Dorsal Hand Veins Based Person Identification

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2011-NUST-MS PdD-ComE-11

MS69-11-113(ComE)

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THESIS

Submitted in partial fulfillment of the requirements for the degree of

Masters in Computer Engineering

Department of Computer Engineering

College of Electrical & Mechanical Engineering

National University of Science & Technology

2014


بسم الله الرحمن الرحيم
In the Name of Allah,
the Beneficent, the Merciful.

Declaration

I hereby declare that this thesis has been built on my personal efforts under the generous supervision of Dr Usman Akram. All the sources that were used in this work have been cited and the contents are not plagiarized. No data of this thesis has been shared as a part of any research work presented in any other institute for fulfillment of degree requirement.

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Dedication

Dedicated to our respected Teachers and loving parents who taught us how to lead this life in stress and strain. And also to my friends who helped me a lot in completing this work.

Acknowledgements

First of all, I would like to thank Allah Almighty who gave me the ability and bestowed me with perseverance to complete this thesis. He is the ONE I always looked to in the event of trouble and He always created a way for me out of the trouble. I would not be what I am today if He did not want me to be.
I would like to express my deep-felt gratitude to my advisor, **Dr. Usman Akram**, for his advice, encouragement, enduring patience and constant support. He was never ceasing in his belief in me, always providing clear explanations when I was lost and always giving me his time, in spite of anything else that was going on.
I gratefully acknowledge my committee members, **Dr. Shoaib A. Khan, Dr. Arslan Shoukat** and **Dr. Aasia Khannum**.
Special thanks of **Bulent Sankur,** Bogazici University, Department of Electrical and Electronics Engineering, Turkey for providing database that was very helpful in our research.

Last but not the least; I would like to thank my family and my friends supporting me spiritually throughout my life.

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Abstract

Biometrics is a way that identifies people with the help of physical human features. There are many ways of biometric identification and recognition systems such as fingerprints, face, iris and veins etc. However, these conventional methods have some problems with respect of performance and convenience. Every human hand has unique veins patterns. Hand veins based recognition is most feasible than all of other conventional methods especially because of its easy acquisition process and also difficult to forge hand vein pattern. Patterns are taken from inside the body rather than obtaining from outside the body. Due to no physical contact, internal features and patterns from live body makes it more secure than other methods. In this research, we present a new method for person identification based on hand veins. The proposed system consists of pre-processing, vein enhancement and segmentation, feature extraction and finally matching. A new filter bank based method for hand veins enhancement is presented here. The proposed system is tested and evaluated using Bosphorus hand vein dataset which consists of 1200 hand images from 100 different people with 12 images per person. The proposed system has achieved 1.3% false acceptance and 1.75% false rejection rate respectively at a threshold of 0.85. Overall accuracy achieved by proposed system is 96.97%.

Table of Contents

List of Tables

List of Figures

List of Equations

Chapter 1: Introduction

1.1: Biometrics

Biometric word is taken from Greek language words “bio” and “metrics” that means “life” and “to measure” respectively. Biometrics is the techniques that classify the objects on the basis of their distinguishing properties or characteristics. Biometrics is mostly used in surveillance and security fields where a person has to be identified in groups. Biometric identifiers are sometimes divided in two types: **1) Physiological** and **2) Behavioral**. Physiological traits **[13]** are related to the physical appearance of the body. Examples are hand geometry, retina, iris, hand veins patterns. **Behavioral** traits include the behavior patterns of a person. These include but not limited to typing rhythm, gait, speaking words, movement of body, signature and etc. Biometric is highly secure and reliable than other security systems because it uses human patterns whether they are **behavioral** or **physiological** than are very hard to alter or change. Biometric systems are adopted from a past few years by the world. But most of the techniques are invented on the basis of hundreds and thousands of years old ideas. The oldest technique is facial recognition based on the natural process of differentiating the known and unknown persons. This technique is based on how a person identifies a known person among a crowd**. [14]** Some other but modern techniques are: **Iris Recognition, Voice Recognition, Finger Recognition, Hand Print Recognition, Hand Geometry Recognition, Palm Print Recognition, Hand Veins recognition.** Biometrics systems are very useful for many purposes such as security, criminal records, in forensic, holding large database by the companies, saving huge records of companies for their employees and other many person identification applications.

[14][6] Any trait or characteristic is said to be biometrics whether it is behavioral or physiological if they fulfill following stated requirements.

- The characteristic should be universal means each person must have that characteristic.
- The characteristic must have to be unique from person to person. Characteristic of one person should be as same as of other person.

- The characteristic must have to be sufficiently time invariant.
- The characteristic can be measured on the basis of quantity not quality.
- The data that is captured should be large enough to be easily handled.
- Privacy of person should not be disclosed.
- Number of features should be minimum, so that it takes minimum time to compare and yields result.

1.2: Biometrics Technologies

Biometrics as discussed already is the measure of Physiological attributes of an object that are unique for the identification or verification process. The basic aim to adopt the biometrics is the security issue. But now days it is broadly used for other things where we need comparison of objects for identification or verification of a certain object. These systems are very powerful tool for this because they identify the objects on the basis or discriminating features that do not change during whole life time. Another advantage of these systems is that the person for whom we need identification or verification must be present at the spot. Biometric systems are pattern recognition based systems that read the attributes whether these are physiological or behavioral and give authentic result by recognizing the person. So**, [6]** biometric technologies are defined as the automated systems methods of identifying and recognizing the person with the help of their physiological or behavioral properties.

Firstly, finger print technology is used only to identify the persons. As the computer field kept itself to evolve and provides new technology, new technologies of biometrics systems are also invented. These technologies include Palm Print identification, Iris scan, Retina scan, Foot print identification, Hand veins identification, Signature recognition, Gait recognition, DNA recognition, Ear shape based recognition and etc. Figure 1.1 shows biometric technologies.

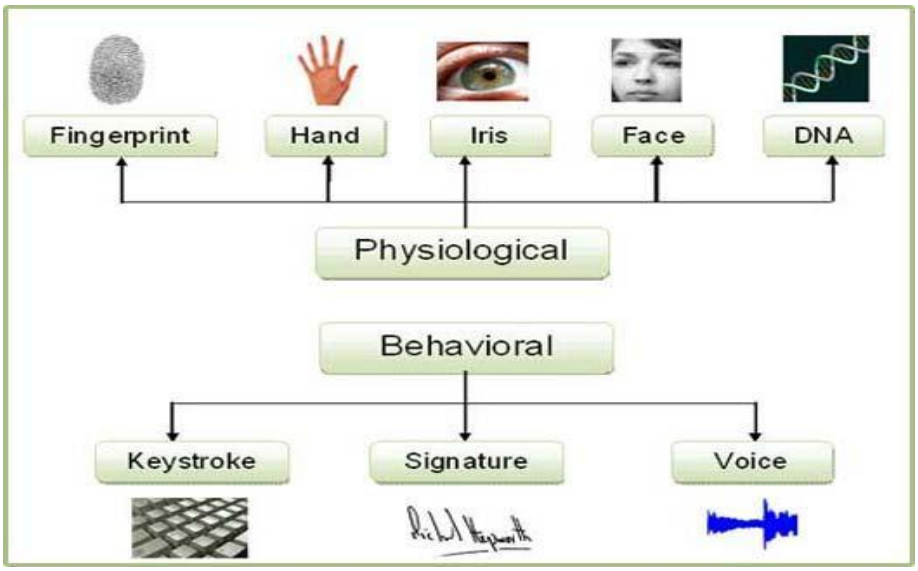


Figure 1.1: Biometrics Technologies [8]

Category	Traits	Universality	Uniqueness	Permanence	Measurability	Performance	Acceptability	Circumvention
Conventional	Face	H	L	M	H	L	H	H
	Finger Print	M	H	H	M	H	M	M
	Vein	M	M	M	M	M	M	H
	Iris	H	H	H	M	H	L	L
	Voice	M	L	L	M	L	H	H

H: High M: Medium L: Low

Table 1.1: Comparison of different Technologies on the basis of characteristics [11]

Category	Traits	Anti-Forgery	Accuracy	Speed	Enrollment Rates	Resistance	Cost
Conventional	Face	M	L	M	M	H	L
	Finger Print	L	M	M	L	L	M
	Vein	H	H	H	M	M	M
	Iris	M	H	M	M	H	H
	Voice	M	L	M	M	H	M

H: High M: Medium L: Low

Table 1.2: Comparison of different Technologies on the basis of System Requirements [11]

Table 1.1 and 1.2 shows the comparison between different biometric technologies on the basis of biometric characteristics and system requirements respectively.

1.3: Biometrics Advantages/Disadvantages

1.3.1: Advantages

1. Biometric properties are safe as compared to code numbers or letters because that cannot be forgotten or lost by anyone.
2. These characteristics are impossible to steal copy or share by anyone.
3. For a system biometrics characteristics holder must be present at the spot.

1.3.2: Disadvantages

1. People need learning to use the system.
2. Biometric constraints may be disturbed by and disease or accident. Finger print, palm prints, Retina, iris, hand geometry, face or etc can be disturbed by diseases or accidents.
3. Some biometric methods are very harmful to human organs such as retinal scan. Strong light can affect the cornia or retina.
4. Tools or machinery used for these systems are expensive.

1.4: Hand Veins Recognition and Difference between Hand and Veins based Identification/Verification

As, this research is based on hand veins so it is necessary to give a short introduction of hand veins, and they are useful in person identification. Veins are the vessels that transport the blood into the body. But they are not like arteries as they transport blood at low pressure after the exchange of oxygen and carbon dioxide takes place. Veins take the blood from body parts back to heart and lungs for the purification process. As we are related to hand veins so these veins transport the blood from hand to heart or lungs. Sometimes these veins are prominent and it's easy to find their pattern and sometimes it's very difficult to see the pattern by a naked eye. These patterns are unique from man to man and bear no resemblance to any other person on earth during the whole life time. There might be a change in their width with the increase of age

but this change is negligible and the overall pattern is not disturbed. Recognizing a person by veins is similar to recognizing the person by hand in such way that in both we use the geometry. But hand geometry is not a unique property. [9]It uses finger length, thickness and curvature as the features. And it is useful for verification but not for identification. By emerging it with other identification biometrics technologies, yields a powerful and more reliable identification system. Whereas veins are used for both identification and verification process cleverly. Each person has a unique ending and bifurcation for veins which gives powerful discriminating features. Figure 1.3 and 1.4 shows hand vein verification and hand veins.

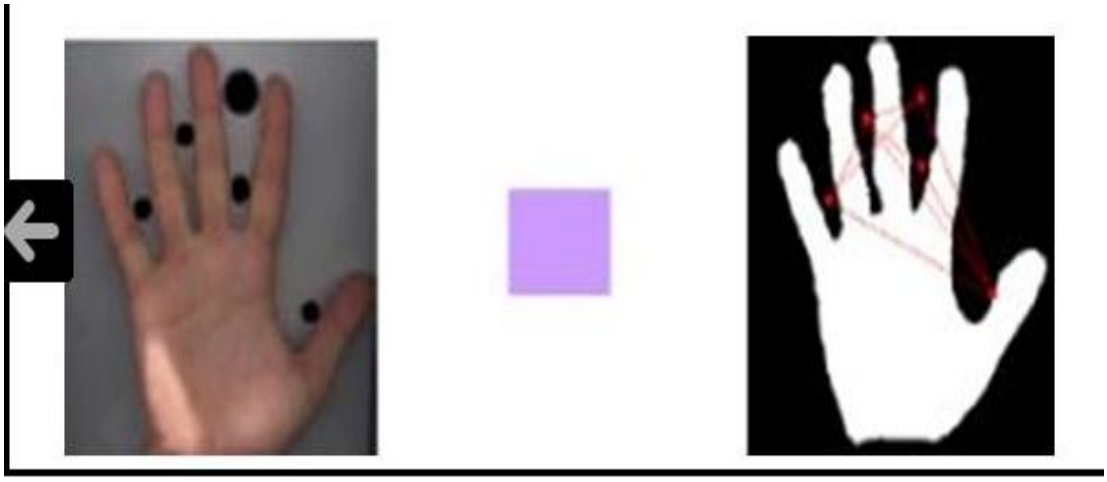


Figure 1.2: Hand Based Verification [10]

Figure 1.3: Hand Veins [12]

1.5: Motivation scope and Objectives

Person Identification is always an important issue in our world. As the science is evolving and making progress day by day, this issue is very much solved and defines more and more new ways to identify a person. Person identification is used in maintaining records of employees, in secured sites where un-authorized trespassing is not allowed, computer login, e- facilities, internet access, ATM, PDA, cellular phones, medical data records, credit cards, attendance management systems, NCIC, license, passports, terrorist identification, criminal records and etc. Before the advent of such systems it was very difficult to record the whole databases and perform identification so thoroughly. The first indexed fingerprints robust system was develop by Aziz-ul-Haque for IGP of Bengal, India. First biometric method was developed in late 1800 named as Bertillon's method that used indexed fingerprints. But true biometric systems are developed in the next half of 20^{th} century emerging with the computers.

To increase the security and decrease the crime rates and holding large amount of data records sites are equipped with these tools. It is noticed that it is easy to handle a number of large records, crimes are decreased and security has been improved. The systems are made so much intelligent that they provide very precise classification and give negligible error. Misclassification is not tolerable especially when this is system is working at a highly protocol sites.

The main objective of the proposed methodology is to solve security, data management and data searching issues. Following are some points used to achieve the objective.

- Acquiring an image captured by infrared camera
- Extracting the hand out of the image.
- Extracting Veins from the hand image.
- Calculate the features from the veins.
- Apply classifier on the basis of extracted features to classify the image.

1.6: Challenges

When a system is to be designed, there are many challenges that we face and should be kept in mind. When designing a system proposed in this thesis, challenges will be:

1. image acquisition containing hand veins,
2. reliable extraction of hand veins,
3. Extracting limited number of best features.
4. Best Classification.
5. Good recognition rate.
6. Minimum error rate.
7. Low Complexity.

1.7: Structure of Thesis

Chapter1 contains introduction of biometrics and its technologies along with their comparisons, advantages and disadvantages. It also includes motivation and scope of the biometrics proposed system.

Chapter2 contains different biometric techniques and hand vein recognition.

Chapter 3 contains literature review.

Chapter 4 contains proposed methodology of our automated human identification system.

Chapter 5 contains experimental results.

Chapter 6 described the conclusion.

Chapter 2: Dorsal Hand Veins

2.1: Biometric Systems

The systems that use these quantitative characteristics to differentiate the object by recording and comparing them are called **Biometrics system**. Biometric system gets the features from the person and then compared these feature with those features that are stored in database. When a new person uses the system, the system capture his/her features and record them into the database for further comparison. Firstly, the features that are taken from a person are verified by comparing them with the database. Secondly on the basis of these comparisons system gives result as output and this result helps to identify the person. Practically, these systems have to satisfy some requirements like performance that includes speed & accuracy, security, acceptability, robustness, low false acceptance rate and etc. Without fulfilling these, system cannot be useful and cannot yields good results.

2.2: Biometrics System Requirements

2.2.1: Performance

Performance refers to the speed and accuracy of the system. System should satisfy these two constraints by delivering the results in time and do not take too much time for processing and by giving minimum number of errors. If the system takes enough time to give output and gives also a lot of errors the system is a failure and not acceptable.

2.2.2: Security

Biometric system must be secured from un-authorized access and deceivable methods. It makes the system protected from unauthorized access and ensure safety of the system.

2.2.3: Acceptability

Acceptability means how many people accept a biometric identification system in their daily life. The system should be user friendly so that people can use it easily and it is accepted publicly. If the system is not user friendly, it will never be accepted by the people.

2.2.4: Low False Acceptance Rate

False acceptance rate (FAR) is the number of objects a system miss classify and incorrectly accept the access. The number of incorrect acceptance should be minimum. A large number of FAR tends to lead the system to failure. Figure 2.1 shows the parameters of biometric system.

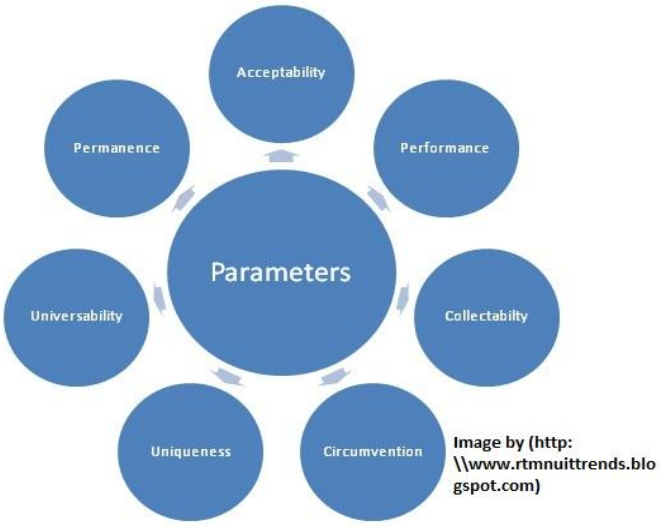


Figure 2.1: Biometrics Systems Parameters [7]

2.3: Commonly Used Biometrics System

Many biometrics systems have been designed by the different companies for different purposes now a day. Each system has its own purposes of design and each of them is application specific. There are many systems that have been built such as Facial Recognition Systems, Retina Based Identification, Ear Based Identification, Hand Geometry Based Person

Recognition, Person Identification on the basis of Gait, Voice, Palm Print, Key Stroke, Signature, Iris and etc. Some of the systems that are being used by people are described below.

2.3.1: Face Recognition System

Face recognition is one of the most common techniques used in the world. It may be static and controlled when used on the entrance of a room or building or when used a password to access any machine. Static facial recognition is also used in passports, identity cards, driving licenses ant etc. The other type of facial recognition method is dynamic facial recognition. This dynamic recognition is used where you have to identify a person in a crowd or when a moving person has to be identified. Face Recognition system uses the physical appearance of the components of face as well as their location like nose, eyes, lips and etc. These systems also identify the person by global analysis. Figure 2.2 shows facial recognition.

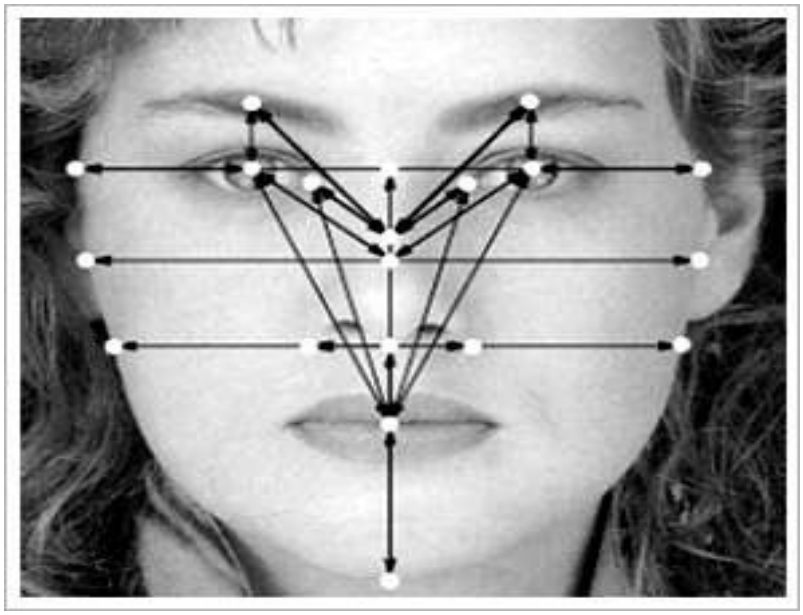


Figure 2.2: Facial Recognition

2.3.2: Ear Recognition

Ears are also used to distinguish people and to identify a specific person. Ear size, texture, color and distance from pinna to some reference points on ear can be selected as features on the basis of which person is recognized. Ear recognition technique is more secured than fingerprints technique as pattern of fingerprints can be disturbed easily. Figure 2.3 shows ear recognition.

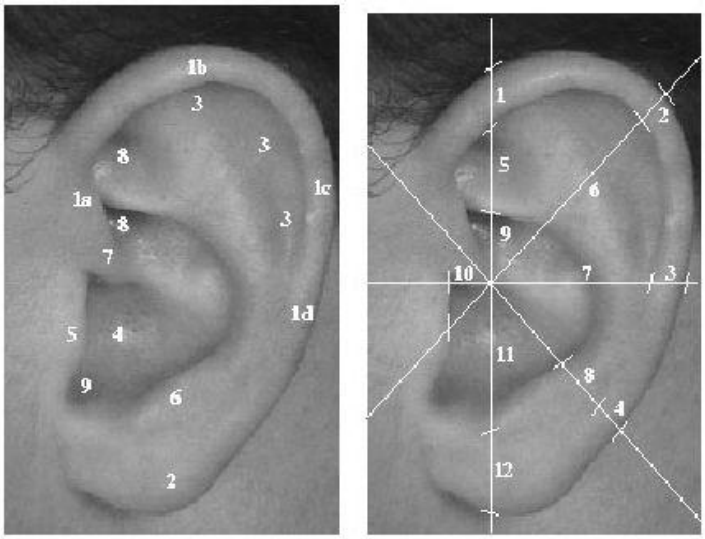


Fig. 2. (a) Anatomy, (b) Measurements. (a) 1 Helix Rim, 2 Lobule, 3 Antihelix, 4 Concha, 5 Tragus, 6 Antitragus, 7 Crus of Helix, 8 Triangular Fossa, 9 Incisure Intertragica. (b) The locations of the anthropometric measurements used in the "Iannarelli System". (Burge et al., 1998)

Figure 2.3: Ear Recognition [2]

2.3.3: Fingerprints Recognition

Fingerprints of every person are unique in the world. These are used from centuries to identify and recognize the people. The accuracy of fingerprints is very high. Every person has unique pattern of lines. Person's identification is done on the basis of the narrow bands of these lines. These lines can appear as an arc, loop or circle. These patterns are used as features by the classifier to take decision including the ending and bifurcation of the lines. Figure 2.4 shows finger line patterns and figure 2.5 shows fingerprint features.

Figure 2.4: Finger Line Patterns [3]

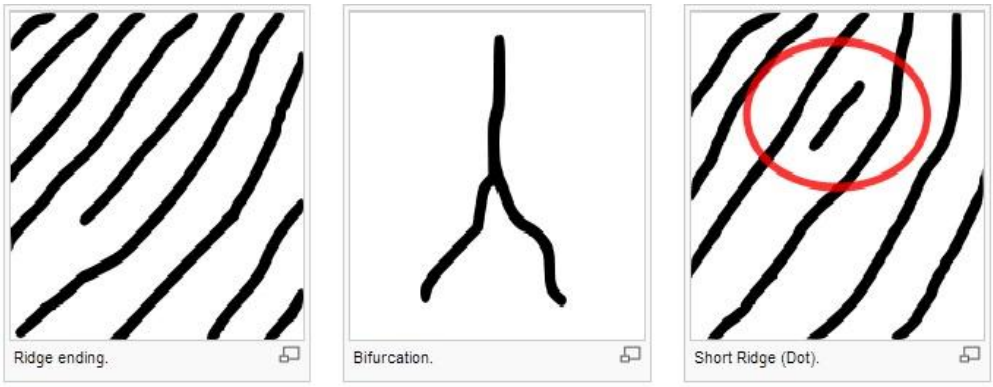


Figure 2.5: Finger Lines Ending and Bifurcation [3]

2.3.4: Palm Print Recognition

Palm print techniques are same as finger print technique. But the difference is that this much useful than the fingerprints because fingerprint has a small region to examine and it is difficult to extract good more efficient features rather than palm where there is a large region of lines pattern , narrow bands and ending and bifurcation of lines. Additional features are wrinkles and principle lines. Palm prints recognition systems are also cheaper than fingerprint systems because the patterns of lines are more prominent as compared to fingerprints and can be captured by a low resolution scanner. But these scanners are bigger than the fingerprint scanner and take more space. Figure 2.6 shows palm print features.

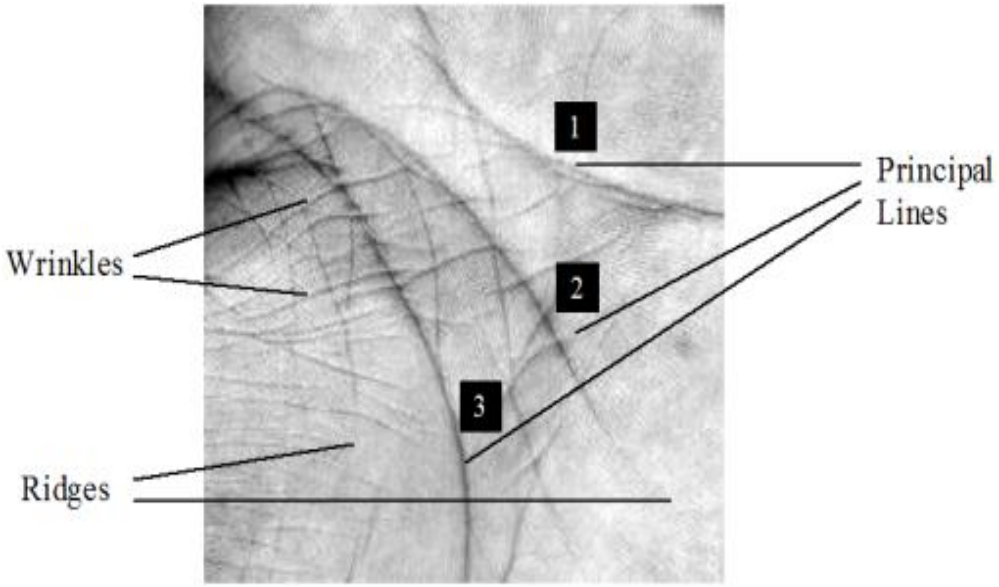


Figure 2.6 Palm Prints [5]

2.3.5: Retina based Identification

Retina is also used for efficient person identification. In fact retina is in the form of tissue which is basically made up to neural cells. Retina is rich of number of blood vessels that provide blood to retina. The pattern of these blood vessels is unique and bears no resemblance to any other man in the world. It does not change its pattern from birth to death. So these patterns provide good features for the identification processes. These patterns can only be changed by diseases such as diabetes, retinal disorder or glaucoma or any other retinal disease. A beam of low-energy is fired into eye. The blood vessels are more absorbent to light as compared to remaining eye part. The light record a specific path when there are variations occur in the reflection of lights during the scan. These variations are recorded after converting to a computer code. Figure 2.7 shows human retinal scan.

Figure 2.7: Retina Scan [4]

2.3.6: Footprint Recognition System

Another type of biometric person identification and verification system is footprint recognition system. It has advantage on other biometric system that based on appearance of a person such as facial recognition systems. In facial recognition system it is very difficult to recognize a person due to low illumination and optional features like hairstyle. Systems that use speech or signatures need person assistance while automated system like footprint recognition system does not need this. However this system is not used on large scale but can only be used in a house for family or roommates. Footprint recognition system distinguishes persons on the basis of their foot print geometry, their direction and position.

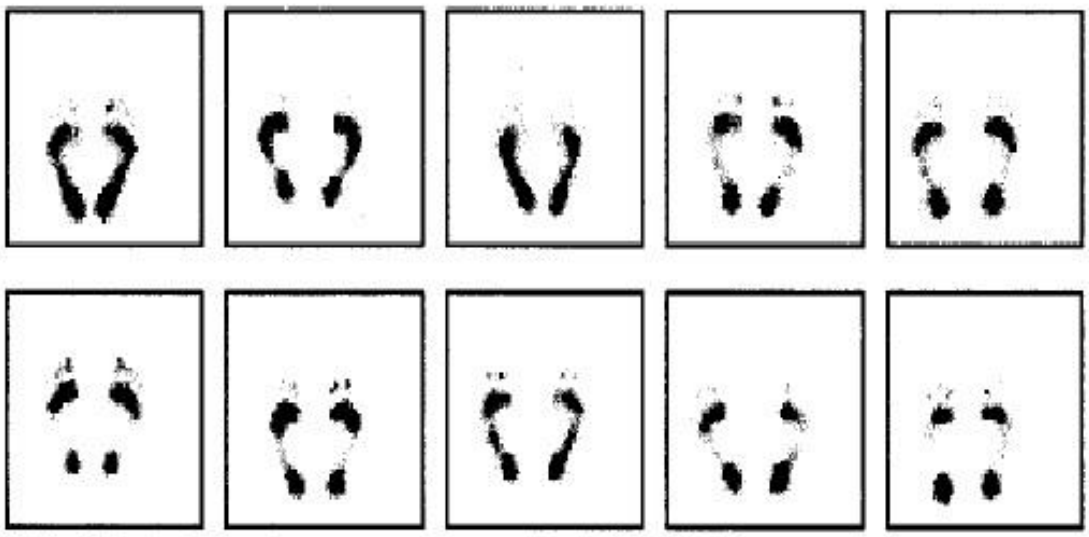


Figure 2.8: Input Raw Footprint Images [4]

2.3.7: DNA based Recognition System

DNA is Deoxyribo Nucleic Acid is a chemical constraint of a human body which is unique to every human and it is one dimensional constraint. But it is difficult to distinguish two twins because both have same DNA. These DNA are also called coding DNA. DNA of every person is different from others because of unique genome. Every person has different genome variations that make him/her different from other people. One main disadvantage of this system is that a DNA sample can be robbed and misused. Figure 2.9 shows DNA of a human person.

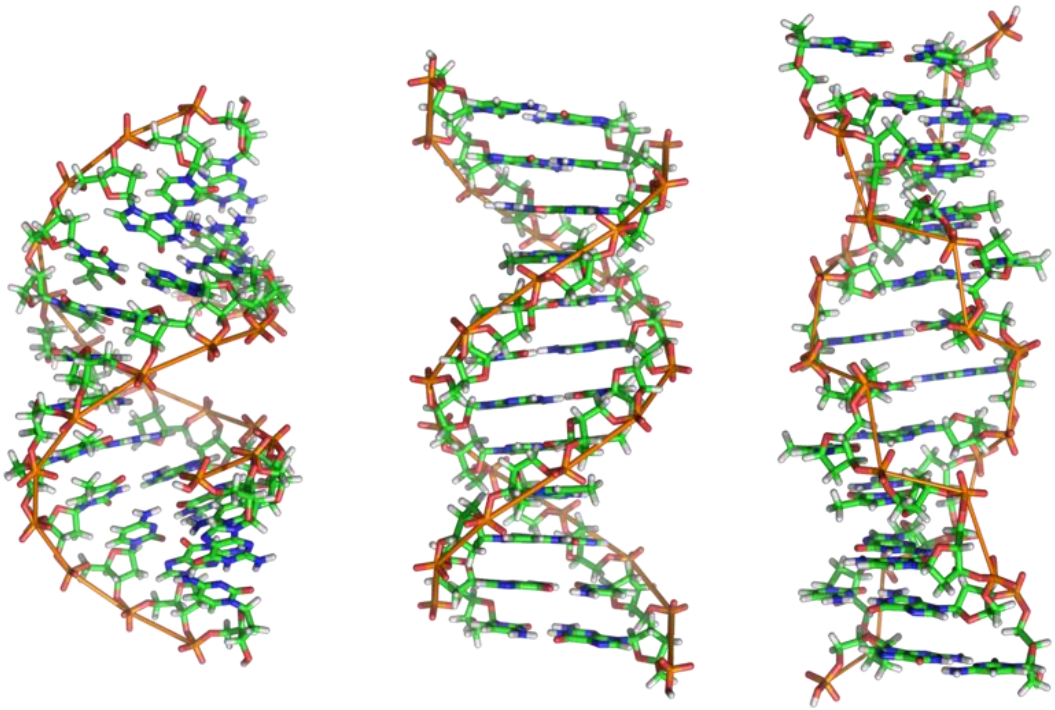


Figure 2.9: Different DNA's of a Human [34]

2.3.8: Iris based Recognition System

Iris is a region bounded with the white area of eye called sclera and with pupil. This region is in form of an annular shape. The texture of iris is developed during the growth of child in pregnancy and stabilized in first 2 years of life. These textures hold information that differentiates the persons uniquely. Like finger prints, iris of every person is unique even though they are twins and impossible to temper. Iris based recognition system is one of the most commonly used recognition system. Figure 2.10 shows NIR Iris scan image of a human eye.

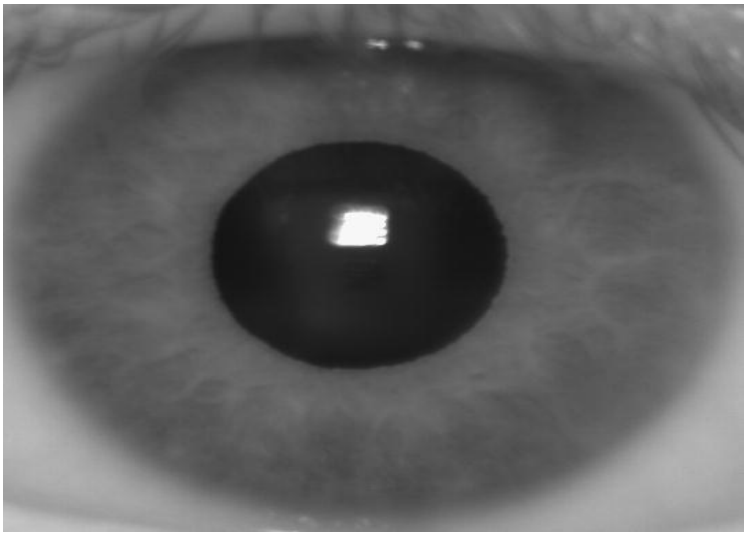


Figure 2.10: NIR Iris Image [36]

2.4: Applications

As stated earlier, this research is useful for the fields where the security is a sensitive issue. The system should meet some requirements; some of them are given below:

- Classifies the samples efficiently
- Takes minimum time for calculations.
- Uses minimum number of resources
- Provides high accuracy and error rate must be minimum.
- Speed should be high.

Applications of the proposed research are as follows:

2.4.1: Security:

- Airports.
- Railway station.
- Hotels.
- Sites where No trespassing for un-authorized personnel (Military sites, Government Sites, Law enforcement Agencies).
- Internet access and etc

2.4.2: Database management:

- Attendance Records
- Bank Records
- ATM and Credit Cards Records
- Medical Record
- Patient Record
- Social security Records

2.4.3: Forensic Records:

- Criminal Records
- Passport Records
- License Records
- Vehicle Registration Records
- Terrorists Records

2.5: Hand Veins

Hand veins are the blood vessels that take blood from the hand back to the heart or lungs for purification after the exchange of carbon dioxide and oxygen. Hand veins are organized in a specific pattern in the hand. These patterns have some features that make the hand a strong biometrics tools to differentiate between people and helps to recognize and identify them. Veins in human body like hand veins, arm veins, palm veins or retinal veins all can be used for person identification but the hand veins are preferred mostly [15]. Dorsal Hand veins, palm veins, finger veins or wrist veins each of them provide unique biometric stability. Figure 2.8 shows the venous plexus of the hand.

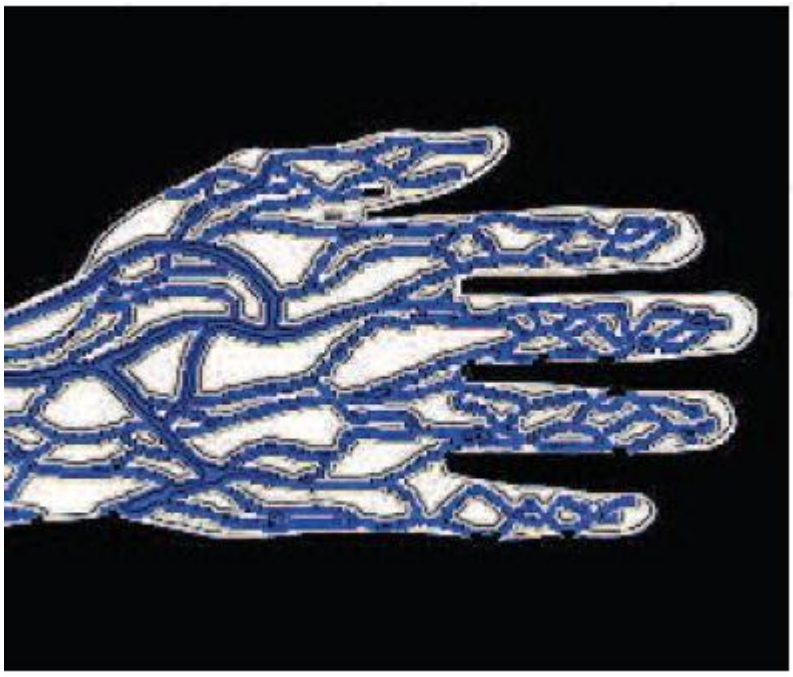


Figure 2.11: the venous plexus of the hand [11]

But our point of interest is dorsal hand veins only. We concentrate only on dorsal hand veins and discuss them.

[16] These veins make a network made up of metacarpel veins on back side of the hand and give rise to veins. Hand veins network is a superficial network and transfer blood into arms main vein cephalic vein and basilic vein that is located at the base of forearm. Figure 2.12 shows the hand vein structure.

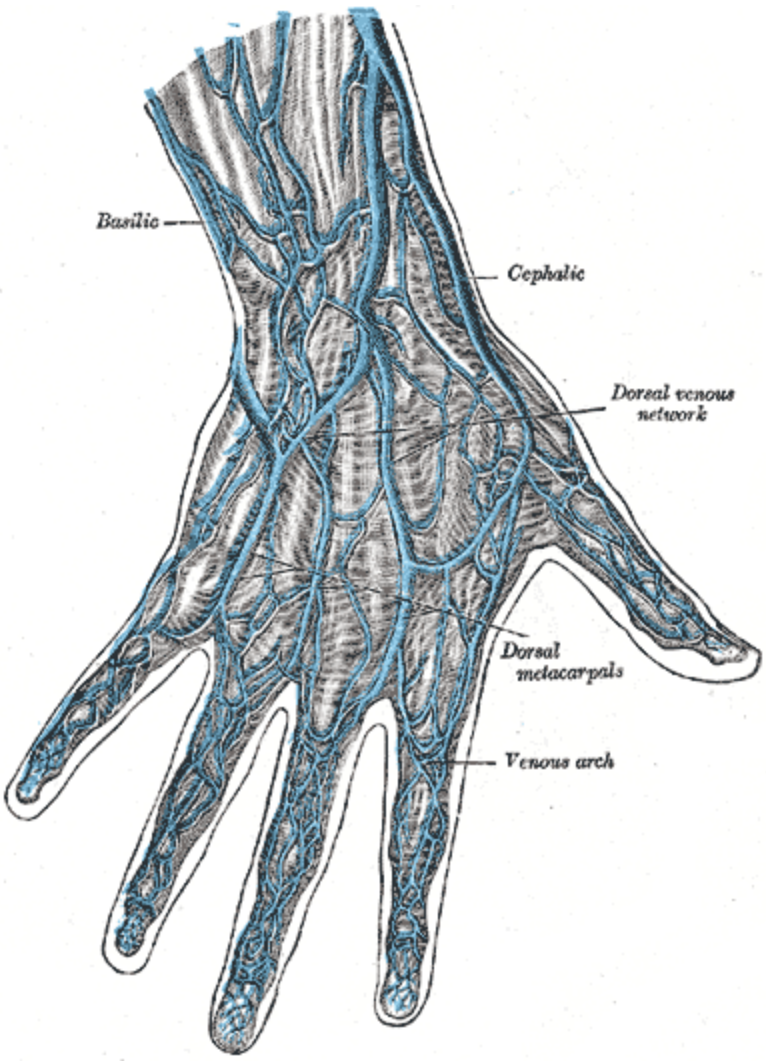
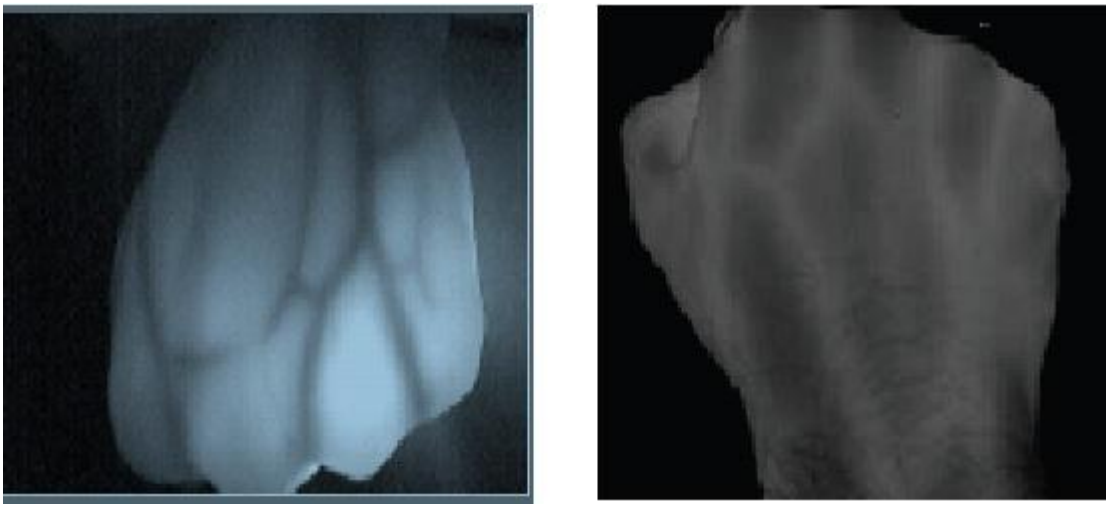


Figure 2.12: Hand veins Structure [37]

2.6: Hand Veins Recognition

Veins lies inside the body so they cannot be seen by visible light. [11] A number of methods are adopted such as: X-Ray, Ultrasonic and infrared. X-Ray and Ultrasonic method is used in medical but not in daily routine because these methods are dangerous to human body and impact bad effect on the body. So, only infrared method is used to acquire the veins pattern. [11] The wavelength of infrared light is equal the visible light and do not harm human body. It penetrates easily into the body and get image clearly. It has a wavelength of 750nm to 1mm. Infrared light

spectrum is divided into 3 parts: (1) Far-infrared, (2) Mid-infrared, (3) Near-infrared. First and the third type of infrared light are useful to acquire the veins image efficiently. FIR gets the image with the help of the temperature of the veins because veins are at higher temperature from the surrounding parts and mapped a thermal image at room temperature. Bur NIR only gets image of the nearby veins but not those that are very deep because NIR has low wavelength as compared to FIR. Figure 2.10 shows hand vein capture using NIR and FIR.



(A) (B)

Figure 2.13: A) NIR, B) FIR [11]

After acquiring the image, the image is pre-processed by using different image process techniques such as noise removal, thresholding, contrast enhancement and etc to make the image ready for further process. After this, features are selected that can give us best discrimination and then on classifier is applied on the basis of these features to get best approximation and minimum error.

2.7: Summary

This chapter consists of a short introduction of biometric system, performance attributes, some common biometric systems that are being used in world such as: iris recognition system, DNA based system, finger and palm print recognition system and etc as well as hand veins anatomy plus hand veins recognition.

Chapter 3: Literature Review

This chapter includes the literature review about the hand veins based identification methods. The researches that have done till now will be discussed in this chapter. While doing research on hand veins based person identification, people discovered many different algorithms and designed different systems to improve reliability and performance and also to make a more secure system. The main and common flow for most of the derived algorithms is given below.

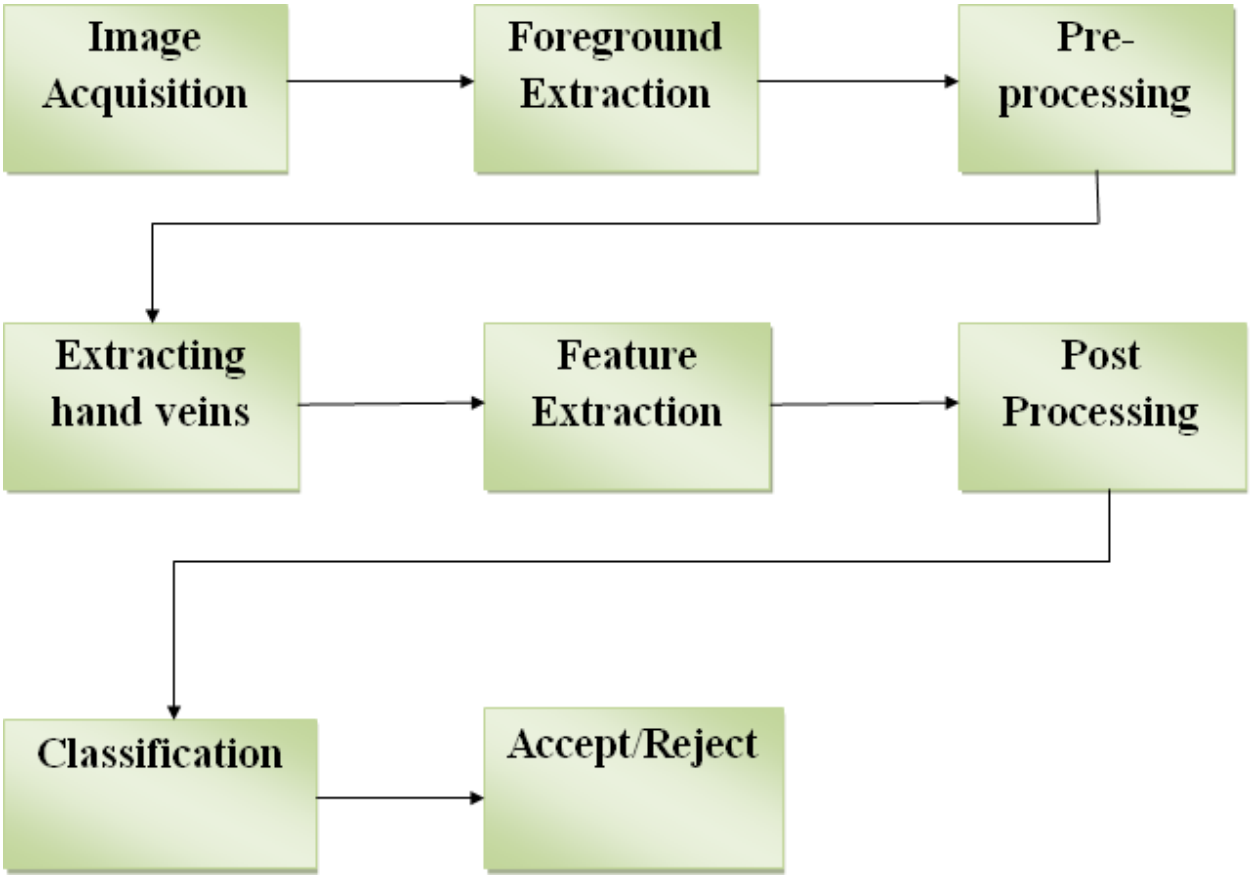


Figure 3.1: A General Data Flow of Systems

3.1: Background

Before invent of technology, in the past few years things are very complex and hard to solve. But as the time passed and people tried to find the ways so that bigger problems can be solved in easy ways and get accurate and reliable results. So as the technology is very much advance now a day that's why home use appliances to very complex scientific devices are reliable and easy to use. Different fields of science are now combined to obtain desired and interesting objectives. Among all the fields that are designed with the fusion of different science technologies is computer vision. This field took birth by the fusion of many different technologies like Control, Robotics, Artificial Intelligence, Digital Signal Processing, Digital Image Processing, Pattern Recognition and etc.

Our subject of interest is biometrics system design which deals with digital image processing and pattern recognition. The recognition rates are very high of these biometrics systems under the controlled conditions. But the robustness, performance and reliability are still a major problem. Hand veins patterns are although unique from person to person. Anatomically, the veins pattern of two twins is also different and it remains stable for long period [18]. A lot of work has been done on biometrics which is discussed as follows.

3.2: Literature Review

3.2.1: Image Acquisition

Aycan et al. [18][19] defines that the visibility of patterns is encountered by many different factors such as: body temperature, depth of veins inside the body, skin's thickness, physical activities and age of the person. It also depends on few body surface factors e.g. wrinkle, moles, wounds, hair and etc. Person recognition/identification is less studied than other human constraints. The reason is that these patterns are not visible to normal light and cannot be acquired. These patterns can be obtained by using infrared light clearly and efficiently. There are two types of infrared technologies are used to get the image of the patterns. First one is Far and the second one is Near typically abbreviated as FIR and NIR respectively. The wavelength of

FIR is 8 to 14 micrometers and suitable to obtained images of large veins but not good for providing a better and stable image under ambient conditions. But NIR works in the wavelength of 700 to 1000 nanometers and provide better images of those veins that lie in the depth of the body. This technology is more tolerable to changes caused by environment and body condition. **[18][19]** Used **Bosphorus Hand vein Database** to train and test the designed algorithm. Images were taken by using NIR technology plus reflection method. The region of interest from the back of the hand is illuminated with the help of two infrared light sources which are made up by using six infrared LED's placed in circular arrangement. Diffusion papers are used on front of light source so that light can be scatter uniformly. A monochromic NIR CCD camera is used to capture the image and it was placed on 80 cm height from hand. This whole setup was designed for a dark room but in real time the device automatically control and limits the visible light. Person was directed to place the back side of the hand facing towards the camera. Total number of images that were taken were 1200 of left hand of 100 different persons. Theses 1200 images are categorized into 4 types depending upon the activity that had been done before taking the images. In each category every person has 3 images. These categories are defined as below:

- Normal Conditions (N: Normal).
- Bag carrying for 1 min. (B: Bag).
- Ball squeezing exercise for one min repetitively. (Activity: A).
- After placing an ice pack on back of the hand (Ice: I).

Hasan et al. [20] [22] acquired image by using a near infrared technology. The infrared of wavelength 880 nanometers is fired by using a lighting source of ring shape mounted with lens. A infrared sensitive CCD camera was used to record the images. The hand is placed on the platform beneath the camera is in the form of fist having the back side of the hand was faced towards camera. Image acquiring device and computer is connected via communication cable. The platform on which fist was placed had two white rods to make sure that fist was placed on right place so that the image of interest was taken accurately. Database of 927 images were taken from 103 subjects while having 9 images per person. During the image acquisition room temperature was 23 °C and taken in a month by people of different ages and genders. [22] obtained images having resolution of 240 x 320. **Zahra et al. [21]** also adopted near infrared

imaging technique. The hand was lighted by array of infrared LEDs. Diffusion glass was used to provide a uniform light on each point of hand. Hemoglobin is sensitive to this wavelength and can absorb it easily from the surrounding so this region is much darker and clear from the surrounding environment. A CCD camera is used to capture the images. Images of 8 bit gray scale with a resolution of 320 x 240 pixels were recorded having 320 rows and 24 columns respectively. **Jia et al. [23]** obtained hand image by illuminating hand with the help of two infrared light arrays at wavelength of 850 nanometers. And image is captured by a CMOS sensor camera.

3.2.2: Pre-Processing

Aycan et al. [18] [19]The obtained images were digitized with the gray scale 8 bit resolution per pixel into 640 x 480. After that images size was reduced to 300 x 240 pixels. The resized image was normalized to extract the features that distinguish each image from other images. Noise is removed so that unwanted information did not cause any hurdle during feature extraction after converting the image into binary form. Contrast of the images was enhanced in order to highlight the hand veins that were not clear plus the morphological operations. **Hasan et al. [20]** Determined a region of interest after acquiring the image. The noise from the image was then removed because that was an extra information and not useful. In order to obtain region of interest the image obtained from camera the initial step image was locally thresholded with a threshold value of T=170. Masking was done on the thresholded image with a circular defined mask of size 7 x 7 and then moved on the image. This masking process yields two reference points which gave a center point of the first one. The top left point of region of interest was obtained by covering a distance of fifty pixels from reference point in downward direction and then 50 pixels to the left side from the newly obtained point. After finding the point a rectangle of size 240 x 180 was cropped from the gray scaled image. Noise from the region of interest is removed by applying a 3 x 3 smoothing mean filter plus histogram equalization phenomenon. Mean filter replaces every value of the centered pixel with the average value of the neighbors. After applying the filter the image contrast was enhanced by using a graphical method known as histogram equalization. The histogram graph shows the intensity values of pixel in the image and

can be adjusted bitterly. So, the distinctive features of the hand veins pattern can be more visible. Histogram equalization contains following steps.

1. Find the resultant of histogram values by adding them.
2. Divide these resultants value by total pixels of the image.
3. Take product of these divided values with highest gray level value.
4. Replace each resultant value with corresponding older values.

This new mapped image was then converted to binary image and then Otsu's thresholding algorithm is applied to extract foreground from the image. **Zahra et al. [21]** have done a number of operations in pre-processing phase. This includes gray scale conversion, contrast enhancement, thresholding, and morphological operation on the image, edge detection and skeletonization. After capturing the image from camera the image was then converted to gray scale image. Original image had 24 bits per pixel for representation while gray scale had only 8 bits per pixel. So these images are easy to handle and operate. Contrast enhancement follows the gray scale conversion steps to highlight the black areas of the veins. In order to obtain contrast enhancement histogram equalization was used that yields a flat histogram instead of the adjacent peaks. Histogram makes the dark areas darker and bright areas brighter. Morphological operation was done after contrast enhancement. These operations removed unwanted little particles from the image without disturbing the large picture particles. The morphological operation depends on structuring elements. Choice of the structuring element is very important thing because a wrong selection can disturb the image. Morphological operation includes erosion and dilation. Erosion shrinks the image and dilation enlarges the image. Edge detection is done by applying sobel edge filter. In the end thinning was done. In **[22]** first the region of interest that was a hand was extracted. This extraction contains a few stages. First the image was changed into gray scale image and then background was estimated by implementing a morphological opening operation. Morphological opening is defined as first dilate the image and then erode the dilated image. After estimating the background by applying opening operation the background subtraction was applied to attain useful and concerning region in which interest lied which was a hand for further processing. Now hand veins were extracted by implementing different threshold values. The process of implementing threshold values is fast and inexpensive segmentation technique and

provides good results. The extracted vein patterns had some noise that need to be removed in order to get better view of the patterns. **[22]** Used match filter, wiener filter and smoothing filter that were defined in **[24].** A 5 x 5 median filter and a 2-D Gaussian low pass filter was used in **[25]** to remove high frequencies but these filters could not be implemented in **[22]** because images captured in **[25]** were taken by a thermal camera not by a CCD camera. Pattern is the most efficient and useful feature because the width or size of the veins increase with the age of the human. Skeletonization is a good technique to obtain the shape of the pattern **[25].** Thinning process was done that was defined by Zhang and Suen **[26]**. After thinning veins pattern was pruned. Pruning process removes the shadows of the veins while keeping the pattern undisturbed. In **[23]** the region of interest was selected by selecting knuckle tips as control points **[27]** and obtained a 256 x 256 image of region of interest. A median filter and contrast enhancement algorithms were applied on the image to remove the noise and adjust the contrast. And then the image was converted into binary image and normalization was done as defined in **[28].**

3.2.3: Feature Extraction and Classification

After pre-processing is feature extraction. Hassan et al. **[20]** used Average Absolute Deviation (AAD) algorithm to extract the features because many people used different methods based on thinning and minutiae extraction to extract the features. In **[20]** a 240x180 image was divided into sub images of size 20x20 and then average absolute deviation algorithm was implemented on them. As a result a feature vector of dimension 12x9 was obtained. These features are then sent to a multi-layer neural perceptron network classifier as inputs. Every neuron was sent as input through input layer via some weights towards the hidden layers. Inputs are multiplied with weights and then add. This was done for every node of hidden layer. The output was obtained at the output layer by revising the same product and sum procedure for every node of hidden layer and weights. The output calculated value was compared with the desired value; if the values are equal then the classification is correct otherwise training process was done. Training process is changing the weights and calculating the new outputs. **[21]** Took four images of one person. A distinguishable and unique feature was calculated and a couple of random points were taken from each image. Classification was then done. First of all clustering method was used that is based on data of features of every pixel of veins intersection point and then classes were

compared and the most common class was assigned as a true class. **[22]** Extracted the co-ordinates of the veins as a feature after the thinning and pruning process. These co-ordinates were the pixel values of the images. **[22]** "eigenvein" features were taken by using Principle Component Analysis and then mapped these features on a space called vein space. When the pre-processing was done then eigenvalues were calculated and after this an eigen space was generated to retain eigenveins. Only those N eigenveins were retained whose eigen values were largest. Then contribution of each eigenvein was calculated by calculating the weight of that eigenvein in eigen space. The arbitrary distance was measured between test image and vein space. If this distance is close enough to any class then the image was assigned that class. All vein images were in the vein space and "Euclidean Distance" was used to calculate the distance. **[18][19]** have defined three types of hand recognition ways namely **Independent Component Analysis** (ICA), **Non-negative Matrix Factorization** (NMF) and **Line Edge Map** (LEM). These algorithms are in nature. **ICA** and **NMF** operate on whole image whereas the third method **LEM** works on the basis of contours that represent the hand, so it is shape based. ICA extracts the features from a mixture and it extracts only those features which are independent on the basis of their statistics. There are two types of architectures for ICA and **[18][19]** have used both of them for feature extraction. Both of them are defined as follow.

1. N hand vectors are linear which are individual and having a mixture of a set of N unknown hands which are statically independent.

2. Superposition coefficients are statically independent and the basis images are not independent.

The second method discussed in **[18][19]** is NMF. This is also a matrix factorization technique but the addition is that there are only non-negative coefficients for each matrix. Columns of one non-negative image are called basis vectors and columns of second non-negative image are called feature vectors. **[18][19]** Defined a third way called LEM that extracted veins from image as vectors. The method is based on matching the templates and matching the features on the basis of their geometry. Line-segment were extracted by using pixels that were present on edge map and this was the basic unit of LEM whereas Line Segment Hausdorff Distance (LHD) was used to match the lines. Two lines were addressed from same class when the distance between them was very small. **[18][19]** Have used local thresholding because the global thresholding does

not yields good results as compared to local thresholding. **[18][19]** et. al. used LHD to compare the similar veins by calculating parallel, angular and perpendicular distances. These distances are calculated on the basis of structural information of the veins. For identification of a person, distance is calculated between the image taken from that person and database images having more than one image per person. Classification for all three methods LEM, ICA and NMF are same but the difference is that uses LHD and ICA and NMF uses **Cosine Similarity Measure** (CSM) that increases the angle between the test image and a template and this angle is a cosine angel. Now these three classification methods are fused to get a single result so that a correct class could be assigned to the image. Different type of fusion methods were used by people some of them are defined as follows.

First method was borda count that was discussed in this chapter**.** This method assigns a rank to each vein pattern on the basis of distances calculated from the database vein patterns. Then the rank for each pattern is summed up to get a single rank value and then the final result is that rank that is highest rank value. Second fusion method that was defines was majority voting. In this method each classifier assigns a voting value '1' to the input test image if it is classified correctly otherwise '0' voting value is assigned. The test image is assigned that class that has more votes than the other. The last method was z normalization method that contain sum or product rule. Each classification procedure yields a calculated distance between class and the image that has to be classified. First the distance is mapped between the range of [0, 1] by using Z-normalized method and then product or sum procedure is applied to get the final distance and that class is assigned whose distance is minimum with the test image.

3.3: Performance

Aycan et. al. [19] has used **"Bosphorous Database"** that has 1200 images recorded from 100 persons where three images of each person were recorded of their left hands. These three images for every person were stored as three sets: Set 1, Set 2, Set 3 and every person's three images were recorded under specific conditions that are given below:

- N = Normal Condition.

- B = Carrying bag exercise.
- A = Hand after ball pressing exercise.
- I = Hand after cooling with ice.

Sets for each case are given below. Each set has one image for every person and each case has three sets.

- N = N1, N2, N3.
- B = B1, B2, B3.
- A = A1, A2, A3.
- I = I1, I2, I3.

To make experiment more effective and to analyze the effect as the size of training samples changed, the experiment was done by using a single and double training set. N1, N2 and N3 were the sets of images under normal conditions and each set has one image of each person. In single training set only one set was chosen and checked in other two sets. But in double training set two sets were chosen and searched in third set. The identification score was then averaged from all these given test and training combinations. Verification was done by using "Equal Error Rate" for same sets of training and test sets. Both ICA and NMF that were appearance based techniques gave better results than the geometrical based technique LEM. Identification rate in B and A slightly increased in LEM because the size of the veins was increased. In case of fusion, sum rule was more effective than other fusion methods. ICA1, LEM and NMF combined together to achieve the best result. **Hasan et al. [20]** designed **"Learning Based Multi-Layer Perceptron Neural Network"** algorithm. These are three algorithms namely as**: "Batch Back-Propagation", "Online Back-Propagation" and "Quick Propagation".** Neurons were activated by using tangent hyperbolic transfer function and the performance criteria was measured by calculating mean square error. The proposed system in **[20]** has 108 inputs, 101 hidden layers neurons and 103 numbers of subjects. Value of parameters such as momentum and learning rate was 0.7 and 0.3 respectively. Database consists of 927 images recorded from 10m persons, each one had 9 images. Whole database was divided into three sections, one was for

training that held 70% database, second was for validation that had 15% of the database and the last one was for testing and it had also 15% of the database. Hidden neurons were determined by heuristic method. This designed algorithm was run twice but the testing time was less than 1 second so that was neglected and found that Batch Back-Propagation was the best algorithm. **[21]** Had used NCUT database for experiments. This dataset contains images of 102 persons each have 10 images of the left hand and 10 of right hands. The resulting number of images was 1040 images. This is the biggest dataset that ever taken in field of dorsal hand veins. This proposed firefly algorithm extracted the features by veins intersection. This method placed the veins in corresponding classes numerically and performed identification on the basis of similarity percentage of similar data. The class that was more similar was assigned to that feature. **[21]** Had done two experiments, in the first experiment the light was taken into account and its conditions were considered. The second experiment was done with the 10% gaussian noise condition.One more thing that was done in **[21]** was that evaluation was done between the recommended method **[28][29][30][31][32]** and the previous methods by measuring the distance between patterns of one hundred images.

[22] et. al. implemented PCA on hand veins and different thresholding values are applied in order to calculate "False Acceptance Rate" (FAR) along with "False Rejection Rate" (FRR). False Acceptance Rate means total persons who were not allowed and tried to access the system divided by total persons who had tried to access the systems. While FRR means number of authorized people who were rejected divided by total number of persons who tried to access the system. **[23]** Had used a dataset of 600 images obtained from 100 persons and each person has six images at six different times and all images are passed through six-fold cross-validation method. Six-fold cross validation method means making six images of each and every image, so that five of them could be used as the training samples and one as test sample. Parameters M, N and T are increased step by step. The probability was calculated by forward-backward hidden markov algorithm. The values of parameters for the given database were selected as follows:

- N = 3 to 17
- M = 5 to 9
- T = 5 to 12

. There were number of combination of these parameters to achieve recognition rate equal to 1. When the value of M is 8 and N and T were increased from 3 to 17 and 5 to 12 step wise respectively then the recognition rate was equal to 1. Following table shows the value of D where D is the smallest value in iteration. When more than one combination yields the correct identification then only that combination was selected whose parameters were less complex.

A comprehensive table for the literature review is given below that includes the writer, database, method used by that author and performance measure of methods.

Author	**Database**	**Methods**	**Performance Measures**
Aycan et. al. [18]	Bosphorus Hand Veins Database	Apply ICA1, LEM, ICA2 and NMF by using single and double enrollment and then did fusion of these multiple classifiers	➢ **Single Enrollment** **1. IR** **EER** • ICA1=91.67 ICA1= 4.85 • ICA2=90.29 ICA2=4.41 • NMF=90.63 NMF=4.92 • LEM=90.21 LEM=5.05 **2. Fusion Results** • Majority Voting=92.75 • Borda Count=93.67 • Sum=97.45 • Weighted Sum=96.74 • Product=96.28
Aycan et. al. [18]	Bosphorus Hand Veins Database	Apply ICA1, LEM, ICA2 and NMF by using single and double enrollment and then did fusion of these multiple classifiers	➢ **Double Enrollment** **1. IR** **EER** • ICA1=96.67 ICA1= 3.17 • ICA2=95.92 ICA2=2.25 • NMF=95.75 NMF=2.35 • LEM=96.25 LEM=2.79 **2. Fusion Results** • Majority Voting=91.25

			• Borda Count=97.33 • Sum=99.49 • Weighted Sum=98.91 • Product=98.08
Aycan et. al. [19]	Bosphorus Hand Veins Database	Apply ICA1, LEM, ICA2 and NMF by using single and double training sets and then did fusion of these multiple classifiers	➢ **Single Enrollment** **1. IR** **EER** • ICA1=77.82 ICA1= 8.18 • ICA2=75.06 ICA2=10.90 • NMF=72.06 NMF=12.53 • LEM=69.95 LEM=13.12 **2. Fusion Results** • Majority Voting=77.78 • Borda Count=78.67 • Sum=8.25 • Product=79.67
Aycan et. al. [19]	Bosphorus Hand Veins Database	Apply ICA1, LEM, ICA2 and NMF by using single and double training sets and then did fusion of these multiple classifiers	➢ **Double Enrollment** **1. IR** **EER** • ICA1=86.74 ICA1= 5.40 • ICA2=83.60 ICA2=7.24 • NMF=83.03 NMF=7.64 • LEM=79.97 LEM=9.17 **2. Fusion Results** • Majority Voting=87.00 • Borda Count=88.67 • Sum=88.97 • Product=88.39
Hasan et. al. [20]	Database Local, 927 images	Used Multi-layer Neural Network Method for classification by testing BBP, QP and OBP algorithms	• Quick Propagation = 97.2 • Online Back Propagation = 97.8 • Batch Back Propagation = 98.9

Zahra et. al. [21]	NCUT Database	Applied Firefly Algorithm	➢ Error Rate = 0.005 ➢ Error Rate Through Noise Filter = 0.012 ➢ Error Rate in 100 Images = 98.02%
M. Heenaye et. al. [22]	Database Local	Used Eigen Value Method	FAR = 0% at Threshold**(t)** = 0.90 FRR = 0% at Threshold**(t)** = 0.90
Xu Jia et. al. [23]	Database Local, 600 images	Identification is done by using optimized Hidden Markov Method	Highest Recognition Rate at M=8,

***Legend: (Performance Measure)**

- **IR= Identity Rate**
- **EER= Equal Error Rate**
- **FAR= False Acceptance Rate**
- **FRR= False Rejection Rate**

Table 3.1: Comprehensive table of authors, databases, techniques and performance measures

3.4: Summary

In this chapter we defined some work that was done by different people. We discussed different methods that people used for hand veins based identification that consists of different datasets and how they captured the images. What methods they have used and what steps they followed and the performance measures that they calculated.

Chapter 4: Proposed System

Biometric techniques are growing rapidly in the field of human identification and recognition fields because it uses distinct characteristics of humans that are unique in every person. The process of identification ensures that who is that person, whether the person is authorized or not. The time and power constraints of a biometric system depends on the size of database. If the size of the database is large then it will take more time and power as compared to a small database. Many biometric systems were developed throughout the world during past few years such as: palm recognition system, retina scan, iris scan, finger print and foot print recognition system and etc. Biometric systems are safe and secure because every person's features are unique and bear no resemblance with others. A biometric system consists of three main parts, firstly an image is captured by using an image capturing device, secondly image is converted into digital form by using software and thirdly these digitally converted images are stored in the form of database. The proposed algorithm is discussed as follows.

4.1: Overview

Our proposed algorithm detects dorsal hand veins to identify a person. Algorithm has three stages: pre-processing, feature extraction and classification or matching. First of all pre-processing stage is done by enhancing and segmenting the hand images. Techniques known as Multilayered Thresholding and Gabor Wavelet Transform are applied to achieve the desired pre-processing. After pre-processing features are extracted and validated by applying Windowing method and Crossing Number Technique. In the end Mahalanobis Distance is applied for classification. After classification result is issued whether person is identified or not. Bosphorus Database is used in this algorithm.

4.2: Proposed System

System consists of two parts. One is enrolment part and the other is identification part. In enrollment part an image of hand is captured first and then pre-processing is done on the captured image by applying F to achieve enhancement and then Multilevel Thresholding to get segmentation which is supervised. Pre-processing is done here. When the pre-processing is done, Crossing Number Method is applied in case of extracting feature and then windowing process to validate the feature points. These feature points are then stored in database. The second part of the system is identification part. In identification part a test image is captured and all the processes that were applied in enrollment part are applied on it. After the feature points extraction step this image is matched with the database image and result is generated whether the person is identified or not. A block diagram of system is given below.

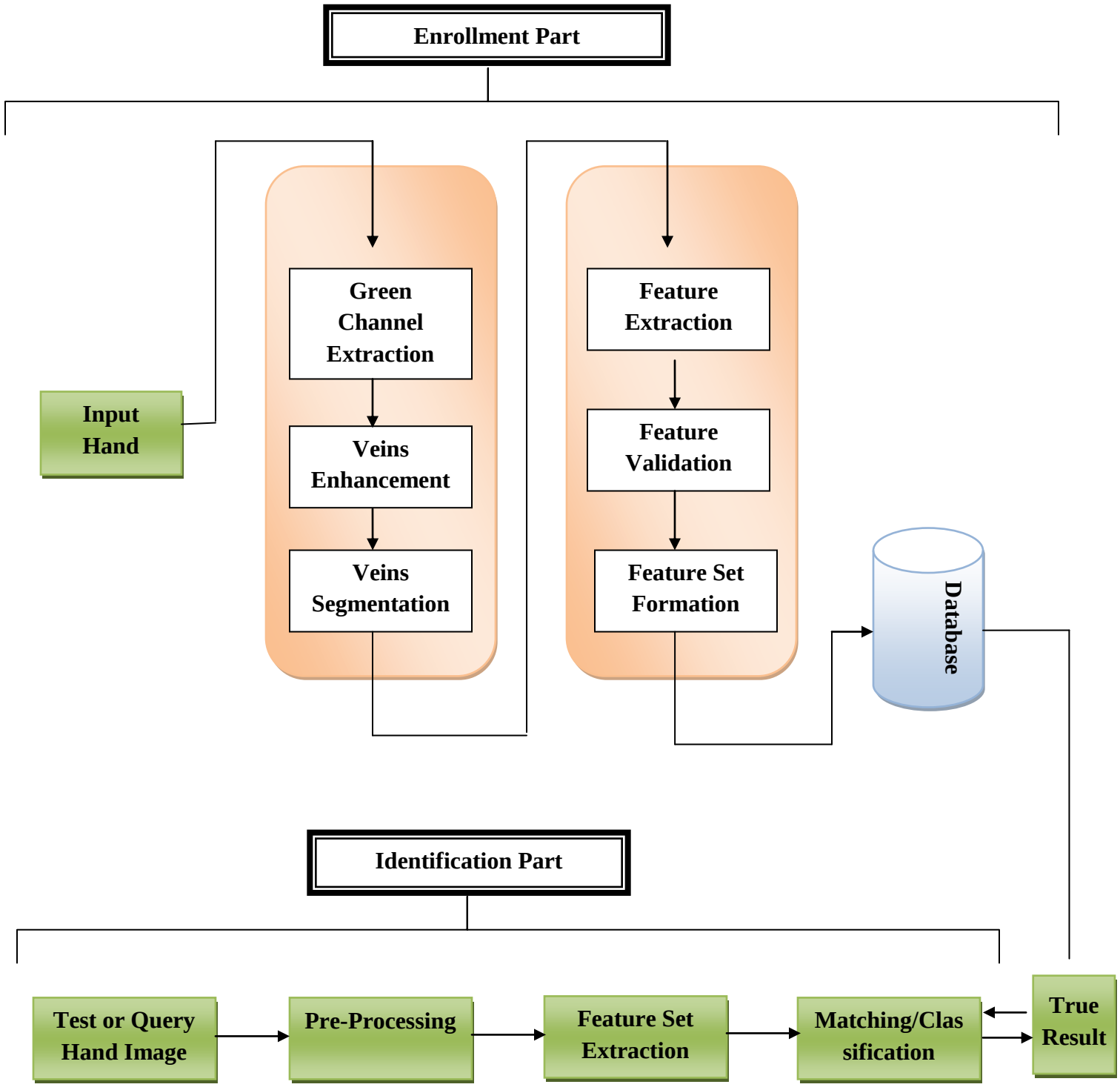


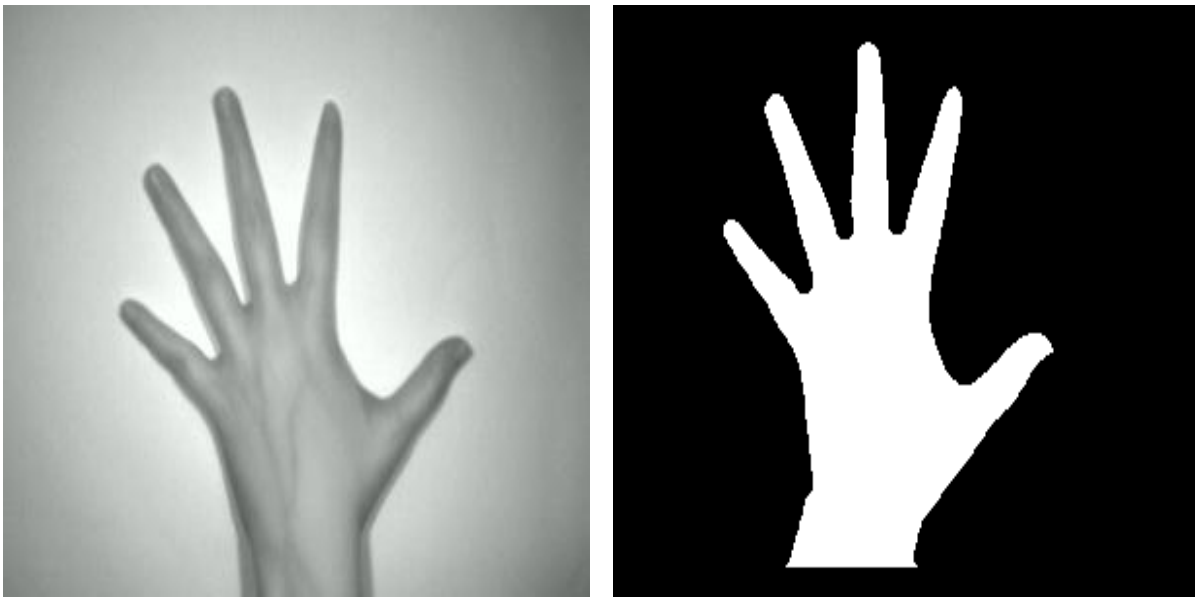
Figure 4.1: Block Diagram of Proposed System

4.2.1: Enrollment Part

Enrollment part is an offline processing part where as images were taken by using NIR technology plus reflection method. The region of interest from the back of the hand is illuminated with the help of two infrared light sources which are made up by using six infrared LED's placed in circular arrangement. Diffusion papers are used on front of light source so that light can be scatter uniformly. A monochromic NIR CCD camera is used to capture the image and it was placed on 80 cm height from hand. This whole setup was designed for a dark room but in real time the device automatically control and limits the visible light. Person was directed to place the hand on the dark background while the back of the hand will be towards the camera. 1200 images of left hand were taken of 100 different persons. Theses 1200 images are categorized into 4 types depending upon the activity that had been done before taking the images. In each category every person has 3 images. The categories are normal, activity, bag and ice. After capturing the images first step is started which is pre-processing.

4.2.1.1: Pre-Processing

During pre-processing stage hand image is passed through a feature channel called green channel to enhance the contrast of the veins so that it is easy to operate the veins when they are very clear. If this channel is compared to other channels such as red and blue, they increased the brightness of the veins to be easily visible and lower the contrast of the image respectively. The operation of the pre-processing is done to ensure that the noise that leads to wrong structure of veins and any unwanted information that will cause any trouble to identify a person is removed. As the system distinguishes the persons on the basis of the veins pattern of each person which are unique in every human hand and different from rest of people so, it is necessary to get the veins image accurately out of the hand. Therefore vein image is segmented after enhancing the veins in the image.



(a) **(b)**

Figure 4.2: (a) Original Image (b) Background mask

4.2.1.1.1: Enhancement of Veins

The foreground of the image is under consideration. Veins of hands are enhanced in order to achieve the less and poor visible veins accurately to abandon the mismatching. This is done by following three steps. In first step morphological operations are applied in order to improve the contrast plus normalizing the contrast and applying the filter banks. In second step parallel segmentation for the hand veins is done. In final step all spurious hand veins are eliminated so that the classification is increased. There are many factors that make the image unclear to view and make the identification very difficult for the systems such as: variability in clarity of the image, texture on the background of an image varies, low illumination on region of interest and etc. Figure 4.3 tells the way how dark regions of the veins are detected.

In order to smooth the dark regions of the hand veins morphological operation known as opening is used as defined in following equation 4.1.

$$\emptyset_f^{(sB)} = \max\left[minf(x+b)\right] \quad \textbf{(4.1)}$$

Where sB is a structuring element B having size s. b ∈ sB and f is an image before processing.

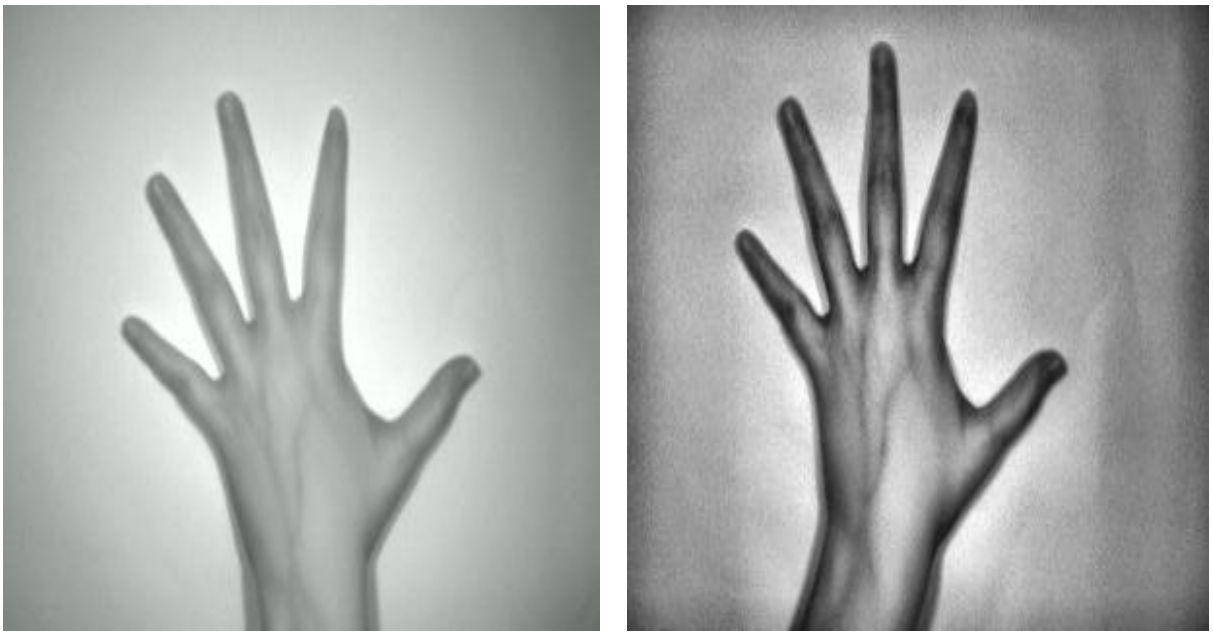
As a result of this morphological operation we find smooth dark veins that need .only contrast enhancement now. Contrast enhancement is done only because of improving the visibility of the veins in order to achieve better detection. This enhancement is done by using a w X w moved over the image keeping in mind that local distributions are independent on the basis of statistics and window is large enough for it.

$$G = 255\frac{[\alpha_\omega(\phi_f) - \alpha_\omega(\phi_{fmin})]}{[\alpha_\omega(\phi_{fmax}) - \alpha_\omega(\phi_{fmin})]} \quad \textbf{(4.2)}$$

$$\alpha_\omega(\phi_f) = [1 + \exp\left(\frac{m_\omega - \phi_f}{\sigma_\omega}\right)]^{-1} \quad \textbf{(4.3)}$$

ϕ_{fmin} And ϕ_{fmax} are minimum and maximum values of intensity of the image obtained after smoothing whereas m_ω and σ_ω are mean and variance of the intensity values located inside the region covered by the window respectively. G is an output image after the contrast enhancement step which is provided to obtain veins to Gabor filter bank.

Figure 4.4 shows the output image after applying morphological opening and contrast enhancement.



(a) (b)

Figure 4.3: (a) Original Image (b) Image after enhancement

Gabor filter bank is very famous and widely used by people because of very fine tuning of different frequencies, selection of different orientations, easy to represent the texture and to discriminate them. A guassian kernel is used in order to represent Gabor filter which can model various shapes that depend on its parameters.

$$g(x, y, \sigma, \Omega, \theta, \mathrm{r}) = \frac{1}{\sqrt{\pi \mathrm{r} \sigma}} \mathrm{e}^{\frac{-1}{2}\left[\left(\frac{\mathrm{d}_1}{\sigma}\right)^2 + \left(\frac{\mathrm{d}_2}{\sigma}\right)^2\right]} (\mathrm{d}_1(\cos\Omega + \iota \sin\Omega)) \quad \textbf{(4.4)}$$

Here, r is the aspect ratio, Ω is the spatial frequency and σ is the standard deviation of guassian kernel. Figure 4.4 and 4.5 represent 3-d kernel for Gabor filter bank for scaling values 2 and 5.

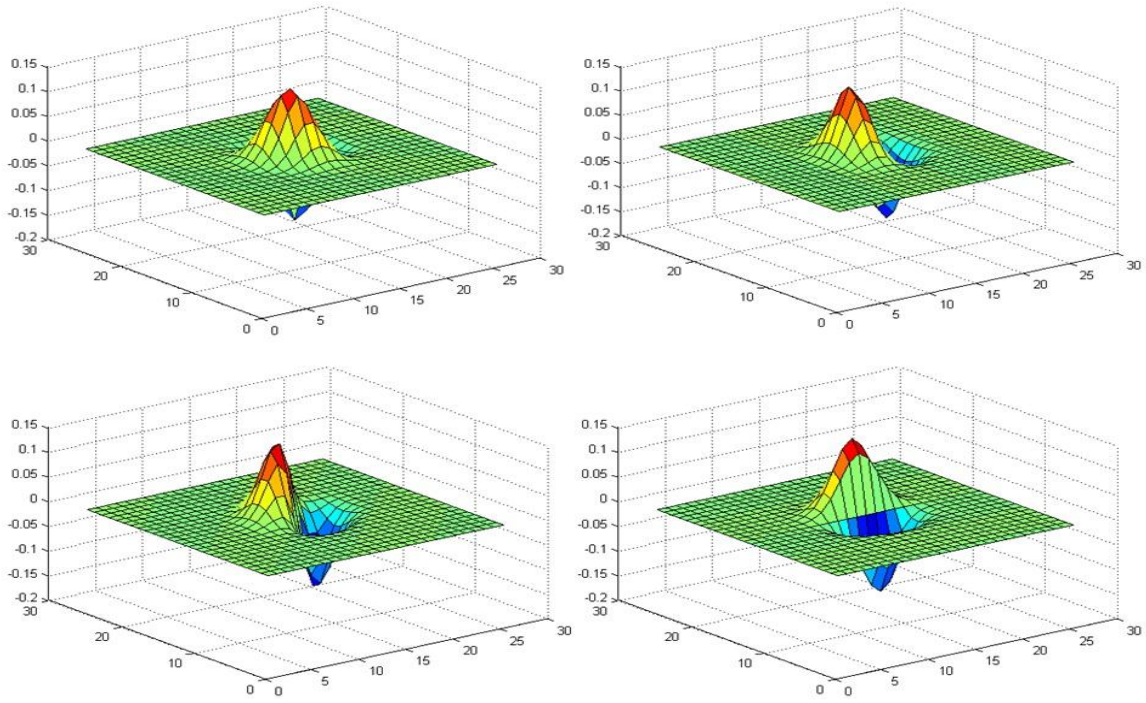


Figure 4.4: Filter Bank with Scaling value 2

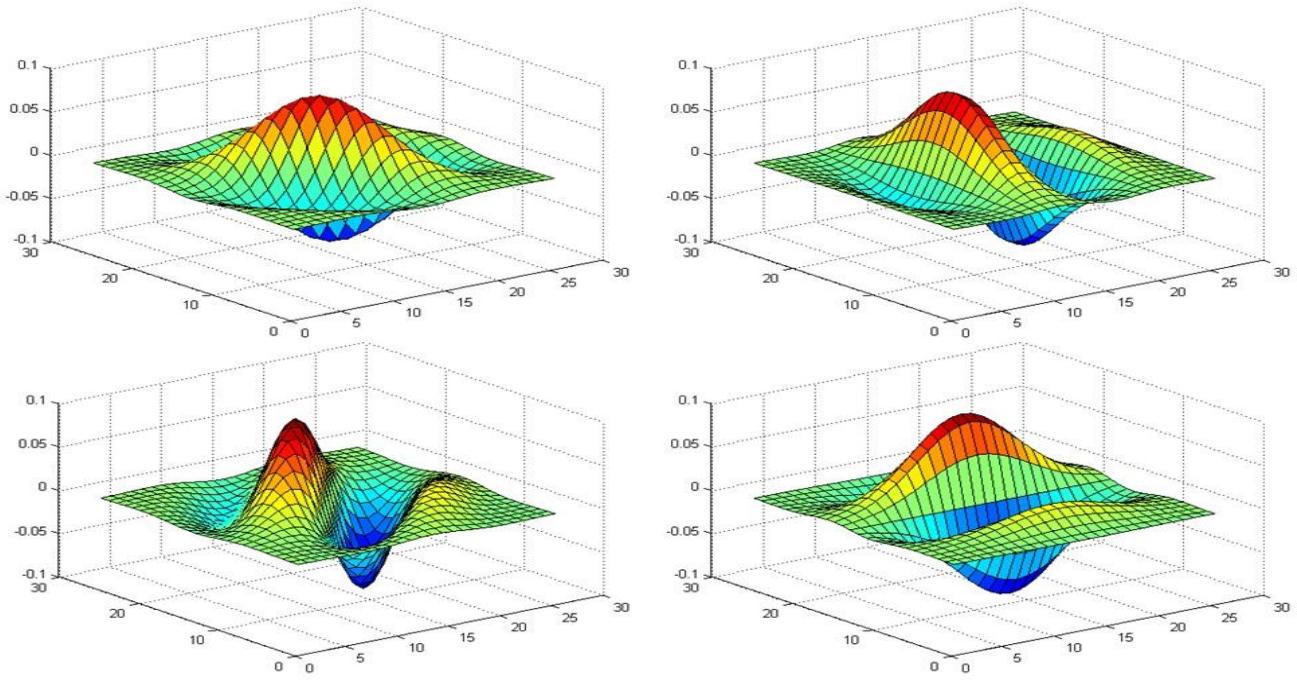


Figure 4.5: Filter Bank with Scaling Value 5

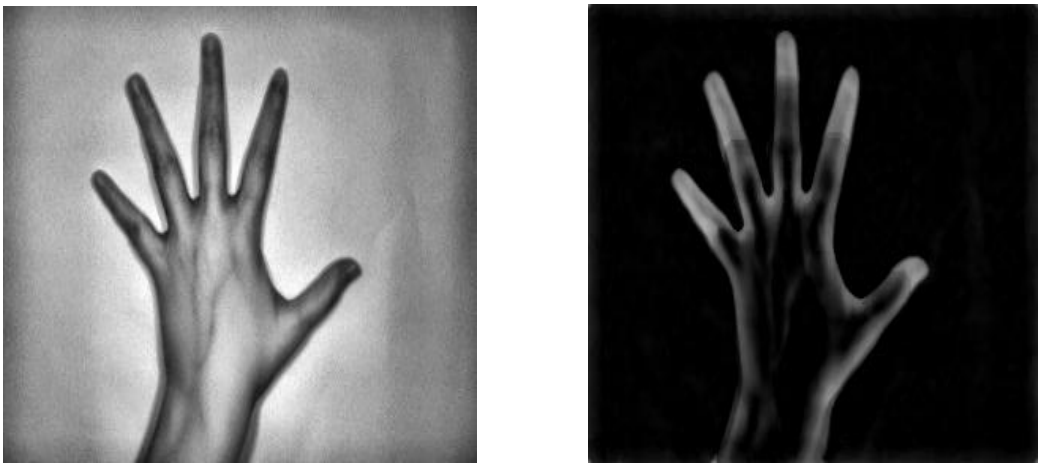
Image G whose contrast was enhanced is convolved with g Gabor filter whose centre is at location (s,t) in order to generate γ which is response of Gabor filter for selected values of σ, Ω and θ. It is also shown in following equation 4.5.

$$\gamma(s,t,\sigma,\Omega,\theta) = \sum_{x}\sum_{y} G(x,y)g(s-x,t-y,\sigma,\Omega,\theta,r) \quad \textbf{(4.5)}$$

Maximum Gabor filter response is obtained by following equation 4.6 by changing θ from 45 degree to 180 degree by increasing 45 degree step wise.

$$M_{\gamma}(\sigma,\Omega) = \max\ |\gamma(\sigma,\Omega,\theta)| \quad \textbf{(4.6)}$$

Figure 4.6 (a) and (b) defines the enhancement of different regions response of filter banks respectively.



(a) **(b)**

Figure 4.6: (a) Image after enhancement (b) Filter Bank Response

4.2.1.1.2: Veins Segmentation

When the enhancement is done, veins are segmented by using local adaptive thresholding. After the enhancement process while doing segmentation only one general threshold is not selected because thick veins provide higher response as compared to thin veins. That's why an adaptive threshold is applied and also recorded. The enhanced image provided by the filter bank response is recorded and then histogram of this enhanced image is calculated. For the grayish background, there occur maximum intensity values but veins have values slightly greater than the background values because veins are of bright colors. Adaptive thresholding separates the veins from the rest of the hand. A binary image is obtained by using this threshold. This is shown in following figure: 4.7.

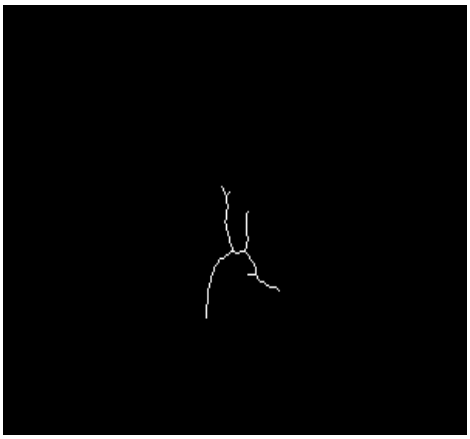
(a) **(b)**

Figure 4.7: (a) Filter Bank Response (b) Binary Image

This thresholding method yields veins structure that is segmented having variable thickness. The thickness is made uniform by using morphological thinning procedure. These morphological operations decrease the width of hand veins to one pixel. Background mask is eroded to extract the back side of the hand corresponding to palm area. So region of interest is extracted and all the extra area is neglected.

Figure: 4.8 show the binary image, thinning and the extracted region of interest.

(a) (b)



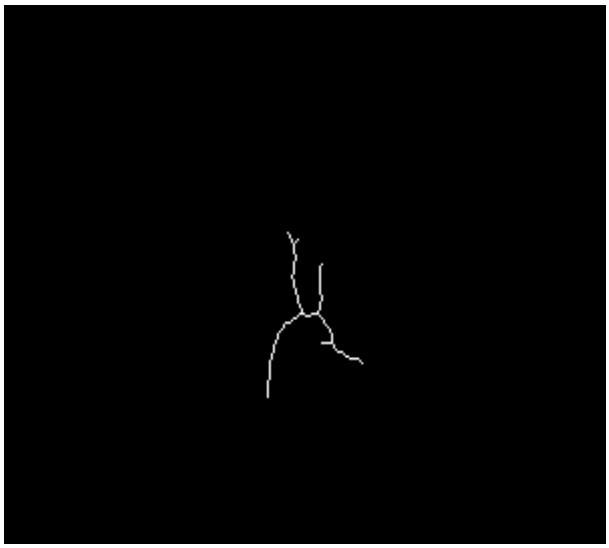
(c)

Figure 4.8: (a) Binary Image (b) Thinning (c) Region of interest ROI (Veins)

Feature extraction is the next step after morphological operation because now extracting the features is easy and useful.

4.2.1.2: Feature Extraction

Features are extracted from the image obtained after the morphological operation. Features that are extracted from the image are veins ending point and veins bifurcation points. Ending point is the point where veins end and the bifurcation point is a point where veins are divided into branches.



(a) **(b)**

Figure 4.9: (a) Region of Interest (b) Feature Extraction

4.2.1.2.1: Extraction of Features Points

Ending and Bifurcation points that are used as features to distinguish one vein pattern from another are calculated by using crossing number algorithm. All veins are assigned value of 1 and all other part is set to 0. A neighbourhood of size 3x3 is taken and moved along the boundaries in a clockwise direction and the transitions are also calculated as well. By noting the transitions value we came to know that if the transition value is 3 then it will be a bifurcation point and if the value is 1 then it will be an ending point. Following equation is used to extract bifurcation and ending points.

$$F(x) = \frac{1}{2}\sum_{i=1}^{8} | P(x_i mod 8) - P(x_i - 1)| \quad \textbf{(4.7)}$$

Here, x is vein's pixel occurring in an image named P whereas g0 to g7 are the neighborhood pixels defined by a 3x3 mask of pixel F. the pixel is of vein if the value of P(x) is equal to 1. If

the value is not 1 then it is zero. Value of F(x) will tell whether it is an ending point or a bifurcation point. For ending point value is 1 and for bifurcation point value are 3.

Figures 4.8 and 4.9 shows how the ending and bifurcation points will be viewed in a 3x3 mask respectively.

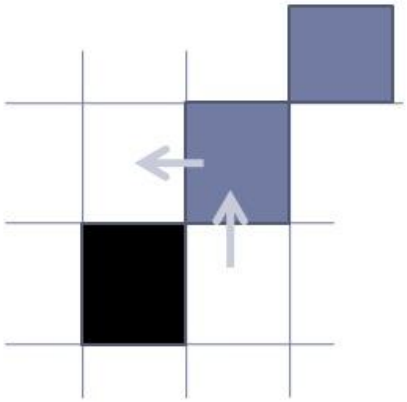


Fig 4.10: Ending Point

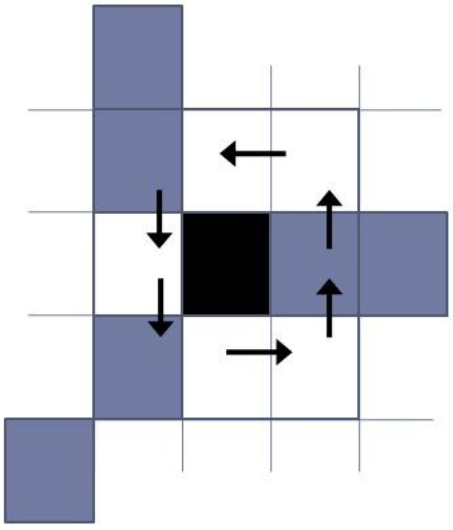


Fig 4.11: Bifurcation Point

4.2.1.2.2: Validation of Feature Points

Validation technique is adopted in order to obtain true feature values. Because if we get false or poor feature points or values it will lead us to poor results. High misclassification error rate will occur and the system will be totally failed to identification. Windowing method is applied for the validation process. A window of size 9x9 is applied on the vein image. The size of the window is selected wisely in order to get more and more true features. To find an ending the connected region is assigned a value of 1 and the window is moved along the boundary and the transitions are calculated. If a break occurs it is not labeled as true ending. It is labeled as false ending and discarded. However, in bifurcation case connected regions are assigned values of 1, 2 and 3 and window is moved in three different directions. If a break or spur exists then it is not considered as a true feature and discarded. Sort veins are also discarded and in the end true feature points are obtained. Figures 4.10 and 4.11 represents the validation of ending and bifurcation points respectively.

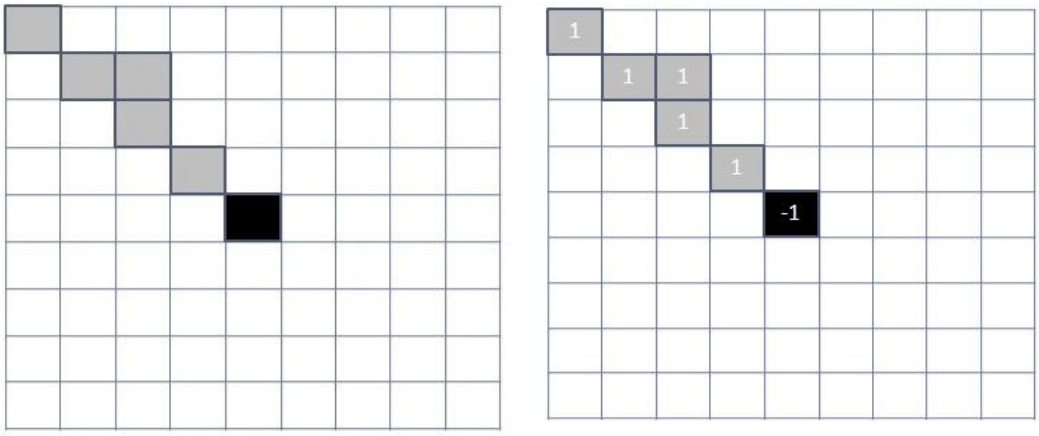


Fig 4.12: Validation of Ending Points

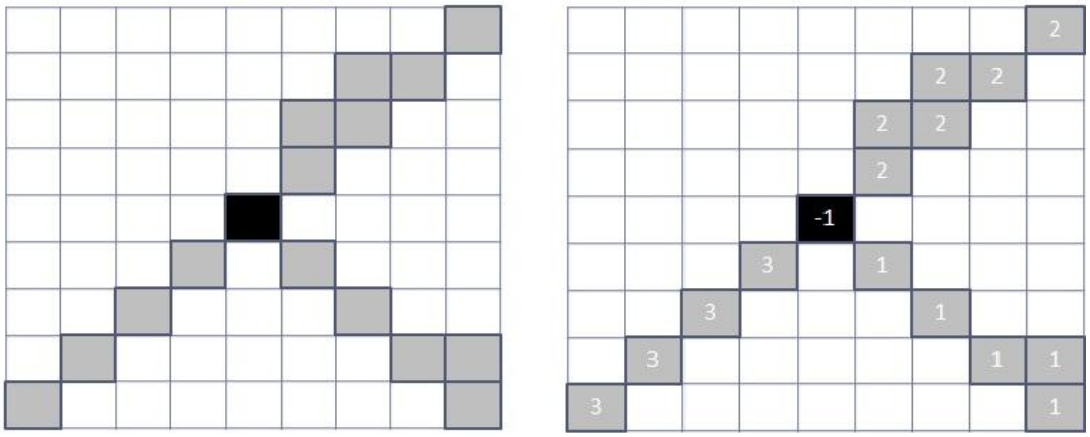


Fig 4.13: Validation of Bifurcation Points

Figure 4.14 shows the validation of feature points.

(a) (b)

Figure 4.14: (a) Extracted Features (b) Feature Points Validation

4.2.1.2.3: Set of features

All the true features that were extracted previously are saved in form of feature vectors by calculating their position or location and the distance with 4 most nearest pixels. This all information is stored in the form of database in following format: α1, α2, α3, α4, r11, r12, r13, r14. Whereas α is the orientation and r is the relative distance. Feature point's orientation and displacement for centre is shown in figure 4.12.

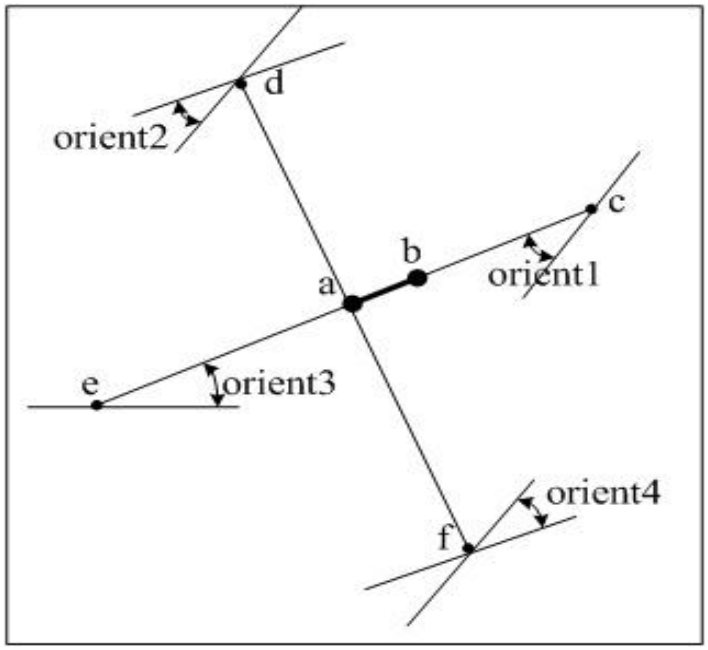


Fig 4.15: Orientation and distance from 4 nearest feature points for centre

4.2.2: Identification Part

In identification part the hand image of the person is acquired and the processed in same way. This part is online processing part. In the end, this processed image is matched with the database and the result is shown whether the person is authorized or not. This matching is done by using a classifier that classify the samples by matching the features of test and training samples or features.

4.2.2.1: Classification

Classification is done by matching the query image with the database images in order to get the correct and true identity of the person that is accessing the system. The system matches the feature templates and the feature of the query image and the features of images in the database are matched by using Mahalanobis Distance and KNN Method. Mahalanobis distance classifies the objects on the basis of distance between features and this value is calculated by counting the number of similar features between the test image's features and database features. Formula of Mahalanobis Distance is given below:

$$D_M(x) = \sqrt{(x-\mu)^T S^{-1}(x-\mu)} \qquad \textbf{4.8}$$

KNN method classify the object by calculating K number of nearest neighbors and assign the object that class that is most common in the neighbors. So this classification is on majority voting. KNN matches the features in the feature space. KNN classify the samples on the basis of Euclidean Distance between the test and training samples. Algorithm of KNN is given below.

Algorithm:

- For each testing point
- measure distance to every training point
- find the k closest points
- identify the most common class among those k
- assign that class
- End

Equation of Euclidean Distance is defined as equation 4.9:

$$d = \sqrt{(w - w_1)^2 + (h - h_1)^2} \quad \textbf{4.9}$$

Where w & h are features of test samples and w1 and h1 are features of training set. Figure 4.17 shows how to calculate Euclidean distance between two classes having two features by using equation 4.8.

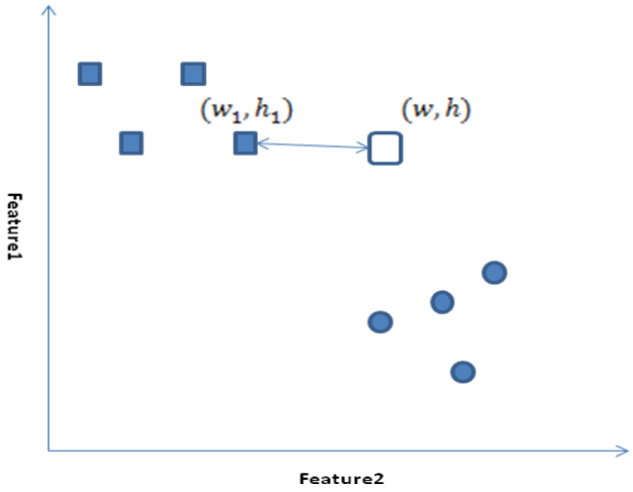


Figure 4.16: Euclidean Distance

4.3: Summary

This chapter consists of complete description of our proposed algorithm. This includes background extraction, enhancement of the image, applying filter banks on the enhanced images. After that, binarization is done on the processed image. Thinning, extracting region of interest, extraction features on the basis of ending and bifurcation of the veins, validation of the features and in the end classification on the basis of these features come next to image binarization respectively.

Chapter 5: Results

5.1: Data (Material)

I have Used **Bosphorus Hand vein Database** to train and test the designed algorithm. Images were taken by using NIR technology plus reflection method. The region of interest from the back of the hand is illuminated with the help of two infrared light sources which are made up by using six infrared LED's placed in circular arrangement. Diffusion papers are used on front of light source so that light can be scatter uniformly. A monochromic NIR CCD camera is used to capture the image and it was placed on 80 cm height from hand. This whole setup was designed for a dark room but in real time the device automatically control and limits the visible light. Person was directed to place the back side of the hand facing towards the camera. Total number of images that were taken was 1200 of left hand of 100 different persons. Theses 1200 images are categorized into 4 types depending upon the activity that had been done before taking the images. In each category every person has 3 images. These categories are defined as below:

- Normal Conditions (N: Normal).
- Bag carrying for 1 min. (B: Bag).
- Ball squeezing exercise for one min repetitively. (Activity: A).
- After placing an ice pack on back of the hand (Ice: I).

Resolution of the images that were used is 640 x 480. Figure 5.1 shows six different images from the above defined database.

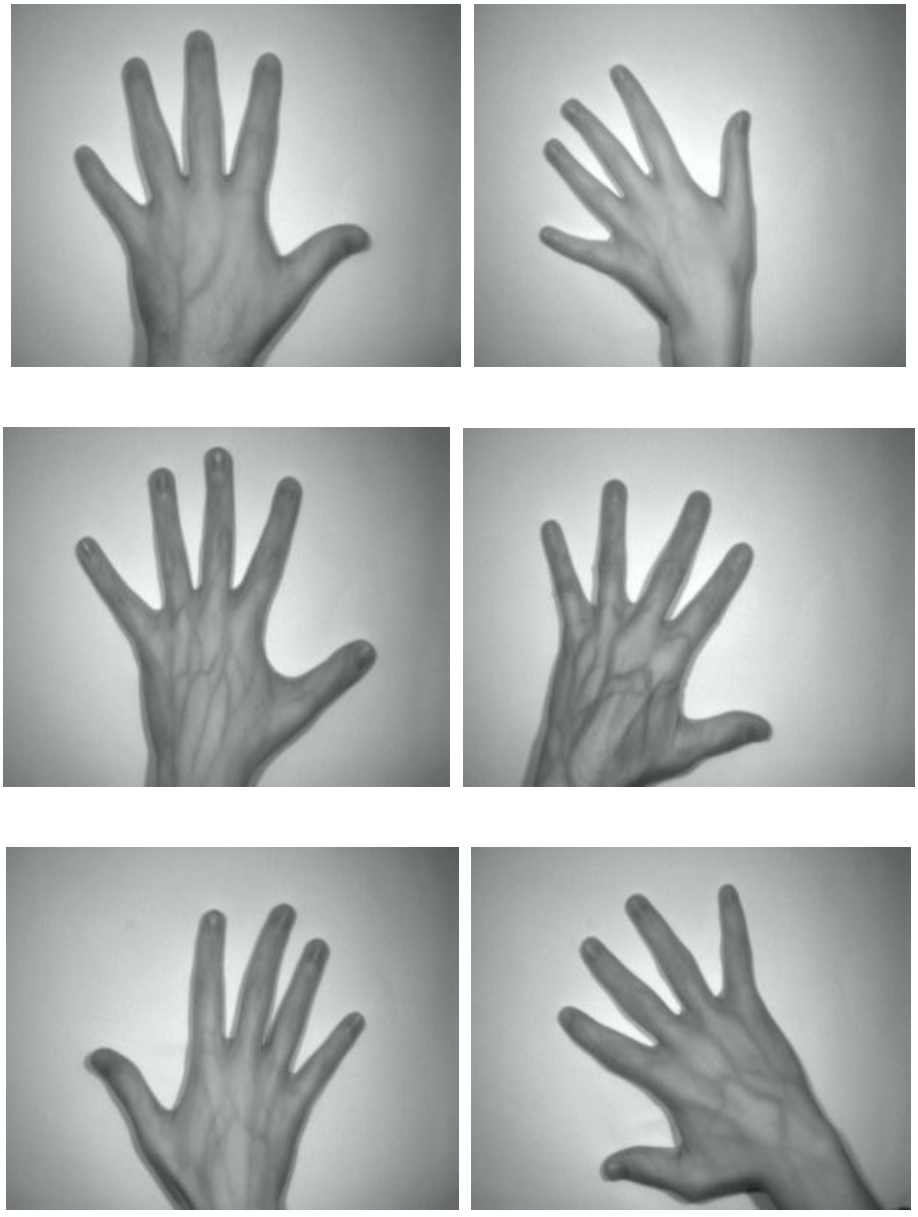


Figure 5.1: Sample images from above defined Bosphorus Database

5.2: Results

Results of the proposed system are given below.

5.2.1: Pre-processing and image Enhancement

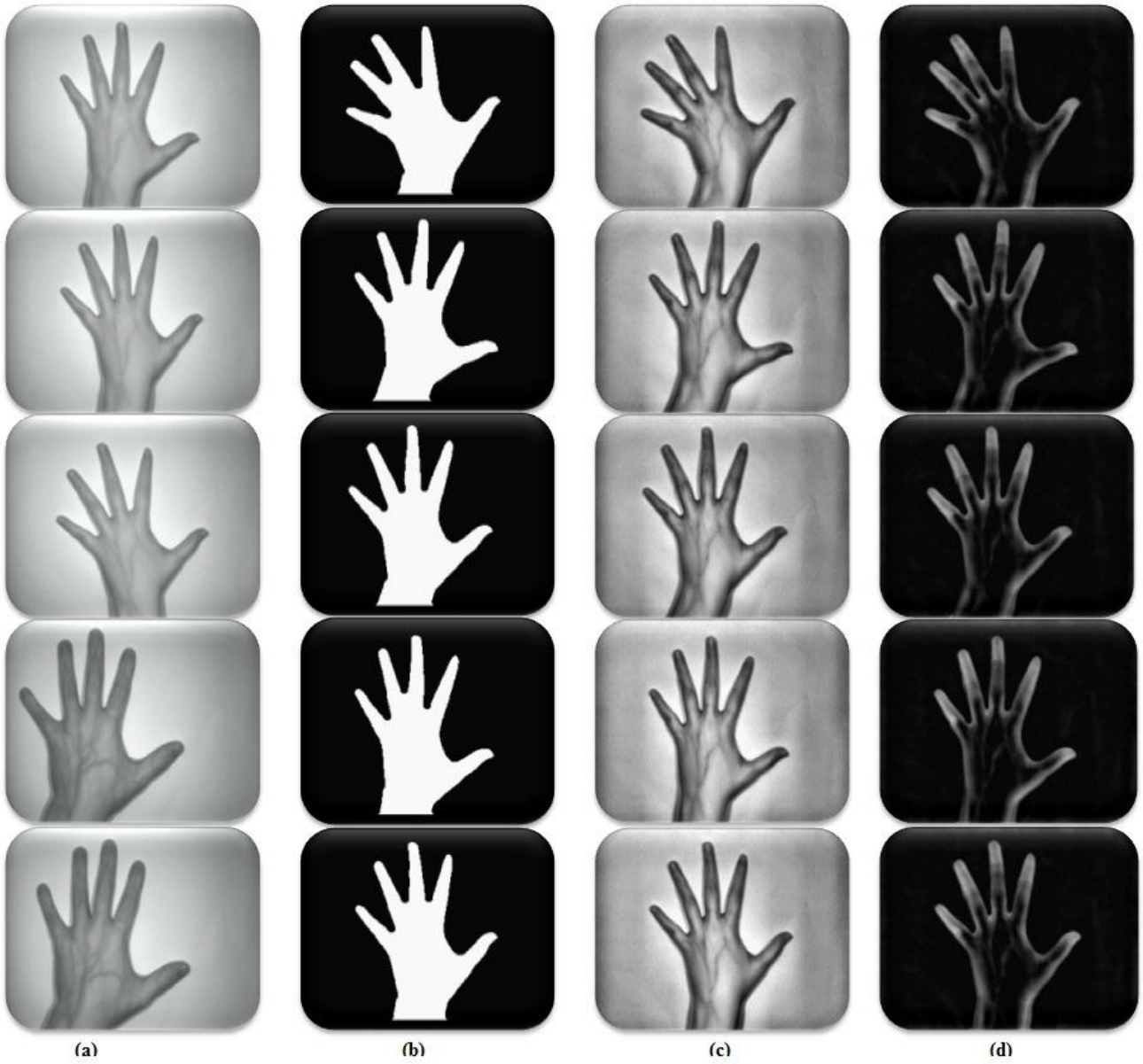


Figure 5.2: (a) Original Image (b) background Image (c) Image after Enhancement (d) Filter Bank Image

5.2.2: Binarization and Feature Extraction

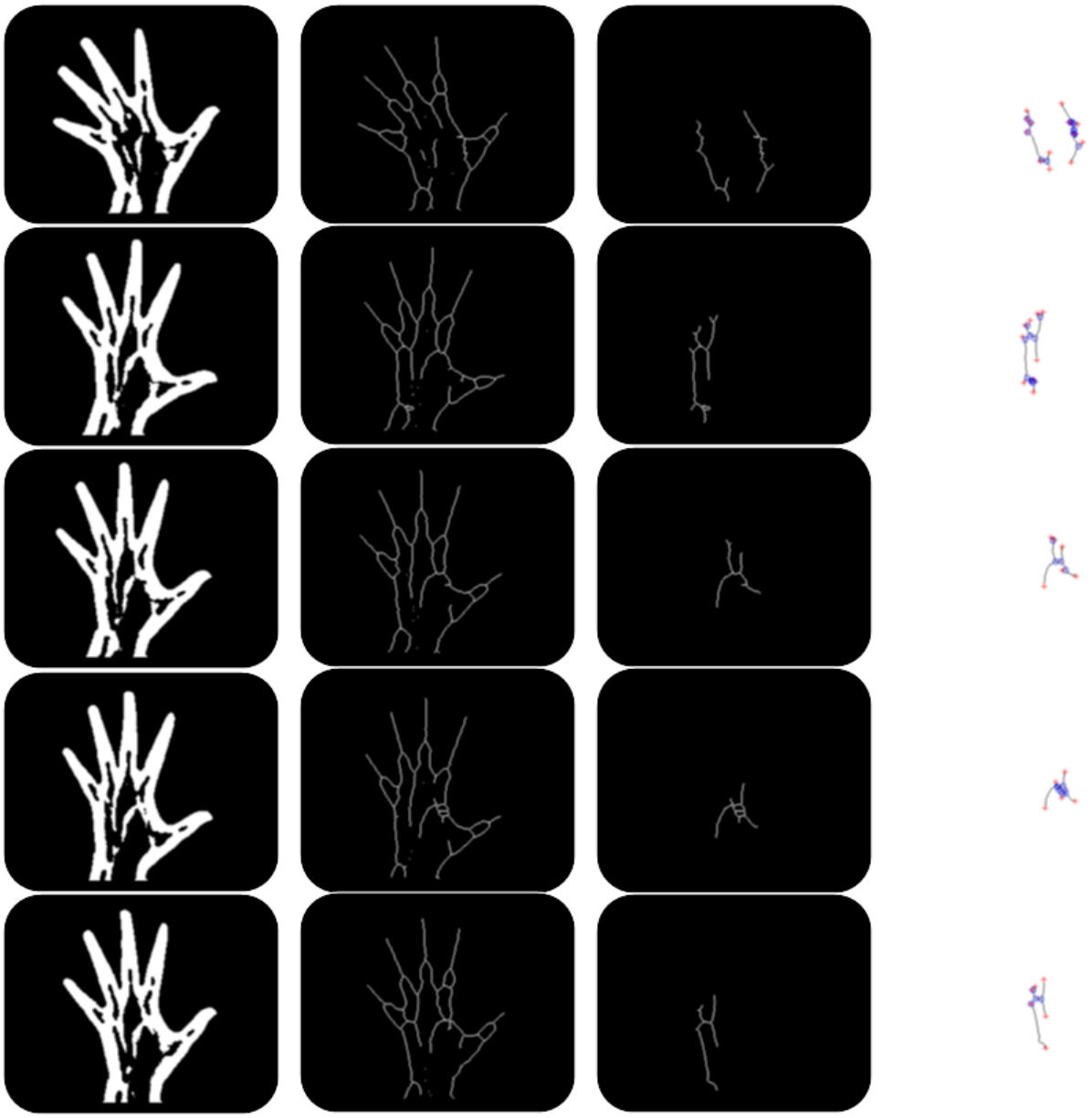


Figure 5.3: (a) Binarization (b) Thinning (c) Extracting Region of Interest (d) Feature Extraction

5.3: Quantitative Analysis

The testing of proposed system is done using Bosphorus hand vein dataset. The dataset consists of total 1200 images of 100 people with 12 images per person. We divided these 12 images in two parts, training and testing. Training part consists of randomly selected 75% of 12 images and testing part has remaining 25% data. Same scenario is done on whole database of 1200 images of 100 persons. In order to avoid biasness, the experiments are repeated 10 times and in each experiment randomly selected 900 images are used as training and remaining 300 are used for testing. Averaged results for all 10 experiments are given in this section.

5.3.1: Processing Time of each Phase

The proposed system is implemented and tested on a 64bit Ci-5 system with 2.60GHz processor, 4GB RAM and MATLAB 2013b. The computational time for each step is given in table-5.1.

Phase	Processing Time (sec)
Image Enhancement Phase	1.1365
Filter bank image Phase	2.96
Feature Extraction Phase	0.4667
Classification Phase	0.9975
Total Time	5.5607

Table 5.1: Processing Time of each Phase

5.4: Performance Measure

Performance Measures of a system are taken in order to check the performance, integrity and stability. It shows how much system works correctly and efficiently. The performance measures which we have used for proper evaluation of proposed system are defined as follows:

5.4.1: Accuracy (Identity Rate)

Accuracy is defined as how much the calculated value is close to actual value. Accuracy is high if the closeness is minimum and vice versa. There is an indirect proportional relation between accuracy and closeness.

5.4.2: False Acceptance Rate

False Acceptance Rate defines number of unauthorized people who tried to attempt the system and allowed. In this case an unauthorized person is recognized as an authorized person. It is type II error that was occasionally made by the system and considered as a serious error. It may be expressed in probability form. For example, if this rate has value of 0.1%, this means 1out of each 1000 unauthorized person who tried to attempt the system is authorized to use the system. It is also defined as the ratio between false acceptance and the total number of identification attempts. In our case, it is defined as the total number of false samples labeled as true. Another way to calculate FAR is defines in [38] which is defined as below.

$$FAR = PR \times FMR \times (1 - FTA) \qquad 5.1\ [38]$$

Where:

PR= Penetration Rate means search of the sample over all input samples regardless of whether it is found or not.

FMR= False Match rate means sample from two different persons are considered from one person.

FTA= Failure to Acquire rate means number of failures by the system to acquire a significant quality image.

5.4.3: False Rejection Rate

False Rejection Rate defines number of authorized persons who are rejected to attempt the system. In this scenario n authorized person is not allowed to access the system. It is a type I error. we can define it in probability form, For example if this rate has a value of 0.1% then it means that 1 authorized person out of every 1000 persons who are authorized was rejected to access the system. It can be expressed as the ratio of between number of authorized persons who are rejected to access the system and total number of attempts to access the system. In our case, it is defined as the total number of true samples labeled as false. Another way to calculate FRR is defines in [38] which are defined as below.

$$FRR = FTA \times (1\text{-}FTA) \times BER + (1\text{-}FTA) \times (1\text{-}BER) \times FNMR \qquad 5.2[38]$$

Where:

FTA= Failure to Acquire rate means number of failures by the system to acquire a significant quality image.

BER= Binning Error Rate means error when enrolled and test samples are placed in different partitions of the database. More the partitions lesser the binning rate.

FNMR= False Non Match Rate means different samples from one person are considered from different persons**.**

5.5: Evaluation Results

Evaluation Results of our proposed system are defined below in form of **False Acceptance and Rejection Rates.**

5.5.1: False Acceptance Rate

False acceptance Rate of the proposed system is defined in table 5.2 and scatter plot is shown in fig 5.4.

Threshold Value	False Acceptance Rate (%)
0.1	**0.7517**
0.2	**0.1517**
0.3	**0.07**
0.4	**0.0283**
0.5	**0.0133**
0.6	**0.0133**
0.7	**0.01**
0.8	**0.01**
0.9	**0.01**
0.95	**0.01**

Table 5.2: False Acceptance Rate of proposed system

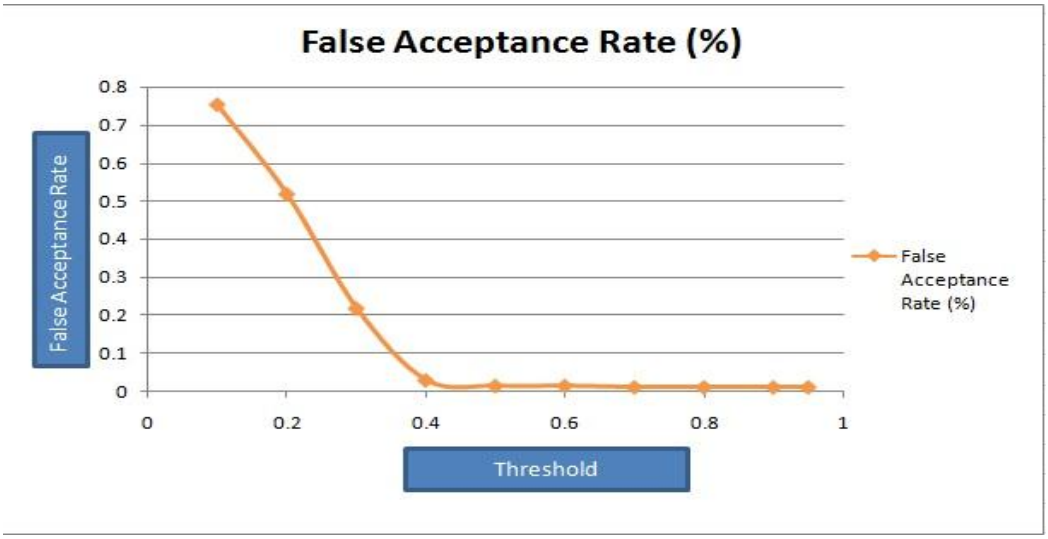


Figure 5.4: Scatter Plot of False Acceptance Rate

5.5.2: False Rejection Rate

False Rejection Rate of the proposed system is defined in table 5.3 and scatter plot is shown in fig 5.5.

Threshold Value	False Rejection Rate (%)
0.1	**0.0667**
0.2	**0.29**
0.3	**0.51**
0.4	**0.72**
0.5	**0.89**
0.6	**0.9433**
0.7	**0.98**
0.8	**0.993**
0.9	**0.9967**
0.95	**0.9967**

Table 5.3: False Rejection Rate of proposed system

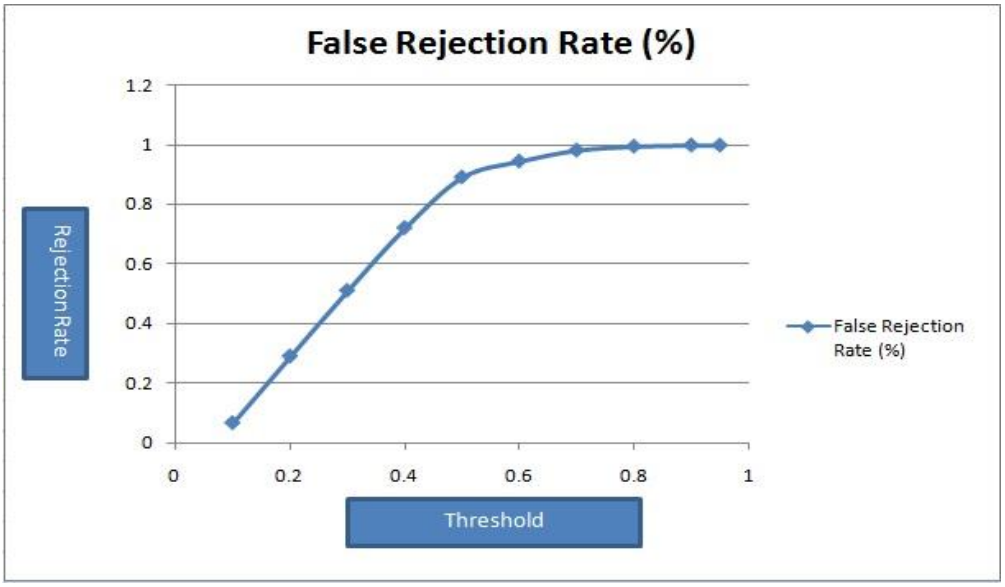


Figure 5.5: Scatter Plot of False Rejection Rate

5.6: Comparison of Proposed System with Previous Methods

A brief comparison between some previous methods and our proposed method in form of accuracy is defined in the form of table in Table 5.3. This comparative analysis is done with only those methods which have used same database.

Author	Identity Rate(%)	Equal Error Rate	False Acceptance Rate	False Rejection Rate
Aycan et. al. [18]	96.67	3.17	--------	--------
Aycan et. al. [19]	86.74	5.40	--------	--------
Proposed System	96.97	3.03	1.3%	1.75%
Proposed System	94.32	5.68	1.9%	2.1%

Table 5.4: Comparison between Proposed and Previous Methods

5.7: Summary

This chapter includes a brief description of the dataset that we used and the results we obtained. It also consists of the comparison between previous methods and our proposed method as well as processing time taken by each step.

Chapter 6: Conclusion

Biometric Systems are used in identification and recognition of persons in order to ensure the security, avoiding fraudulent activities and managing records. Several biometric systems like fingerprint, facial recognition, iris scan, retina scan, palm print recognition, foot print recognition, voice recognition system and etc are used for this purpose. We designed a biometric system named as: "Dorsal Hand Veins based Person Identification" that uses dorsal hand veins in order to distinguish different persons and recognized them. Main objective to design this system is to provide safety and security to people and facilitate them in order to maintain the records and databases by using this method. It is also useful in identifying the people in crimes and in forensic.

6.1: Model Description

System consists of two parts. One is enrollment part and the second is identification part. Enrollment part consists of pre-processing, veins enhancement, veins segmentation, features extraction, features validation and feature set formation that were stored in database. Second step is identification part in which a test sample is processed by steps defined in first part and in the end a comparison is made with the database for identification purpose. In pre-processing green channel is extracted that is then passed to enhancement phase where we use morphological operation and Gabor filter bank for enhancement purpose and segmentation is done by using adaptive thresholding after enhancement. Ending and bifurcation are the main features that are used and KNN-Method is used for classification. KNN classifies the sample on the basis of Euclidean Distance and assigns a class to the sample that is more near to it.

6.2: Advantages of this method over other biometric systems

Biometric system based on hand veins has a reasonable advantage over other systems. This system used pattern of dorsal hand vein located on the back side of hand to differentiate the people. Because, this pattern of veins is unique in each human being and bear no resemblance with any other person in whole world even in twins like same DNA of twins. Systems based on hand veins need not to contact with the scanner like in finger print, foot print and palm print

system. This discriminative pattern can only be taken from a living human body because in a dead body whole pattern is disturbed and this property provides an advantage to these systems over other like retina recognition system, finger print recognition system, facial recognition system.

6.3: Achieved Results

The result achieved by implementing this system is in the form of accuracy and it is 96.5% and error obtained is 3.5%.

6.4: Future Work

This method can be extended by applying different classifiers in order to improve the classification rates and accuracy such as: SVM, GMM and Neural Networks and different tests can be performed to compare the performance by using different pattern recognition techniques. SVM is Support Vector Machine that is a supervised classifier is useful especially in higher dimensions no matter number samples are less or greater than the number of dimensions. Gaussian Mixture Model is an unsupervised classifier. A neural classifier works on the function of human neurons. It has an input that is processed but some functions and passed to next layer and in the end a result is generated in the form of action or no action.

Future work to improve performance by implementing other classifiers can also be done on the defined dataset that we used in our method.

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