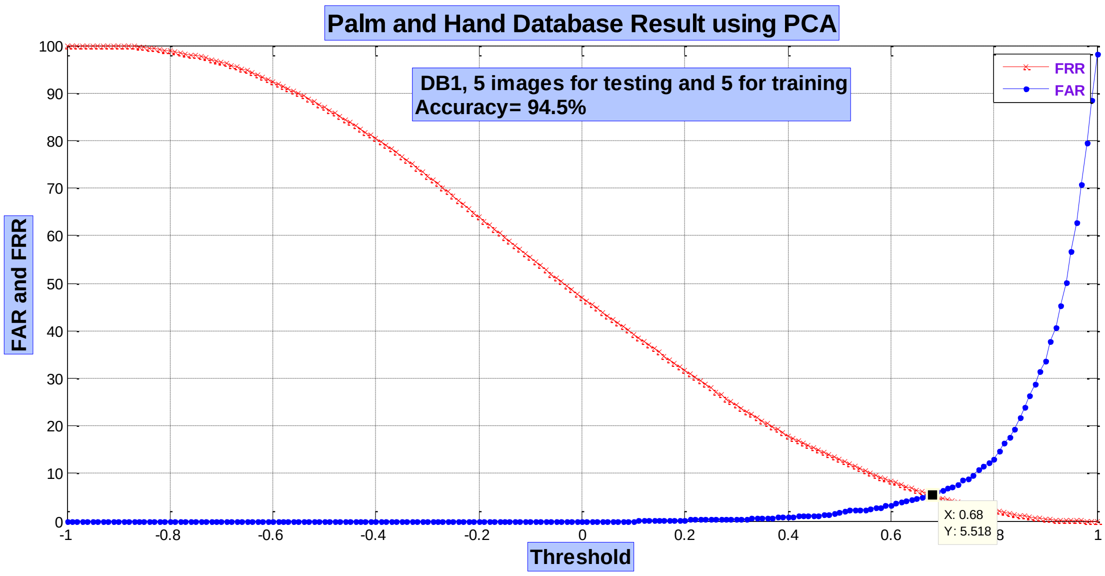


Figure 4-1 The Experimental Results Generated by Using PCA and DB1

PIEAS Hand Database 2 contain 1100 images from 110 individuals i.e. 10 images from each individual. Out of ten images from each individual, first five images are used for training and the remaining five images are used for testing. The false acceptance and false rejection rates are shown in figure 4-2. Using DB2 and applying Principal Component Analysis for feature extraction the identification system can operate at the 91.49 % accuracy rate and the optimum threshold value is about 0.61 as shown in figure 4-2.

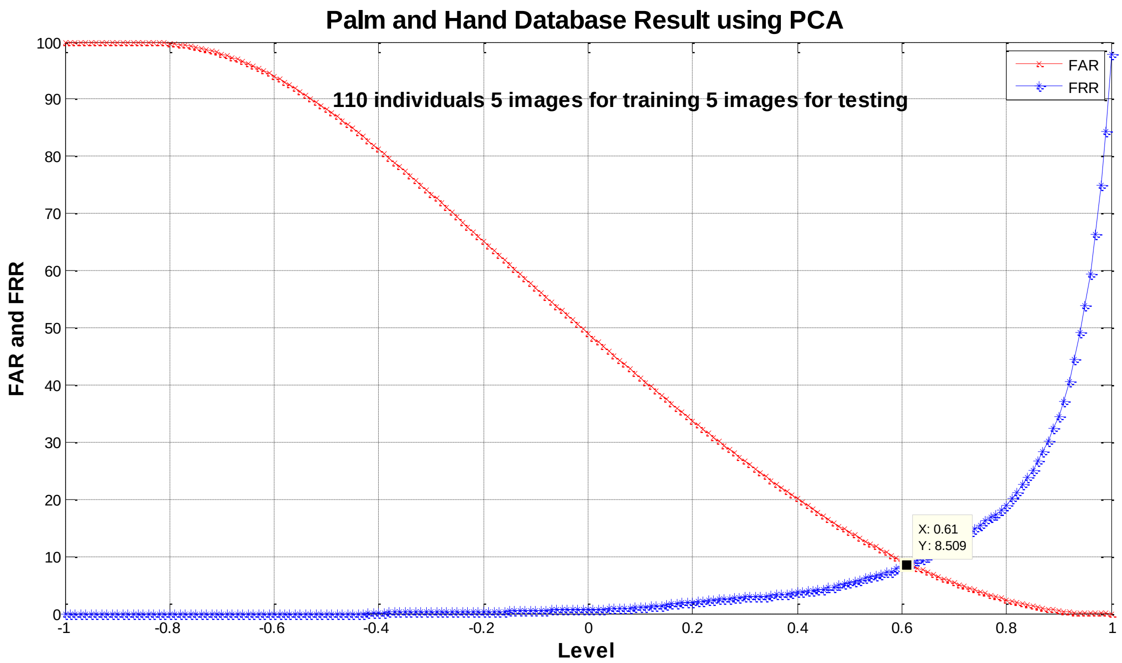


Figure 4-2 Results of DB2 Applying PCA

4.2 Extraction of Hand Geometry Features using Image Processing Techniques

Systems using Hand Geometry features to identify individuals have been developed in the past decades. In recent years, hand geometry (Figure 4-5) has become a very popular access control biometrics. The characteristics of hand geometry include the length and width of palm, length and width of figures, length of hand etc.

In the proposed system binary image is used to compute significant hand geometry features. A total of 16 hand geometry features are extracted from each hand image as shown in figure 4-4.

4.2.1 Image pre-processing

Image pre-processing is the first step of hand geometry based recognition system. The processes in this step include image cropping, grayscale conversion, binary thresholding, noise, peg removal and edge detection. All these processes have been explained in chapter 2.

4.2.2 Feature Extraction

Feature selection and extraction is the most essential part of image recognition systems. In the proposed system, sixteen meaningful features of hand geometry are extracted for person identification. These features include:

(i) Finger lengths (4 features)

(ii) Finger widths (8 features)

(iii) Palm width (1 feature)

(iv) Palm length (1 feature)

(v) Palm area (1 feature)

(vi) Hand length (1 feature)

<u>Finger length</u>

In order to find the length of fingers, the first step is to find the finger tips (P_1, P_2, P_3 and P_4) and valleys (V_1, V_2 and V_3). For finger tip detection a portion of the hand image is selected that contain only fingers i.e. selecting the hand image form initial point to peg No. 4 and cropping the hand image from peg No.4 to the bottom point in vertical direction as shown in figure 4-4. In order to find the finger tips, local maxima of each finger is found by traversing the selected portion of the image. In such a way four local maxima are obtained. Each local maxima represents a finger tip i.e. first local maxima is the little finger tip and second local maxima represents the ring finger tip and so on. Once the finger tips are identified, next step is to find the finger valleys. Finger valleys are detected using the similar method as we have used for finger tip detection but the difference is that for finger valleys detection we select part of the image from peg No. 1 to peg No. 5 (i.e. the portion of the image little finger supporting peg and thumb supporting peg). The selected portion of the image is shown in figure 4-4. In order to find the finger valleys, local minima of each finger is found. Each local minima represents the finger valley. There are three local minima representing three finger valleys. The bottom point of the little finger is determined by finding a point between leftmost point and valley1 as shown in figure 4-4. Middle point between the two valleys is found by taking of two consecutive valley points. Similarly the bottom points of the other fingers can also be identified. Finally the length of a finger is determined by finding the length between the finger tip and finger bottom point. Using the same procedure four features of finger length (L_1, L_2, L_3 and L_4) are obtained.

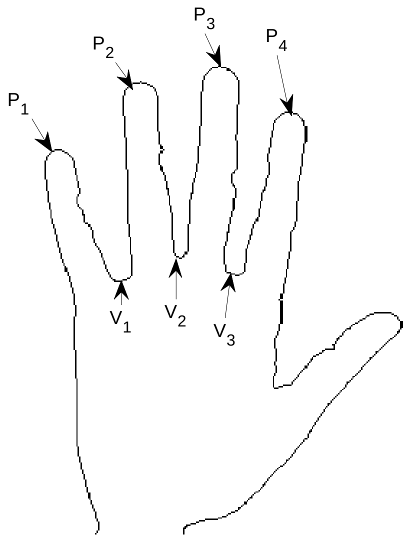


Figure 4-3 Finger Tips and Valley Point Detection

[REMOVE EXTRA SPACING]

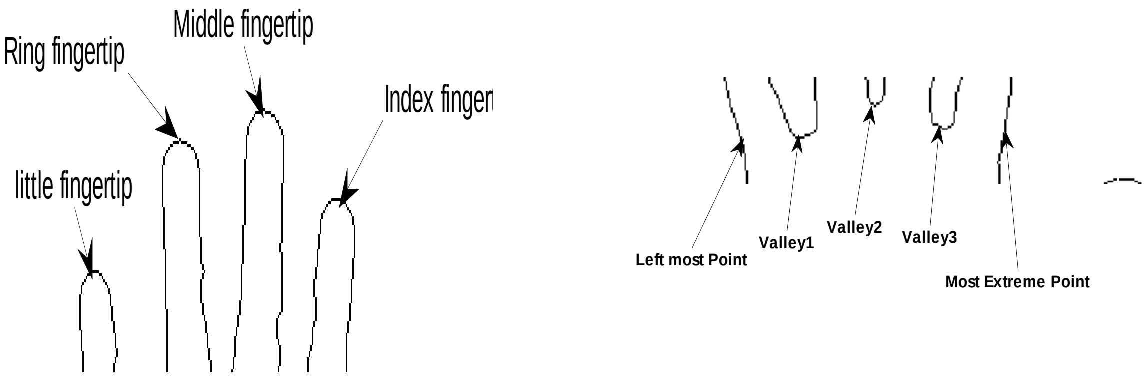


Figure 4-4 Image Cropping for Fingertip Identification and Valley Identification

Finger width

For finger widths two fixed points are found on the finger boundary and the width is taken at these fixed points. In order to find these two fixed points the finger length is divided by 2 to find the middle point on the finger. Then this point is taken as a pivot point and traverse left and right until the two points (left and right) on the finger boundary. Then the distance between these two points is determined as a finger width. In similar manner four finger widths are found. Four more finger widths are determined by finding the lengths between valley points of fingers. In the proposed system a total of eight finger width features are used for identification.

Hand and Palm length, width and Area

For Palm length and width calculations, two fixed points are found on the palm boundary along x-axis and two fixed points are found on the palm boundary along y-axis. Then the distance between these two points are find to determine the palm length and palm width. The palm area is found by taking the product of palm width and palm length. To find the hand length, the distance between the middle finger tip and the hand bottom point is determined. To find the hand and palm bottom point we used a technique such that starting from the index finger right most valley point the image is traversed along y axis until we found bottom most point at which the value obtained is 1.

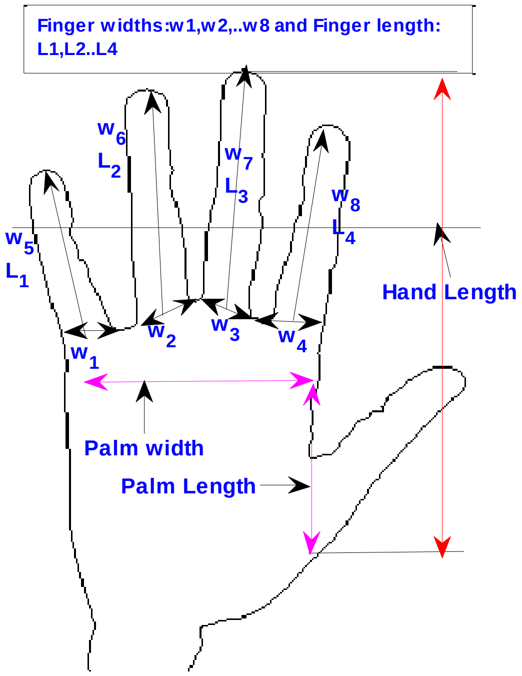


Figure 4-5 Features of Hand geometry

4.2.3 Experimental Results

In order to access the performance of identification system, two Datasets i.e. PIEAS Hand Database1, PIEAS Hand Database 2 are used for experimental results. The description of two datasets is given in chapter 2. The experimental results of the two Datasets using hand geometry features are given below.

Out of ten images from each individual, first five images are used for training and the remaining five images are used for testing. The false acceptance and false rejection rates are shown in figures 4-6 and 4-7 below. The optimal threshold value is obtained by plotting the FAR and FRR against threshold levels from minus 1 to plus 1.

The similarity of two feature vector is measured by using Euclidean distance as similarity measure which is explained in detail in chapter 3.

Using PIEAS hand dataset 1 and hand geometry features the system can operate at the **91.8**% accuracy rate and the optimum threshold value that is calculated is about **0.61** as shown in figure 4-6.

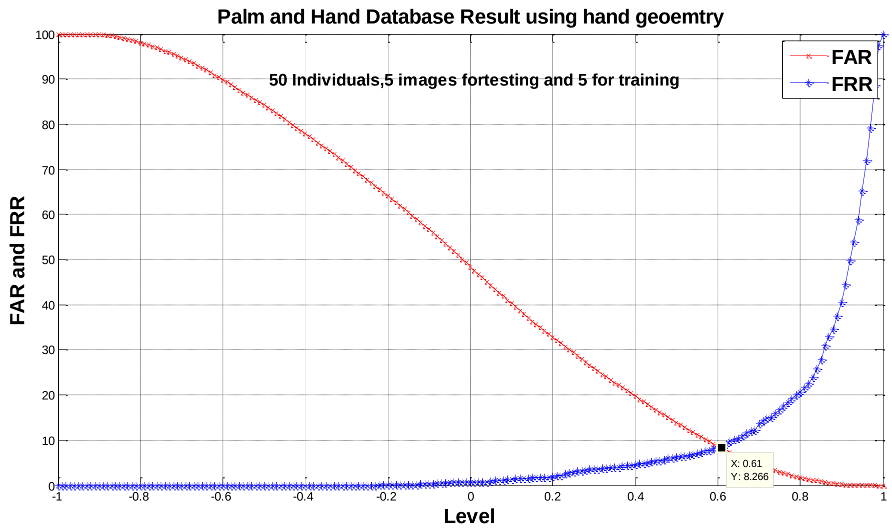


Figure 4-6 Experimental Results Using Hand Geometry Features and DB1

PIEAS Hand Database 2 contain 1100 images from 110 individuals i.e. 10 images from each individual. Out of ten images from each individual, first five images are used for training and the remaining five images are used for testing. The false acceptance and false rejection rates are shown in figure below.

Using PIEAS hand dataset 2 and hand geometry features the system can operate at the **90.3**% accuracy rate and the optimum threshold value that is calculated is about **0.61** as shown in figure 4-7.

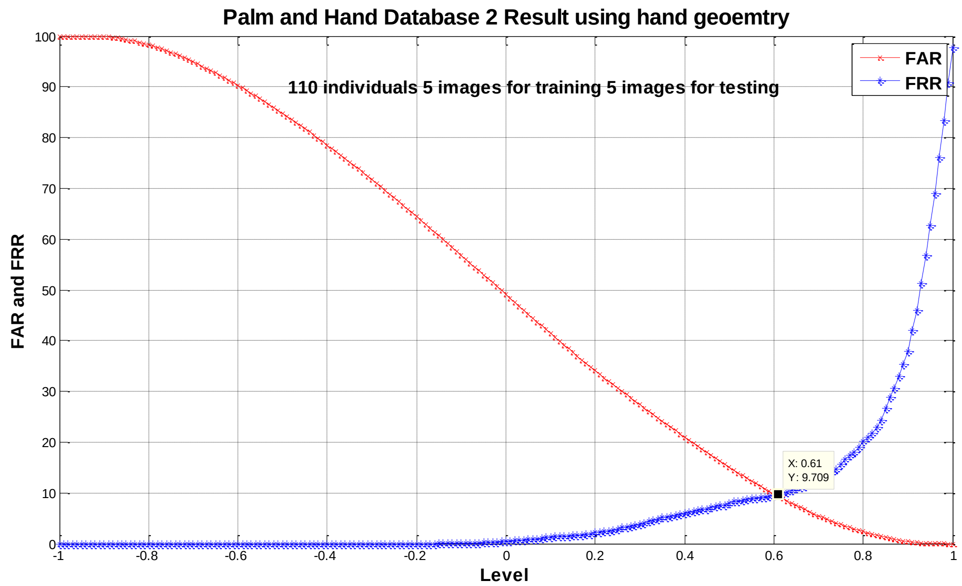


Figure 4-7 Experimental Results Using Hand Geometry Features and DB2

[SPACING – REMOVE]

4.3 *Texture analysis of Palmprints using Wavelets*

The wavelet transform is a tool for carving up functions, operators, or data into components of different frequency, allowing one to study each component separately. There are many other transforms that are used quite often for example Hilbert transform, short-time Fourier transform, Wigner distributions, the Radon Transform, and the wavelet transform etc.

The discussion is started from Fourier analysis to get some historical background of Wavelet transformation.

4.3.1 Evolution of Wavelet Transform [WHY HEADINGS DOWN]

Fourier Transform (FT

Short Time Fourier Transform (STFT

Wavelet Transform (WT

Comparative Visualisation

Fourier Transform

Fourier analysis is a mathematical technique in which a signal is transformed from time domain to frequency domain. FT (as well as WT) is a reversible transform. However, only either of them is available at any given time. That is, no frequency information is available in the time-domain signal, and no time information is available in the Fourier transformed signal. Fourier analysis is often better to be used when only frequency contents of a signal are needed. It has a serious drawback in situations where we need time information as well i.e. where a particular frequency exists. It means that it tells us how much of each frequency component exists in the signal, but it does not tell us when in time these frequency components exist. When the signal is stationary this information is not required because the frequency content of stationary signals do not change in time. Due to this drawback FT is not a suitable technique for non-stationary signal.

The Short Time Fourier Transform

To overcome the limitations of the standard FT, Gabor [24] introduced the initial concept of Short Time Fourier Transform (STFT). Short Time Fourier Transform (STFT) is used when the time localization of the spectral components is needed. STFT is used to analyze only a small section of the signal at a time - a technique called Windowing the Signal. In STFT, we have to choose proper sized window which is often considered as a drawback. In STFT, good frequency response can be achieved by large window but it will not give very good time information and vice versa. This problem known as resolution problem led to the development of wavelet transform [12, 13].

Wavelet Transform

Wavelet Transform is an alternative approach to the short time Fourier transforms to overcome the resolution problem. Similar to STFT in wavelet transform signal is multiplied with a function but width of the window is changed as the Transform is computed for every spectral components.

Wavelet analysis allows the use of long time intervals where we want more precise low-frequency information, and shorter regions where we want high-frequency information [14].

The following figure summarizes the above mentioned signal analysis approaches.

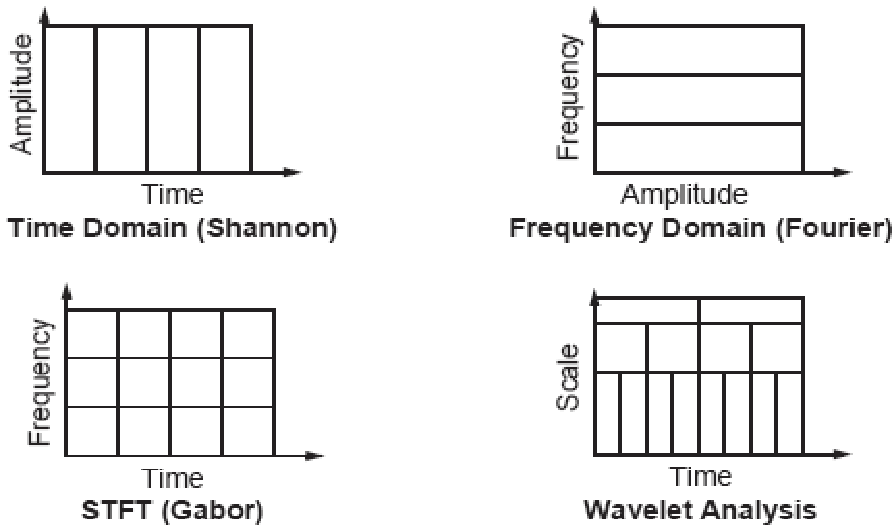


Figure 4-8 Signal Analysis Approaches

4.3.2 Theoretical Aspects of Wavelet Transform

Continuous Wavelet Transform

The equation of continuous wavelet transform is

The mother wavelet is chosen to serve as a prototype for all windows in the process. All the windows that are used are the dilated (or compressed) and shifted versions of the mother wavelet. There are a number of functions that are used for this purpose. The Morlet wavelet and the Mexican hat function are two candidates.

For the computation of CWT following procedure is used

a. The wavelet is placed at the beginning of the signal, and set s=1 (the most compressed wavelet);
b. The wavelet function at scale "1" is multiplied by the signal, and integrated over all times; then multiplied by $\frac{1}{\sqrt{|s|}}$;
c. Shift the wavelet to $t=\tau$ and get the transform value at $t=\tau$ and s=1;
d. Repeat the procedure until the wavelet reaches the end of the signal;
e. Scale s is increased by a sufficiently small value, the above procedure is repeated for all *s;*
f. Each computation for a given *s* fills the single row of the time-scale plane;
g. CWT is obtained if values corresponding to all s are calculated.

Discrete Wavelet Transform

The foundations of the DWT go back to 1976 when Croiser, Esteban, and Galand devised a technique to decompose discrete time signals. It is difficult to calculate the wavelet coefficients at all possible (continuous) scales of the original signal. Therefore only a subset of scales and positions is chosen at which we calculate the wavelet coefficients.

Wavelet Analysis

In wavelet analysis, we often speak of approximations and details. The approximations are the high-scale, low-frequency components of the signal. The details are the low-scale, high-frequency components. Filtering process is used to obtain the approximation and detail coefficients of a signal. Figure 4-9 illustrates the filtering process [14].

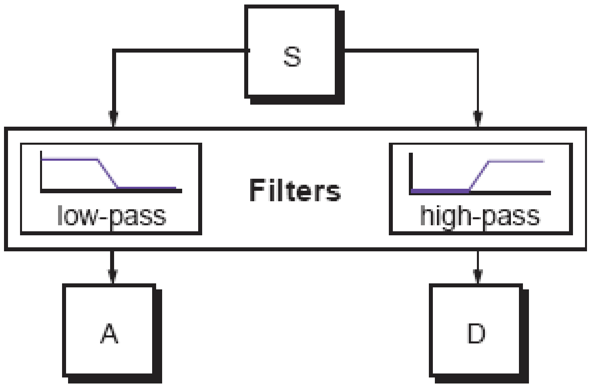


Figure 4-9 Filtering Process

Here S is the original signal and a low-pass filter is used to calculate approximation coefficients (A) and a high-pass filter for detail coefficients (D).

If we perform this operation on a real discrete signal consisting of say 1000 data points, then we will end up having 2000 data points (1000 from each filter). To avoid this problem, a process called down-sampling is used in which only one out of two in each of the two 1000 samples is kept to get the complete information [14].

This process is illustrated in figure 4-10.

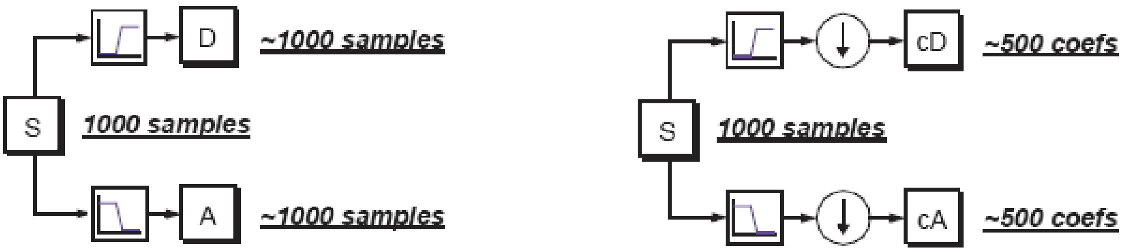


Figure 4-10 Process of Down Sampling

Signal can be decomposed into approximation and detail coefficients. This decomposition process can be iterative to produce a wavelet decomposition tree as shown in Figure 4-11.

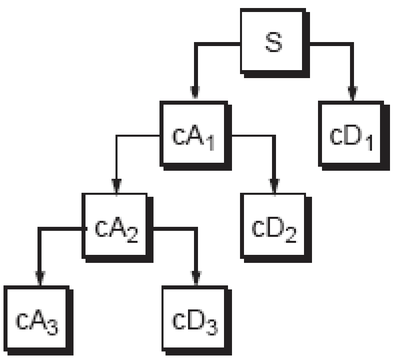


Figure 4-11 Signal Multilevel Decomposition

Approximation coefficients at each level are further decomposed using this approach.

4.3.3 Image Pre-processing

Image pre-processing is the first step for texture analysis of palmprint using wavelets. The processes in this step include image cropping, grayscale conversion, binary thresholding, noise and peg removal and edge detection. All these processes have been explained in chapter 2.

4.3.4 Feature Extraction

In proposed system texture features are extracted by applying wavelet transform on palm prints (ROI).

Image segmentation is applied to extract the palmprint images such that a square palm image of variable side length depending on the distance between the two extreme fingers is extracted. Palm print image is further segmented into four equal segments and then 2-D wavelet decomposition is applied on each segment.

Different level of decomposition is applied on palm segments but optimal decomposition level that is found was three. Similarly different wavelets are tested and best results are obtained by using dmey wavelet. Following two types of features are extracted as texture features of the palmprint.

(iii) The percentage of energy corresponding to the approximation, horizontal, vertical, and diagonal details.

(iv) Energy of autocorrelation functions of the wavelet coefficients.

In this way we get eighty features of a palm. Feature reduction is done by applying the PCA such that those features are retained containing 98% energy. Using threshold 0.98, 40 features retained and remaining 40 features are discarded.

The similarity of two feature vector is measured by using Euclidean distance as similarity measure which is explained in chapter 3.

4.3.5 Feature Normalization

Each feature is normalized before matching score to have range [0, 1]. The normalization procedure is to transform the feature component x to a random variable with zero mean and unit variance as

where μ_i and σ_i are the sample mean and the sample standard deviation of that feature respectively.

4.3.6 Experimental Results

Similar to the previous techniques (hand geometry and PCA), the experimental results are obtained using the two Datasets i.e. DB1 and DB2.

The experimental results Using PIEAS Hand Database 1 are shown in figure below

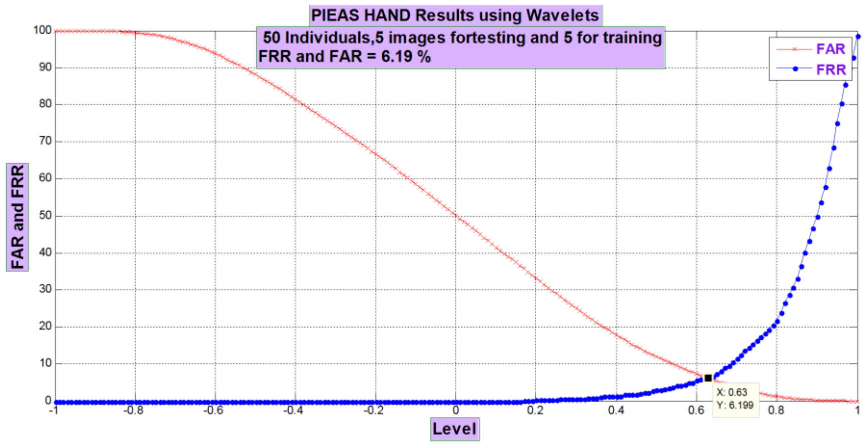


Figure 4-12 Experimental Results by Using Texture Features and DB1

The experimental results Using PIEAS Hand Database 2 is shown in figure below. The optimal threshold value is 0.66 and accuracy is approximately 91.24%.

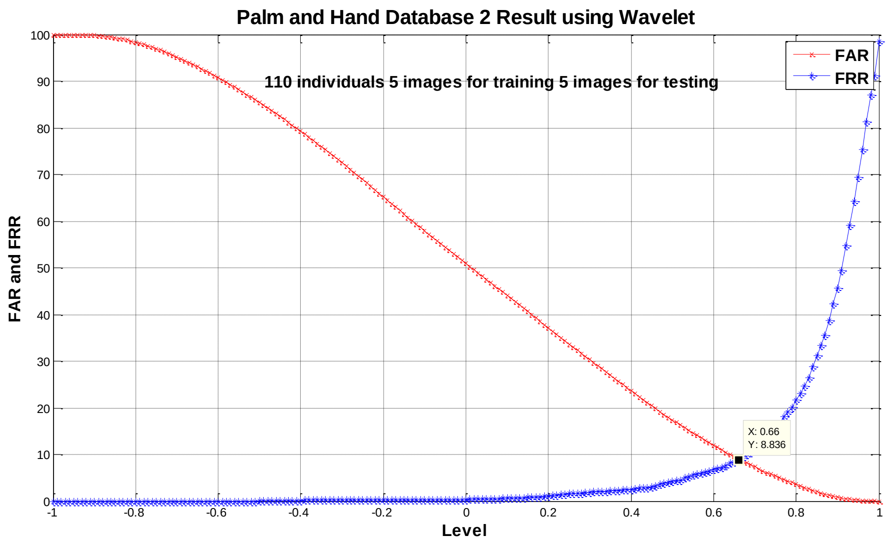


Figure 4-13 Experimental Results by Using Texture Features and DB2

Chapter 5- Feature Integration and Reduction

5.1 Feature Integration

In the proposed system three types of features are extracted from a hand image i.e. PCA based global hand shape feature, hand geometry features and wavelet domain features of palm print. The extracted features are merged to enhance the accuracy of the verification and identification system. These three types of features can be combined by a number of information fusion strategies that have been proposed in the literature [22], [23].

(i) fusion at representation level, where the feature vectors of multiple biometric are concatenated to form a combined feature vector

(ii) fusion at decision level, where the decision scores of multiple biometric system are combined to generate a final decision score

(iii) fusion at abstract level, where multiple decision from multiple biometric systems are consolidated.

In the proposed system features of the three techniques (i.e. hand shape features extracted by using PCA, hand geometry features and texture features of palm prints) are integrated at the representation level.

The accuracy of the system using PCA is 94.5%. it is 91.73% by using hand geometry features and 93.74% on texture features of palm prints. But after integrating the three types of features, accuracy of the system increase to 96.4% which is more than any individual technique as shown in table.

Table 5-1 Performance Analysis of the Techniques (Individual vs. Integrated)

METHOD	PCA	HAND GEOMETRY	WAVELETS	PCA+ WAVELETS + HAND GEOMETRY
Accuracy (%)	94.5%	91.73%	93.74%	96.4%
Number of Features	15	16	40	71
Time for training (per image)	1.5 sec.	1.65 sec.	3.2 sec.	6.35 sec.

5.2 Feature Reduction

The feature reduction is an important process to improve the system performance. Feature reduction reduces the classification time and it is also used to avoid the curse of dimensionality.

5.2.1 Principle Component Analysis as a feature reduction technique

PCA is a useful statistical technique that has important use in fields such as face recognition and image compression, and is a common technique for extracting relevant information from confusing data sets. With minimal additional effort PCA provides a roadmap for how to reduce a complex data set to a lower dimension to reveal the sometimes hidden, simplified structure that often underlie it [9].

Using the PCA feature extraction technique a total of 250 features are obtained. In order to reduce the number of features, a threshold is applied. To reduce the number of features upto 15 a threshold of 0.98 is used. This threshold value reduces the complex dataset by retaining those features containing more than 98% energy and discards other features having less than 98% energy.

Using the Wavelet Domain analysis of palm as feature extraction technique a total of 80 features are extracted. In order to reduce the number of features, PCA with a threshold 0.98 is applied. This reduces the number of features from 80 to 40 and the remaining 40 features are discarded. The performance wavelet domain analysis of palm prints is evaluated by changing the number of selected features and also by changing the wavelet function as shown in table below.

After the feature reduction the feature vector contained 71 features and the remaining 275 features are discarded because they have low contribution to variance of the data.

Table 5-2 Experimental Results of Wavelets Selecting Diff. No. of Features

Experiment No.	Database	Selected Features	Wavelet Function	Accuracy %
1	DB2	all	Db3	92.71
2	DB2	34	Db3	92.6
3	DB2	15	Db3	91.28
4	DB2	08	Db3	90.08
5	DB2	06	Db3	89.76
6	DB2	05	Db3	88.18
7	DB2	04	Db3	86.96
8	DB2	03	Db3	84.32
9	DB2	05	Dmey	88.96
10	DB2	06	Dmey	89.52

11	DB2	08	Dmey	91.32
12	DB2	16	Dmey	93.26
13	DB2	24	Dmey	93.52
14	DB2	38	Dmey	93.74
15	DB2	all	Sym3	91.6
16	DB2	all	Coif3	91.84
17	DB2	all	Haar	89.8

Chapter 6- Experimental Results by Combining the three Techniques and after Feature Reduction

In order to perform a comparison we integrate the features of individual techniques with one another in such a way that first of all hand geometry and Hand image PCA features are integrated and then PCA and Palm print Wavelets features are integrated and obtained the results. In similar way hand geometry and texture features are integrated and finally features of all the three techniques are integrated and result are noted. The results obtained by integrating the three techniques are much better than the result obtained by integrating any two techniques.

6.1 Experimental Results by Integrating Hand Geometry and PCA Features

The experimental results using PIEAS Hand Database1 and combining the features of hand geometry and PCA are shown in figure below. The optimal threshold value is 0.63 and error rate is approximately 6.96%.

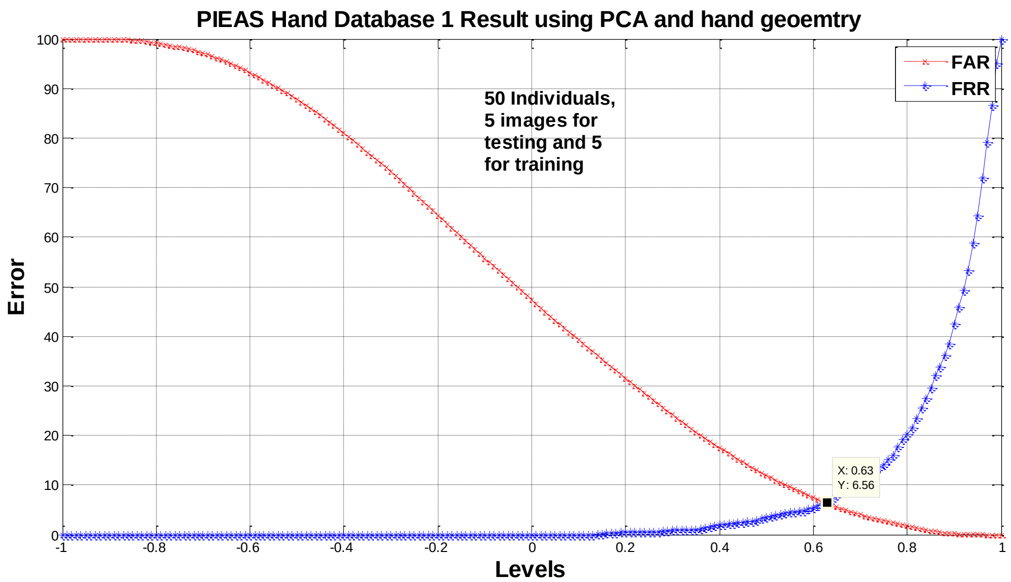


Figure 6-1 Experimental Results Using PCA and Hand Geometry and DB1

The experimental results using PIEAS Hand Database2 and combining the features of hand geometry and PCA are shown in figure below. The optimal threshold value is 0.61 and error rate is approximately 8.18%.

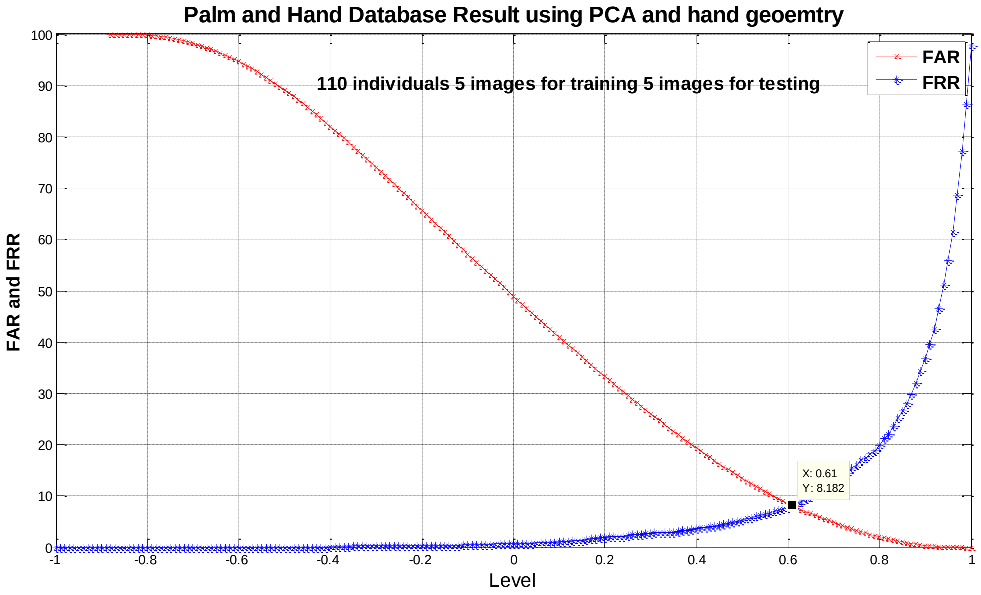


Figure 6-2 Experimental Results Using PCA and Hand Geometry Features and DB2

6.2 Experimental Results by Integrating Hand Geometry and Palm Texture Features

The experimental results using PIEAS Hand Database1 and combining the features of hand geometry and Wavelets are shown in figure below. The optimal threshold value is 0.53 and error rate is approximately 5.93%.

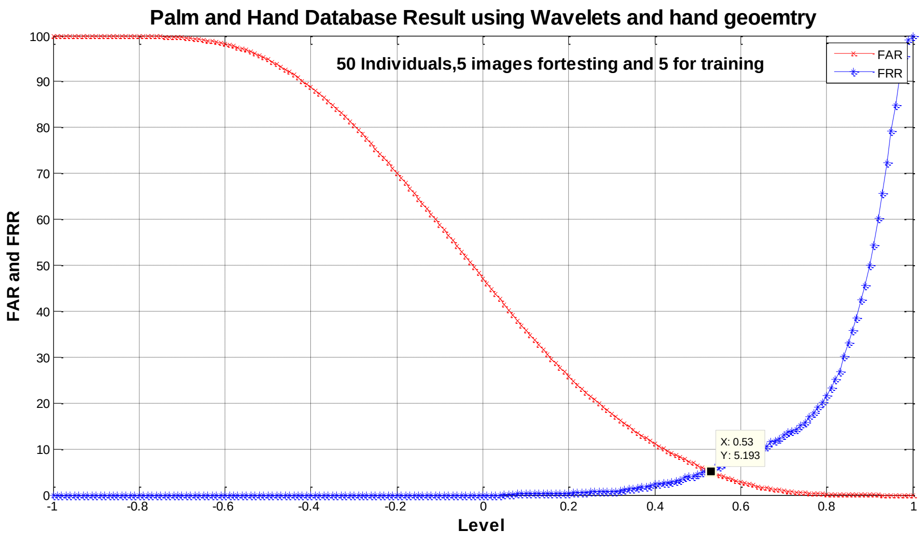


Figure 6-3 Experimental Results Using Wavelets and Hand Features and DB1

The experimental results using PIEAS Hand Database2 and combining the features of hand geometry and Wavelets are shown in figure below. The optimal threshold value is 0.56 and error rate is approximately 6.43%.

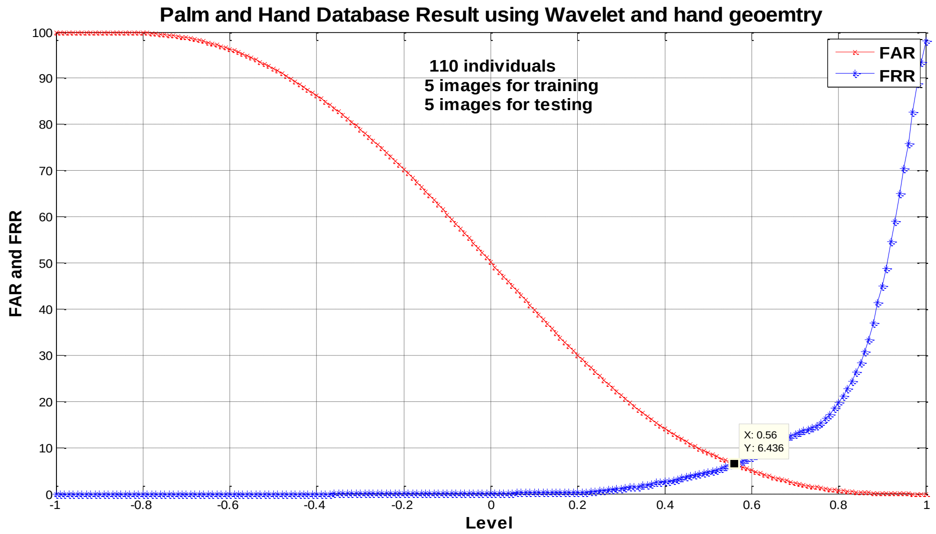


Figure 6-4 Experimental Results Using Wavelets and Hand Features and DB2

6.3 Experimental Results by Integrating Palm texture and PCA Features

The experimental results using PIEAS Hand Database1 and combining the features of PCA and Wavelets are shown in figure below. The optimal threshold value is 0.62 and error rate is approximately 5.123%.

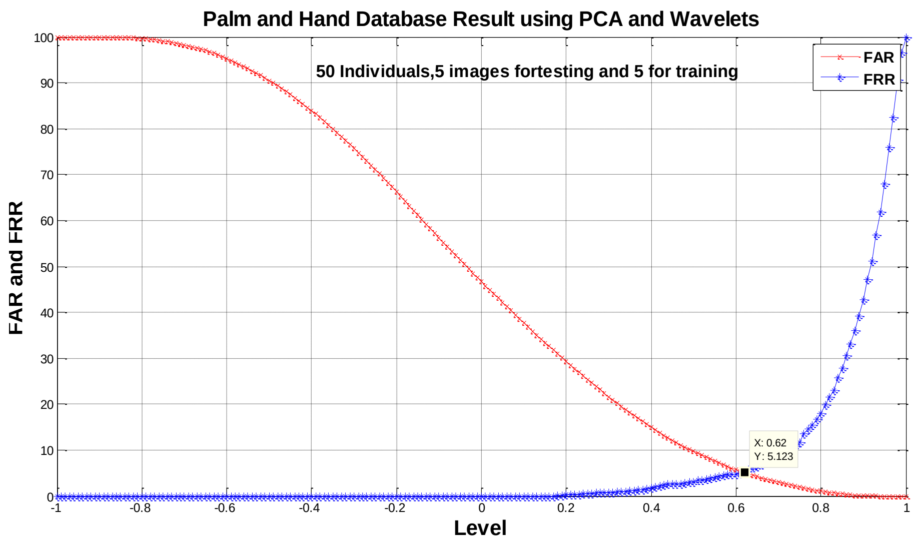


Figure 6-5 Experimental Results Using PCA and Wavelets

The experimental results using PIEAS Hand Database2 and combining the features of PCA and Wavelets are shown in figure below. The optimal threshold value is 0.61 and error rate is approximately 7.67%.

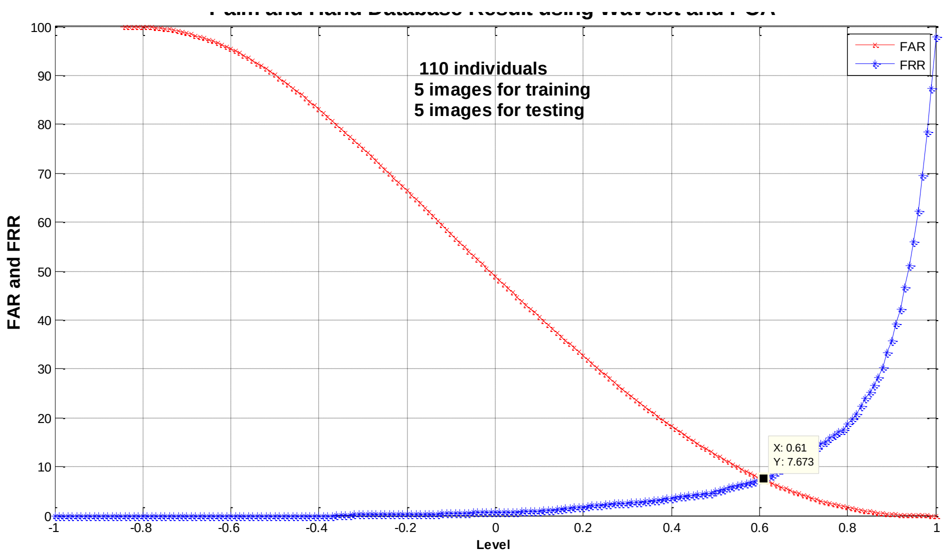


Figure 6-6 Experimental Results of DB2 using PCA and Wavelets

6.4 Experimental Results by Integrating all the Three Techniques

The experimental results using PIEAS Hand Database1 and combining the features of PCA, hand geometry and Wavelets are shown in figure below. The optimal threshold value is 0.61 and error rate is approximately4.88%.

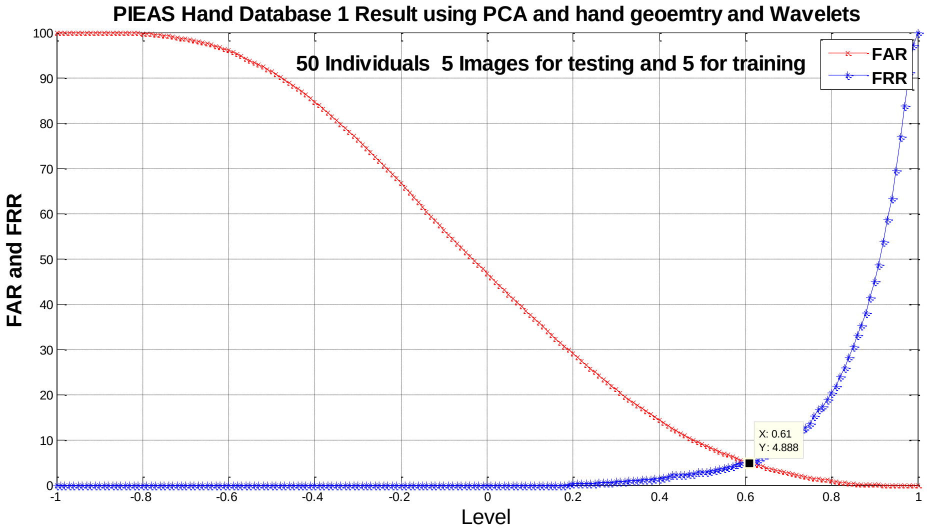


Figure 6-7 Experimental Results Using Combine Features of Hand Geometry, PCA and Wavelets

The experimental results using PIEAS Hand Database 2 and combining the features of PCA, hand geometry and Wavelets are shown in figure below. The optimal threshold value is 0.6 and error rate is approximately 7.38%.

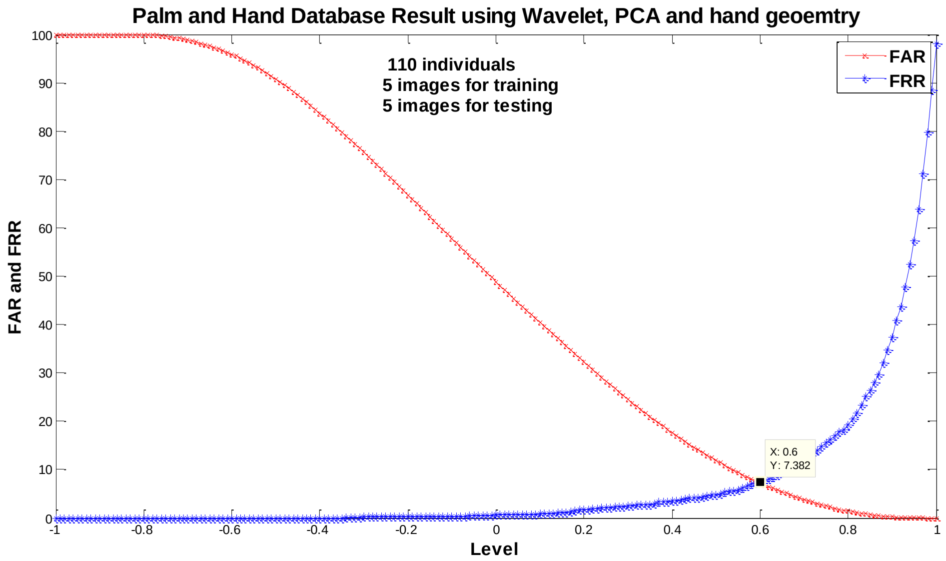


Figure 6-8 Experimental Results of DB2 Using PCA, Hand Geometry and Wavelets

Chapter 7- Conclusion and Future Directions

In this thesis, a novel approach is presented to identify person using their hand shape, hand geometry and palm texture features. These features are proposed to be extracted from a single hand image acquired using a simple flatbed scanner. A palm print image contains the texture information and wavelet transform is applied to extract the texture information. PCA is applied to extract the hand shape features and image processing techniques are applied to extract the hand geometry features. The hand shape includes the hand geometry features and the interior contents of hand. The hand geometry features that are used for identification includes finger lengths, finger widths, palm length, palm width and hand length. By the integration of features extracted by proposed techniques i.e. PCA, Hand geometry, and wavelet domain analysis of palm, a higher accuracy to identify an individual is achieved. Experimental results suggest that majority features of hand are useful for person recognition. Using DB1 and DB2, accuracy of the proposed system is about 96.4% and 94% respectively.

Currently, we had directed our efforts to improve the accuracy of the identification system. Therefore the optimization of the code in terms of execution time has not been performed. The performance of the system can be improved by optimizing the code.

In the future, there are two fold improvements: In pre-processing phase, image alignment step can be added to align all the images which will defiantly improve the accuracy of the system. In the feature extraction phase, a gabor filter can be used to extract the palm texture features and 2D-PCA can be applied to extract the hand shape features to improve the accuracy of identification system. In future work, a technique of complex wavelet structural similarity index matrix to minimize the effect of rotation of images and the effect of luminance.

Another interesting area of research is the study upon the classification techniques. We have used Euclidian distance as a similarity measure. Other classification techniques can be used for the classification of features such as Support Vector Machine (SVM)**,** LYQ and multilayer perceptron, etc.

The software development and deployment of this project is also the future objective.

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