

# **Fingerprint Recognition and Analysis**

*A Thesis report*

*submitted towards the partial fulfillment of the  
requirements of the degree of*

***Master of Engineering***

***In***

***Electronics Instrumentation and Control Engineering***

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## **ABSTRACT**

Security systems are now computerized. Automated security systems are essential now. These days most of the banking transactions, use of cell phones and personal digital assistants (PDAs) are frequently performed. This rapid progress in personal communication system, wireless communication system and smart card technology in the society makes information more quick & realistic. Due to the growing importance of the information technology and the necessity of the protection and access restriction, reliable personal identification is necessary and essential condition also. There are three main methodologies when performing this verification. The security system can ask the user to provide some secret information known only to the user and the system or can ask the user to provide something only the user has access to, it could identify trait which is unique for the user. Identifying trait that is unique for the user is known as fingerprint recognition, hand geometry, iris, face and signature etc.

Reliable extraction of features from poor quality prints is the most challenging problem faced in the area of fingerprint recognition. Fingerprints are the oldest and most widely used form of biometric identification. Local characteristic called minutiae points represent fingerprints. This can be used as identification marks for fingerprint recognition. The goal of this thesis is to develop a complete system for fingerprint recognition through minutiae extracting and matching minutiae. To achieve good minutiae extraction in fingerprints with varying quality, preprocessing in form of image enhancement, image segmentation and binarization is first applied on fingerprints before they are evaluated. The combination of multiple methods comes from a wide investigation into research papers.

Minutias marking with special consideration of the triple branch counting and false minutiae removal methods are used in the work. Also some novel changes like segmentation using morphological operations, improved thinning, false minutiae removal methods, minutia marking with special considering the triple branch counting, minutia unification by decomposing a branch into three terminations, and matching in the unified x-y coordinate system after a two-step transformation are used in the work. The minutiae based fingerprints recognition technique is studied in detail and implemented in MATLAB.

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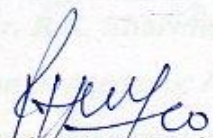
*This work would not have been possible without the encouragement and able guidance of my supervisor, Mrs. Gagandeep Kaur, Assistant professor EIED, Thapar University, Patiala. Most of the novel ideas and solutions found in this thesis are the result of our numerous stimulating discussions. Her feedback and editorial comments were also invaluable for the writing of this thesis.*

*I would also like thank all the faculty members of the department and my friends who directly or indirectly helped me in completion of my thesis.*

*No words of thanks are enough for my dear parents whose support, care and blessings makes me successful. Thanks to them to be with me.*

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*Place: Thapar University, Patiala*

  
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## CERTIFICATE

I hereby declare that the report entitled "**Fingerprint Recognition and Analysis**" is an authentic record of my own work carried out as requirements for the award of degree of M.E. Electronic Instrumentation & Control at Thapar University, Patiala, under the guidance of Mrs. Gagandeep Kaur, Assistant Professor, EIED.

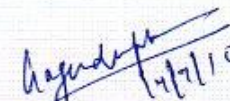
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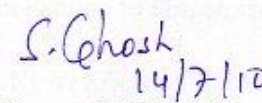
  
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## List of Abbreviation

Sr. no.	Short form	Abbreviation
1.	PDA	Personal Digital Assistant
2.	PIN	Personal Identification Number
3.	OCR	Optical Character Recognition
4.	FBI	Federal Bureau of Investigation
5.	DNA	Deoxyribo Nucleus Acid
6.	FAR	False Accept Rate
7.	FRR	False Reject Rate
8.	ANN	Artificial Neural Network
9.	AFIS	Automatic Fingerprint Identification System
10.	FFT	Fast Fourier Transform
11.	MDM	Minutiae Direction Map
12.	PPI	Pixels Per Inch
13.	ICP	Iterative Closest Point
14.	EER	Equal Error Rate
15.	NIST	National Institute of Standards and Technology
16.	AFPC	Automatic Fingerprint Pattern Classification
17.	JPEG	Joint Photographic Experts Group
18.	WSQ	Wavelet Scalar Quantization
19.	ANSI-NIST	American National Standards Institute- National Institute of Standard and Technology
20.	DPI	Dots Per Inch
21.	USB	Universal Serial Bus
22.	CCD	Charge Coupled Device

# Chapter 1

## Introduction

---

In an increasingly digitized world the reliable personal authentication has become an important human computer interface activity. National security, e-commerce and access to computer networks are now very common where establishing a person's identity has become vital. Existing security measures rely on knowledge-based approaches like passwords or token-based approaches such as swipe cards and passports to control access to physical and virtual spaces, but these methods are not very secure. Tokens such as badges and access cards may be duplicated or stolen. Passwords and personal identification number (PIN) numbers may be stolen electronically. Furthermore, they cannot differentiate between authorized user and a person having access to the tokens or knowledge.

Biometrics such as fingerprint, face and voice print offers means of reliable personal authentication that can address these problems and is gaining citizen and government acceptance.

### 1.1 Biometrics

Biometrics is the science of verifying the identity of an individual through physiological measurements or behavioural traits. Since biometric identifiers are associated permanently with the user they are more reliable than token or knowledge based authentication methods. Biometrics offers several advantages over traditional security measures. These includes

1. Non-repudiation
2. Accuracy and Security
3. Screening

### **1.1.1 Non-repudiation**

With token and password based approaches, the perpetrator can always deny committing the crime pleading that his/her password or ID was stolen or compromised even when confronted with an electronic audit trail. There is no way in which his claim can be verified effectively. This is known as the problem of deniability or of 'repudiation'. However, biometrics is indefinitely associated with a user and hence it cannot be lent or stolen making such repudiation infeasible.

### **1.1.2 Accuracy and Security**

Password based systems are prone to dictionary and brute force attacks. Furthermore, such systems are as vulnerable as their weakest password. On the other hand, biometric authentication requires the physical presence of the user and therefore cannot be circumvented through a dictionary or brute force style attack. Biometrics has also been shown to possess a higher bit strength compared to password based systems and is therefore inherently secure.

### **1.1.3 Screening**

In screening applications, we are interested in preventing the users from assuming multiple identities e.g. a terrorist using multiple passports to enter a foreign country. This requires that we ensure a person has not already enrolled under another assumed identity before adding his new record into the database. Such screening is not possible using traditional authentication mechanisms and biometrics provides the only available solution.

The various biometric modalities can be broadly categorized as

- Physical biometrics: These involve some form of physical measurement and include modalities such as face, fingerprints, iris-scans, hand geometry etc.
- Behavioural biometrics: These are usually temporal in nature and involve measuring the way in which a user performs certain tasks. This includes modalities such as speech, signature, gait, keystroke dynamics etc.
- Chemical biometrics: This is still a nascent field and involves measuring chemical cues such as odor and the chemical composition of human perspiration.

A number of biometric identifiers are in use in various applications. Each biometric has its

strengths and weaknesses and the choice typically depends on the application.

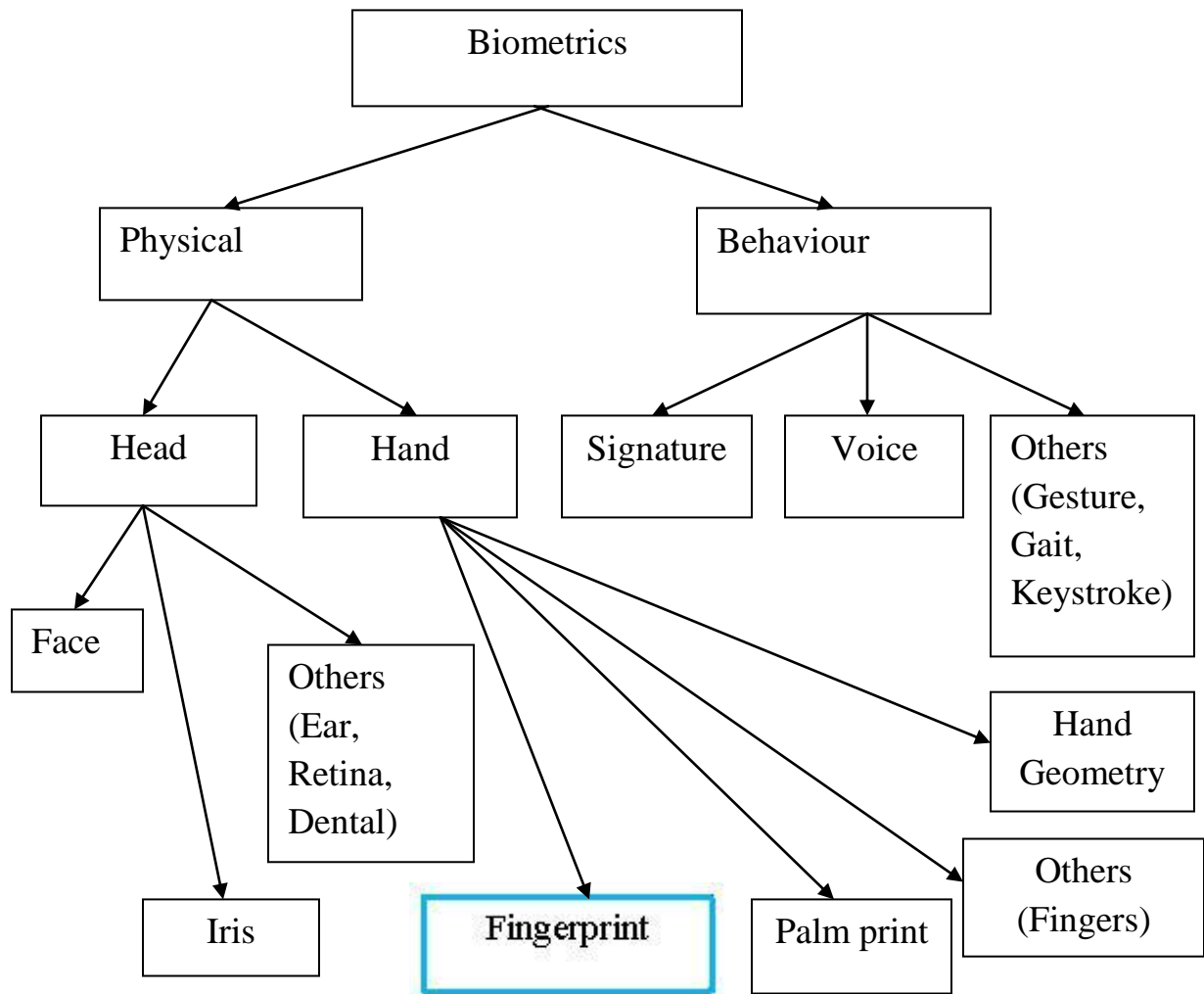


Figure 1.1 Various biometrics

No single biometric is expected to effectively meet the requirements of all the applications. The match between a biometric and an application is determined depending upon the characteristics of the application and the properties of the biometric. These various biometric identifiers mentioned above are compared in table below fingerprint recognition has a very good balance of all the desirable properties.

<b>Biometric identifier</b>	<b>universality</b>	<b>Distinctiveness</b>	<b>Permanence</b>	<b>Collectability</b>	<b>Performance</b>	<b>Acceptability</b>	<b>Circumvention</b>
DNA	H	H	H	L	H	L	L
Ear	H	M	H	M	M	H	M
Face	H	L	M	H	L	H	H
Facial thermo gram	H	H	L	H	M	H	L
<b>Fingerprint</b>	<b>M</b>	<b>H</b>	<b>H</b>	<b>M</b>	<b>H</b>	<b>M</b>	<b>M</b>
Gait	M	L	L	H	L	H	M
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
Odor	L	L	L	M	L	M	M
Retina	H	H	M	L	H	L	L
Signature	L	L	L	H	L	H	H
Voice	M	L	L	M	L	H	H

Table1. Comparison of various biometric technologies. High, Medium, and Low are denoted by H, M, and L, respectively.

Depending on the application, biometrics can be used for verification or for identification. In verification, the biometric is used to validate the claim made by the individual. The biometric of the user is compared with the biometric of the claimed individual in the database. The claim is rejected or accepted based on the match. In identification, the system recognizes an individual by comparing his biometrics with every record in the database. In this thesis, I will be dealing mainly with the problem of verification using fingerprints. In general, biometric verification consists of two stages as shown in figure

## 1.2 Enrollment and Authentication

In enrollment the biometrics of the user is captured and the extracted features templates are stored in the database.

In authentication the biometrics of the user is captured again and the extracted features are compared with the ones already existing in the database to determine a match. The specific record to fetch from the database is determined using the claimed identity of the user. The database itself may be central or distributed with each user carrying his template on a smart card.

The various stages of a typical fingerprint recognition system are shown in Figure 1.2. The fingerprint image is acquired using off-line methods such as creating an inked impression on paper or through a live capture device consisting of an optical, capacitive, ultrasound or thermal sensor. The first stage consists of standard image processing algorithms such as noise removal and smoothening.

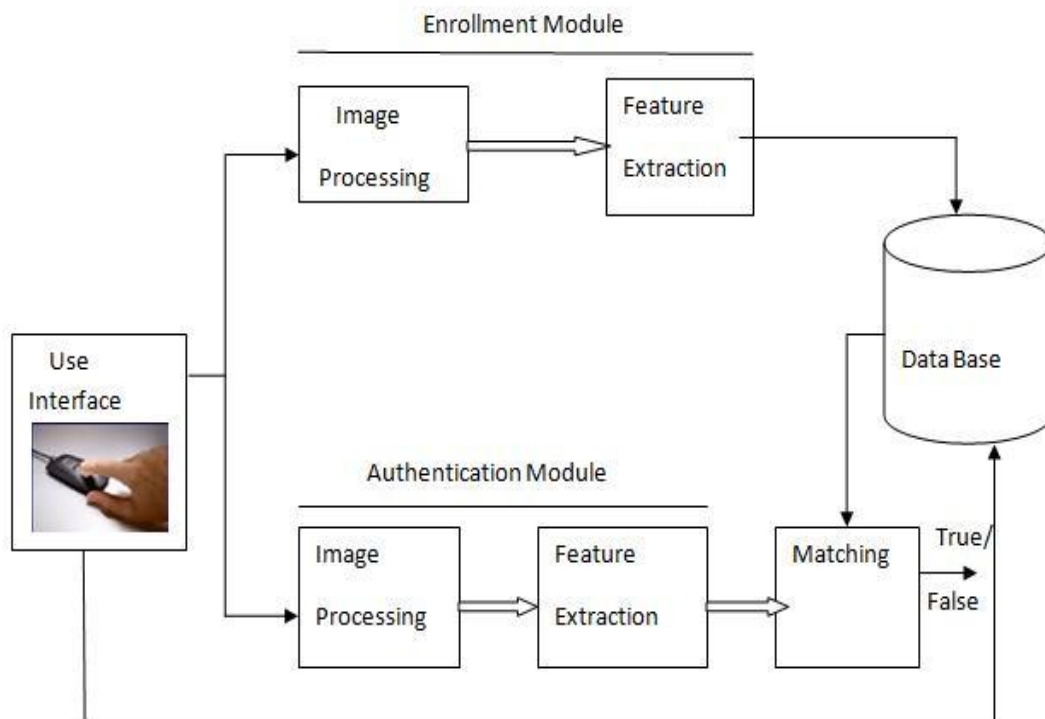


Figure 1.2 General process to recognize a fingerprint.

However, it is to be noted that unlike regular images, the fingerprint image represents a system of oriented texture and has very rich structural information within the image. Furthermore, the definition of noise and unwanted artifacts are also specific to fingerprints. The fingerprint image enhancement algorithms are specifically designed to exploit the

periodic and directional nature of the ridges. Finally, the minutiae features are extracted from the image and are subsequently used for matching. Although research in fingerprint verification research has been pursued for several decades now, there are several open research challenges still remaining, some of which will be addressed in the ensuing sections of this thesis.

## **1.2 Biometrics and Pattern Recognition**

As recently as a decade ago, biometrics did not exist as a separate field. It has evolved through interaction and confluence of several fields. Fingerprint recognition emerged from the application of pattern recognition to forensics. Speaker verification evolved out of the signal processing community. Face detection and recognition was largely researched by the computer vision community. While biometrics is primarily considered as application of pattern recognition techniques, it has several outstanding differences from conventional classification problems as enumerated below

1. In a conventional pattern classification problem such as optical character recognition (OCR) recognition the number of patterns to classify is small (A-Z) compared to the number of samples available for each class. However in case of biometric recognition, the number of classes is as large as the set of individuals in the database. Moreover it is very common that only a single template is registered per user.
2. The primary task in biometric recognition is that of choosing a proper feature representation. Once the features are carefully chosen, the act of performing verification is fairly straight- forward and commonly employs simple metrics such as Euclidean distance. Hence the most challenging aspects of biometric identification involve signal and image processing for feature extraction.
3. Since biometric templates represent personally identifiable information of individuals, security and privacy of the data is of particular importance unlike other applications of pattern recognition.
4. Modalities such as fingerprints, where the template is expressed as an unordered point set

minutiae do not fall under the category of traditional multi-variety features commonly used in pattern recognition.

### **1.3 Fingerprint as a Biometric**

Fingerprints were accepted formally as valid personal identifier in the early twentieth century and have since then become a de facto authentication technique in law-enforcement agencies worldwide. The federal bureau of investigation (FBI) currently maintains more than 400 million fingerprint records on file. Fingerprints have several advantages over other biometrics such as the following.

1. High universality
2. High distinctiveness
3. High permanence
4. Easy collectability
5. High performance
6. Wide acceptability

#### **1.3.1 High universality**

A large majority of the human population has legible fingerprints and can therefore be easily authenticated. This exceeds the extent of the population who possess passports, ID cards or any other form of tokens.

#### **1.3.2 High distinctiveness**

Even identical twins who share the same deoxyribo nucleus acid (DNA) have been shown to have different fingerprints, since the ridge structure on the finger is not encoded in the genes of an individual. Thus fingerprints represent a stronger authentication mechanism than DNA. Furthermore, there has been no evidence of identical fingerprints in more than a century of forensic practice. There are also mathematical models that justify the high distinctiveness of fingerprint patterns.

### 1.3.3 High permanence

The ridge patterns on the surface of the finger are formed in the womb and remain invariant until death except in the case of severe burns or deep physical injuries.

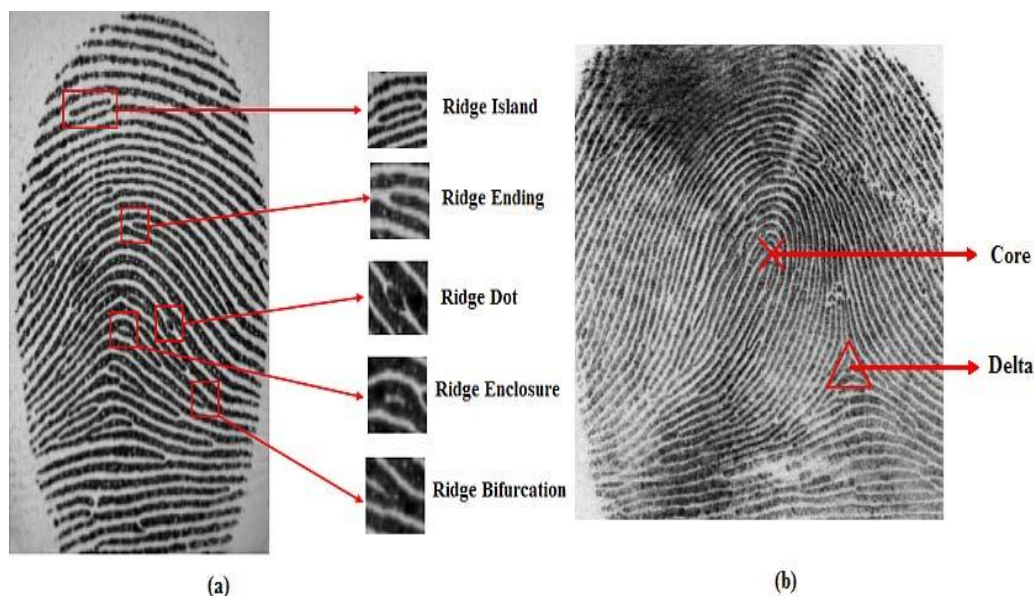


Figure 1.7: (a) Local Features Minutiae (b) Global Features Core and Delta

### 1.3.4 Easy collectability

The process of collecting fingerprints has become very easy with the advent of online sensors. These sensors are capable of capturing high resolution images of the finger surface within a matter of seconds. This process requires minimal or no user training and can be collected easily from co-operative or non cooperative users. In contrast, other accurate modalities like iris recognition require very co-operative users and have considerable learning curve in using the identification system.

### 1.3.5 High performance

Fingerprints remain one of the most accurate biometric modalities available to date with jointly optimal false accept rate (FAR) and false reject rate (FRR). Forensic systems are currently capable of achieving FAR of less than  $10^{-4}$ .

### 1.3.6 **Wide acceptability**

While a minority of the user population is reluctant to give their fingerprints due to the association with criminal and forensic fingerprint databases, it is by far the most widely used modality for biometric authentication.

The fingerprint surface is made up of a system of ridges and valleys that serve as a friction surface when we are gripping the objects. The surface exhibits very rich structural information when examined as an image. The fingerprint images can be represented by both global as well as local features. The global features include the ridge orientation, ridge spacing and singular points such as core and delta.

## Chapter 2

### Literature Survey

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Louisa Lam et.al did comprehensive survey of thinning methodologies discussing the wide range of thinning algorithms, including iterative deletion of pixels and non pixel-based methods whereas skeleton organization algorithms based on medial axis and other distance transforms will be the subject matter of a subsequent study. This paper begins with an overview of the iterative thinning process and the pixel-deletion criteria needed to preserve the connectivity of the image pattern. Thinning algorithms are then considered in terms of these criteria as well as their modes of operation. This is followed by a discussion of non pixel-based methods that usually produce a centre line of the pattern directly in one pass without examining all the individual pixels [2].

Dario Maio et.at presented automatic system for fingerprint comparison is based on minutiae matching. Minutiae are essentially terminations and bifurcations of the ridge lines that constitute a fingerprint pattern. Automatic minutiae detection is an extremely critical process, especially in low-quality fingerprints where noise and contrast deficiency can originate pixel configurations similar to minutiae or hide real minutiae. In this method transform fingerprint images into binary images. An original technique has been proposed which is based on ridge line following, where the minutiae are extracted directly from gray scale images [3].

Ton van der Putte et.al presented one of the most critical issues to solve when building multi-accessible systems, such as computer applications, cars or physical buildings, is to determine the identity of a person. A system protecting confidential information or items of value puts strong security demands on the identification. Biometry provides us with user-friendly method for this identification and is becoming a competitor for current identification mechanisms, especially for electronic transactions. However there are ways to compromise a system based on biometric verification.

This technique focuses on the drawbacks and risks of biometric verification, specifically verification based on fingerprints. It shows how all currently available fingerprint scanners can be fooled by dummies that are created with very limited means and skills. In this paper new methods of identification without first examining the technical opportunities for compromising the identification mechanism and the associated legal consequences are presented. This is especially true for people working with smart cards since it is quite common to store fingerprints on smart cards and due to the developments in solid state fingerprint scanners, integration of a fingerprint scanner on a smart card is possible [4].

Zsolt Miklo et.al proposed an effective fingerprint verification system. It assumed that an existing reference fingerprint image must validate the identity of a person by means of a test fingerprint image acquired online and in real-time using minutiae matching. The matching system consists of two main techniques. The first technique allows for the extraction of essential information from the reference image offline, the second technique performs the matching itself online. The information is obtained from the reference image by filtering and careful minutiae extraction procedures. The fingerprint identification is based on triangular matching to cope with the strong deformation of fingerprint images due to static friction or finger rolling [5].

Milene Arantes et.al discussed biometrics characteristics for recognition/classification and describes how there are used for individual recognition. The approach uses the automated fingerprint recognition based on minutia, which are extracted directly from the fingerprints and the methodology used to its recognition is the artificial neural networks based system. The neocognitron model was the artificial neural network (ANN) chosen. It is possible to verify its usefulness for another kind of pattern recognition as well [8].

Sen Wang Wei et.al proposed fingerprint classification that provides an important fingerprint index which can reduce fingerprint matching time in large database. A good classification algorithm can give an accurate index that is able to search a fingerprint database more effectively. In this technique fingerprint classification algorithm that is based on directional fields had been proposed computed directional fields of fingerprint image and detect singular points cores. Then they features that are define from fingerprint images are extracted k-means classifier and 3-nearest neighbour to classify feature on also be use and it distinguishes which fingerprint is arch, left loop, right loop, or whorl [9].

Sen Wang et.al proposed a minutiae extraction technique for automatic fingerprint identification system is one of the most important steps. The performance of minutiae extraction relies heavily on an enhancement algorithm. There are many algorithms of enhancement that depend on the local orientation field of fingerprint. In the singular point area, because the local orientation changes very rapidly, this cannot make accurate. So, the result of enhancement in the singular point is very bad. In this paper a new method and design presented for a new filter to enhance fingerprint in the singular point area is distinguish the singular point area are first distinguished then a new filter to enhancement this area [14].

Sharat Chikkerur et.al presented majority of the existing fingerprint recognition algorithms are based on matching minutia features. Minutiae extraction is one of the critical steps in fingerprint verification algorithms. Poor quality fingerprint images lead to missing and spurious minutiae that degrade the performance of the matching system. In this paper propose two new techniques for minutiae verification based on non-trivial gray level features. The proposed feature intuitively represents the structural properties of the minutiae neighbourhood leading to better classification. They used directionally selective steerable wedge filters to differentiate between minutiae and non-minutiae neighbourhoods [19].

Antonelli, et.al proposed attacking fingerprint-based biometric systems by presenting fake fingers at the sensor could be a serious threat for unattended applications. This paper introduces a new approach for discriminating fake fingers from real ones, based on the analysis of skin distortion. The user is required to move the finger while pressing it against the scanner surface thus deliberately exaggerating the skin distortion. Novel techniques for extracting, encoding and comparing skin distortion information are formally defined and systematically evaluated over a test set of real and fake fingers. The proposed approach is privacy friendly and does not require additional expensive hardware besides a fingerprint scanner capable of capturing and delivering frames at proper rate [20].

Jayant V Kulkarni et.al presented a new approach for fingerprint classification, based on the distribution of local features minute details or minutiae of the fingerprints. The main advantage is that fingerprint classification provides an indexing scheme to facilitate efficient matching in a large fingerprint database. A set of rules based on heuristic approach has been proposed. The area around the core point is treated as the area of interest for extracting the minutiae features as there are substantial variations around the core point as compared to the

areas away from the core point. The core point in a fingerprint has been located at a point where there is maximum curvature [21].

B.Y. Hiew et.al focused on touch-less fingerprint recognition deserves increasing attention as it lets off the problems of deformation, maintenance, latent fingerprint problems and so on that still exist in the touch-based fingerprint technology. However, problems such as the low ridges-valleys contrast in the fingerprint images defocus and motion blurriness raise when developing a digital camera based fingerprint recognition system. The system comprises of preprocessing, feature extraction and matching stages [22].

Gualberto Aguilar et.al presented a fingerprint recognition is one of the most popular and successful methods used for person identification. Which takes advantage of the fact that the fingerprint has some unique characteristics called minutiae, which are points where a curve track finishes, intersect with other track or branches off. Biometric identification systems using fingerprints patterns are called automatic fingerprint identification system (AFIS). A novel method for Fingerprint recognition is considered using a combination of fast fourier transform (FFT) and Gabor Filters to enhancement the fingerprint images [23].

Nicolas Galy et.al proposed a fingerprint verification system. It is composed of a tactile fingerprint sensor, integrated read out and conversion circuits and dedicated recognition algorithms. The sensor is a single-line sweep mode sensor e.g., it is made of a single line of sensing elements, thus covering the minimum surface of silicon. Compared with  $\text{cm}^2$  sized touch sensors, it offers a large cost reduction and possibility of easy integration into portable devices. The use of a single line to measure a fingerprint requires the user to sweep its finger along the sensor. This sensing scheme produced fingerprint images with several distortions that needs further image processing to allow efficient fingerprint recognition [24].

Raffaele Cappelli et.al presented a minutiae-based templates is a very compact representation of a fingerprint image, and for a long time, it has been assumed that it did not contain enough information to allow the reconstruction of the original fingerprint. This paper proposes a novel approach to reconstruct fingerprint images from standard templates and investigates to what extent the reconstructed images are similar to the original ones. The efficacy of the reconstruction technique has been assessed by estimating the success chances of a masquerade attack against nine different fingerprint recognition algorithms. [25].

Weiping Chen et.al presented a minutiae-based technique is the most popular approach in fingerprint matching. However most existing techniques need to search for the best correspondence of minutiae pairs or use reference points (core and delta points) to estimate the alignment parameters. The problem of lost minutiae or spurious minutiae always occurs during the minutiae detection process. Hence, the corresponding pairs or reference points may not be found under this condition. A new minutiae-based fingerprint matching algorithm using phase correlation. In this paper defined a new representation called minutiae direction map (MDM). First we convert minutiae sets into 2D image spaces. Then the transformation parameters are calculated using phase correlation between two minutiae direction maps to align two fingerprints to be matched. The similarity of two fingerprints is determined by the distance between two minutiae sets [26].

Yi Chen et.al presented fingerprint friction ridge are generally shows in a hierarchical order at three different names, pattern, minutia points and pores and ridge contours. Although latent print examiners frequently take advantage of ridge contours features to assist in identification, automated fingerprint identification systems (AFIS) currently rely only on pattern and minutia point features. Actually the federal bureau of investigation's (FBI) standard of fingerprint resolution for automated fingerprint identification systems is 500 pixels per inch (PPI), which is inadequate for capturing ridge contours features, such as pores. With the advances in fingerprint sensing technology, many sensors are now equipped with dual resolution (500 ppi/1,000 ppi) scanning capability. However, increasing the scan resolution alone does not necessarily provide any performance improvement in fingerprint matching, unless an extended feature set is utilized. Propose a hierarchical matching system that utilizes features at all the three names extracted from 1,000 ppi fingerprint scans. Ridge contours features, including pores and ridge contours, are automatically extracted using Gabor filters and wavelet transform and are locally matched using the Iterative Closest Point (ICP) algorithm. With this method show that ridge contours features carry significant discriminatory information. There is a relative reduction of 20 % in the equal error rate (EER) of the matching system when ridge contours features are employed in combination with pattern and minutia points features. This significant performance gain is consistently observed across various quality fingerprint images [27].

Liu Wei et.al presented a fingerprint classification is an important indexing method for any large scale fingerprint recognition system or database as a method for reducing the number of fingerprints that need to be searched. Fingerprints are generally classified into broad

categories based on global features. In this paper describes a new fingerprint classification algorithm that uses some curve features of ridgelines. The algorithm mainly uses the total direction change of the ridgelines to classify the ridgelines. Using these information, classification is performed. The algorithm was tested on national institute of standards and technology (NIST) database and got a good accuracy for the 6 classes [28].

S.D.Sawarkar et.al focused on a reliable method of computation for minutiae feature extraction from fingerprint images. In this a novel fingerprint representation scheme that relies on describing the orientation field of the fingerprint pattern with respect to each minutia detail. A fingerprint image is treated as a textured image. Improved algorithms for enhancement of fingerprint images, which have the adaptive normalization based on block processing, are proposed. An orientation flow field of the ridges is computed for the fingerprint image. To accurately locate ridges, a ridge orientation based computation method is used. After ridge segmentation a method of computation is used for smoothing the ridges. The ridge skeleton image is obtained and then smoothed using morphological operators to detect the features. A post processing stage eliminates a large number of false features from the detected set of minutiae features algorithm [29].

H B Kekre et.al presented a fingerprint recognition is a widely used biometric identification mechanism. In case of correlation based fingerprint recognition detection of a consistent registration point is a crucial issue this point can be a core point of a fingerprint. Many techniques have been proposed but success rate is highly dependent on input used and accurate core point detection is still an open issue. Here we discuss a core point detection algorithm which is computationally simple and gives consistent detection of a core point. The proposed technique is based on orientation field of the fingerprint which is calculated using gradient based technique and optimized neighbourhood averaging to generate a smoother orientation field, on which we operate a specially designed mask for detecting core point as the orientation field in the region of the core point is different than the other area. Though all fingerprints don't possess core point still this algorithm is useful to detect high curvature regions. This algorithm is helpful in the development of correlation based automatic fingerprint recognition system (AFIS) [30].

Ishmael S. Msiza, et.al presented the problem of Automatic Fingerprint Pattern Classification (AFPC) has been studied by many fingerprint biometric practitioners. It is an important concept because, in instances where a relatively large database is being queried for the purposes of fingerprint matching, it serves to reduce the duration of the query. The fingerprint classes discussed in this document are the Central Twins, Tented Arch, Left Loop, Right Loop and the Plain Arch. The classification rules employed in this problem involve the use of the coordinate geometry of the detected singular points. [31].

#### 3.1 Introduction to Fingerprint System

Fingerprints are graphical flow-like ridges present on every human being fingers. They are fully formed at about seven months of fetus development and finger ridge configurations do not change throughout the life of an individual. Except due to accidents such as bruises and cuts on the fingertips this property makes fingerprints a very attractive biometric identifier. Fingerprint system can be separated into two categories.

1. Verification
2. Identification.

##### 3.1.1 Verification System

Verification system authenticates a person's identity by comparing the captured biometric characteristic with its own biometric templates pre-stored in the system. If individual is true then a verification system either accepts the submitted claim of identity otherwise rejects the claim.

##### 3.1.2 Identification system

Identification system recognizes an individual by searching the entire template database for a match. It conducts one-to-many very similar comparisons to establish the identity of the individual. In an identification system, the system establishes a subject's identity or fails if the subject is not enrolled in the system database without the subject having to claim an identity.

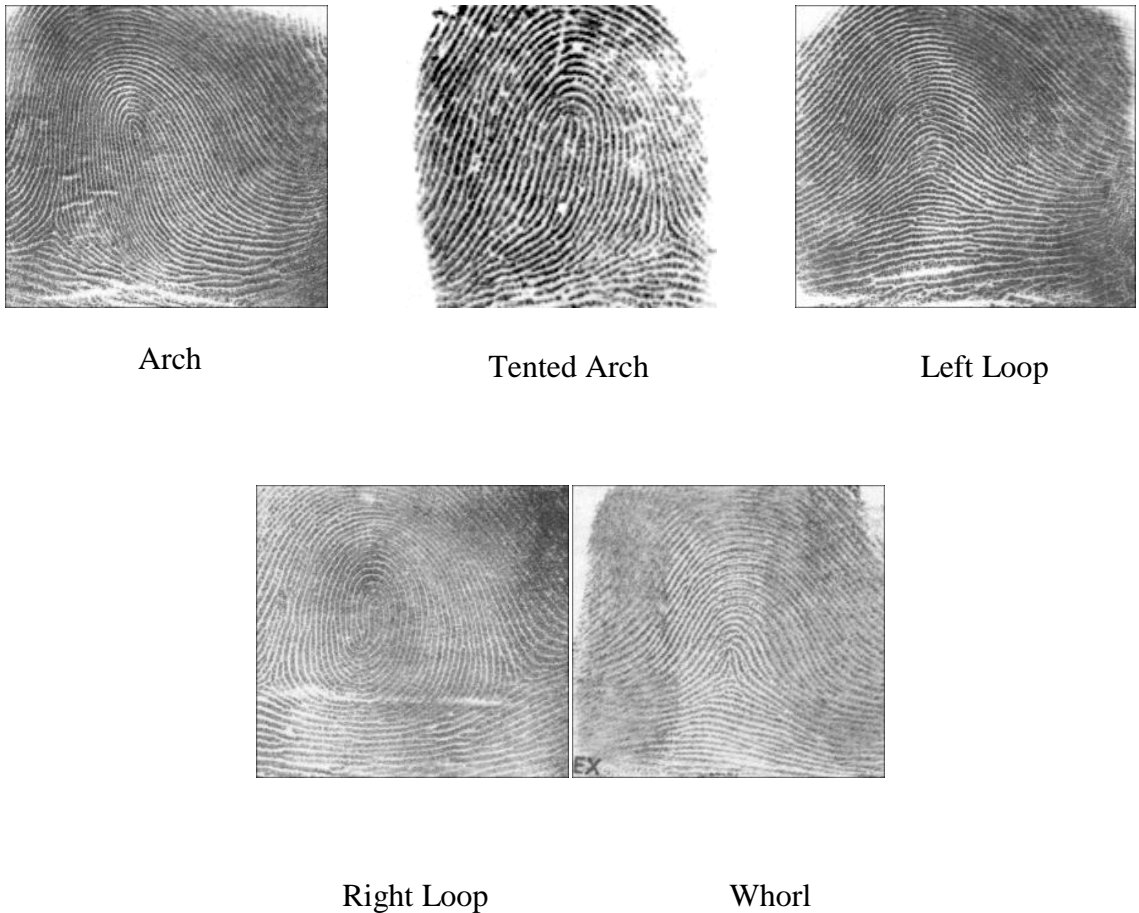


Figure3.1. Fingerprint patterns

The fingerprint has certain important feature as shown in figure 3.1 arch, tented arch, left loop, right loop, and whorl.

### 3.2 Fingerprint Representation

The representations of fingerprints are four types.

1. Image-based representation
2. Global Ridge Pattern
- 3 Local Ridge Detail
- 4 Intra-ridge Detail

#### 3.2.1 Image-Based Representation

In this fingerprint image it is used as a template. There is no need for a specific feature extracting algorithm, and the raw intensity pixel values are directly used. This representation retains the most information about a fingerprint since fewer assumptions are made about the application. However a fingerprint recognition system that uses the image-based representation requires tremendous storage space.

A system with large amount of fingerprint data may have difficulty storing all the templates. Traditional compression techniques, such as joint photographic experts group (JPEG) tend to lose the highest frequency details, which contains discriminating information and the blocking artifacts. It affects the performance of automatic fingerprint recognition systems. FBI recommends a compression method based on Wavelet Scalar quantization (WSQ) which can preserve the discriminating information without blocking artifacts Figure3.2. However, it still requires about 20 Kbytes to store a compresses fingerprint image.

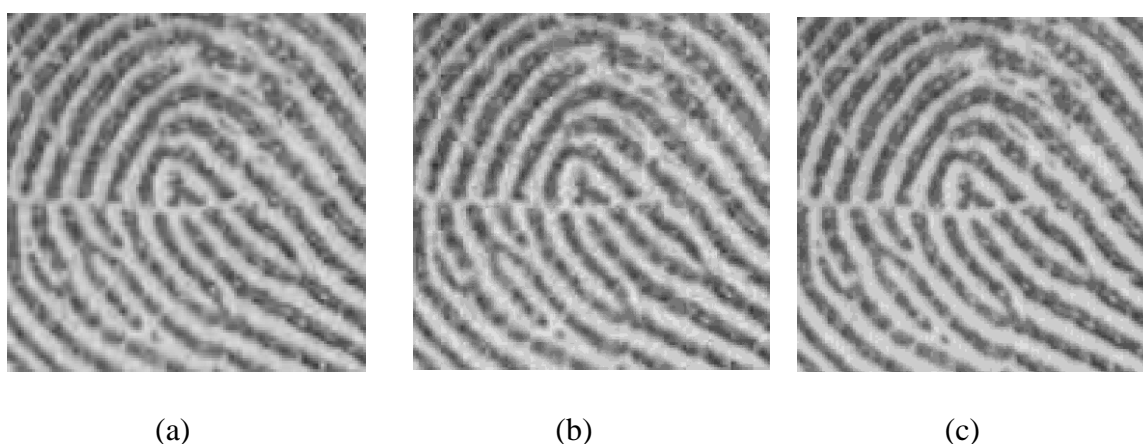


Figure 3.2 Comparison of using JPEG and WSQ compression techniques on fingerprint images. (a) The original fingerprint portion. (b) After being compressed by JPEG (c) After being compressed by WSQ.

### 3.2.2 Global Ridge Pattern

In this type the ridge structure, global landmarks and ridge pattern characteristics, such as the singular points, ridge orientation map, and the ridge frequency map. In this representation is sensitive to the quality of the fingerprint images. However, the discriminative abilities of this representation are limited due to absence of singular points.

### 3.2.3 Local Ridge Detail

This is the most widely used and studied fingerprint representation. Local ridge details are the discontinuities of local ridge structure referred to as minutiae. Sir Francis Galton was the first person who observed the structures and permanence of minutiae. Therefore, minutiae are also called Galton details. They are used by forensic experts to match two fingerprints.

There are about 150 different types of minutiae categorized based on their configuration. Among these minutia types ridge ending and ridge bifurcation are the most used, since all other types of minutiae can be seen as the combinations of ridge endings and ridge bifurcations. Some minutiae are illustrated in Figure 3.3. The American National Standards Institute-National Institute of Standard and Technology (ANSI-NIST) proposed a minutia based fingerprint representation. It includes minutiae location and orientation. The minutia orientation is defined as the direction of the underlying ridge at the minutia location Figure 3.4. minutiae-based fingerprint also has an advantage in helping privacy issues since one cannot

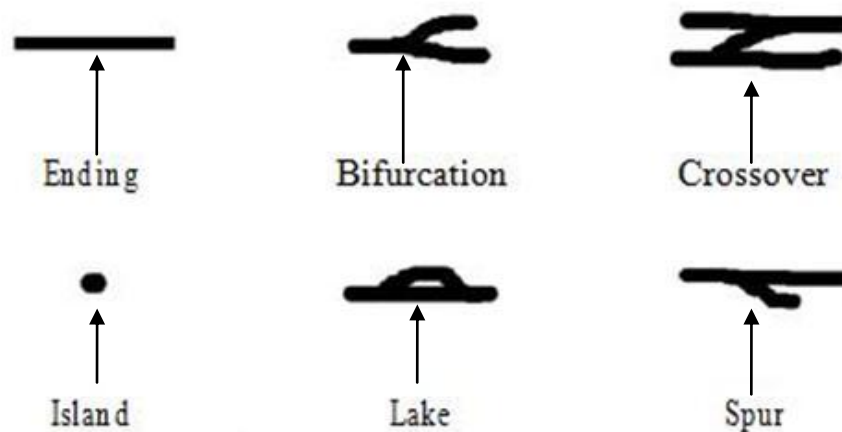


Figure 3.3 Common minutiae types

reconstruct the original image from using only minutiae information. Minutiae relatively are stable and robust to contrast, image resolutions, and global distortion. When we compared to other representations, however to extract the minutiae from a poor quality image is not an easy task.

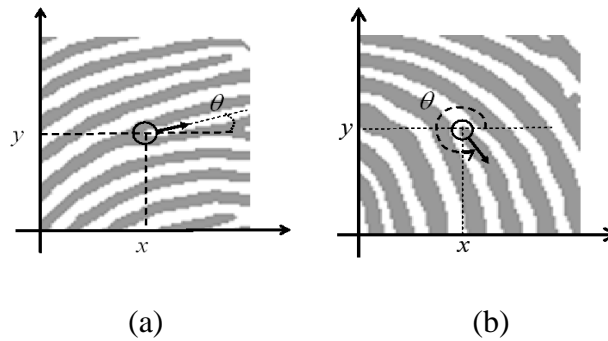


Figure 3.4 (a) A ridge ending minutia:  $(x, y)$  are the minutia coordinates,  $\theta$  is the minutia's orientation (b) A ridge bifurcation minutia  $(x, y)$  are the minutia coordinates,  $\theta$  is the minutia's orientation



Figure 3.5 A portion of a fingerprint where sweat pores (white dots on ridges) are visible today, most of the automatic fingerprint recognition systems are designed to use minutiae as their fingerprint representations.

### 3.2.4 Intra-ridge Detail

In this type of representation on every ridge of the finger epidermis, there are many tiny sweat pores. Pores are considered to be highly distinctive in terms of their number, positions, and shapes. However, extracting pores is feasible only in high-resolution fingerprint images for example 1000 dots per inch (DPI) and with good image quality. But this kind of representation is not practical for most applications.

### 3.3 Minutiae-Based Fingerprint Recognition

The minutiae-based fingerprint representation is used to design the systems due to the advantages of wide accessibility and stability. Minutiae-based fingerprint representation and matching are widely used by both machine and human experts. Minutiae representation has several advantages compared to other fingerprint representations. Minutiae have been historically used as key features in fingerprint recognition tasks. Its configuration is highly

distinctive and several theoretical models use it to provide an approximation of the individuality of fingerprints. Minutiae-based systems are more accurate than correlation based systems and the template size of minutiae-based fingerprint representation is small. Forensic experts use this representation which has now become part of several standards for exchange of information between different systems across the world.

### 3.4 Fingerprint Image Enhancement

Fingerprint image quality is an important factor in the performance of minutiae extraction and matching algorithms. A good quality fingerprint image Figure 3.6 (a) has high contrast between ridges and valleys. A poor quality fingerprint image Figure 3.6 (b) and (c) is low in contrast, noisy, broken, or smudgy, causing spurious and missing minutiae. Poor quality can be due to cuts, creases, or bruises on the surface of finger tip, excessively wet or dry skin condition, uncooperative attitude of subjects, damaged and unclean scanner devices, low quality fingers elderly people, manual worker and other factors.

The goal of an enhancement algorithm is to improve the clarity (contrast) of the ridge structures in a fingerprint. General-purpose image enhancement techniques are not very useful due to the non-stationary nature of a fingerprint image. However, techniques such as

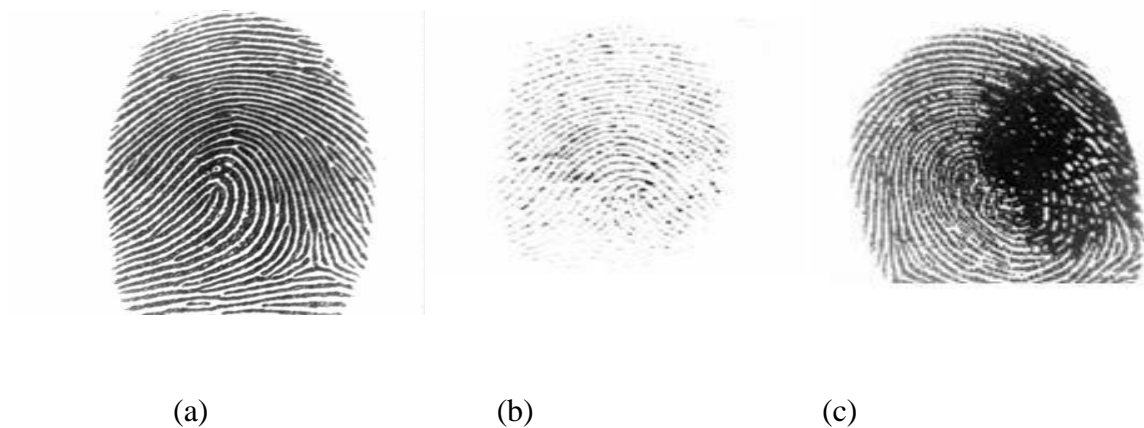


Figure 3.6 (a) A good quality fingerprint image; (b) a poor quality fingerprint caused by extremely dry skin; (c) a noisy fingerprint image.

gray-level smoothing, contrast stretching, histogram equalization, and Wiener filtering can be used as pre-processing steps before a sophisticated fingerprint enhancement algorithm is applied. Techniques that use single filter convolutions on the entire image are not suitable. Usually, a fingerprint image is divided into sub regions and then a filter whose parameters are pre-tuned according to the region's characteristics is applied. Each local region of a fingerprint can be seen as a surface wave Figure 3.7 of a particular wave (ridge) orientation and frequency. Several types of contextual filters in both spatial and frequency domains have been proposed in the literature.

As shown in figure 3.7 of a particular wave (ridge) orientation and frequency. Several types of contextual filters in both spatial and frequency domains have been proposed in the literature. The purpose of the filters is to fill small gaps in the direction of a ridge and to increase the discrimination between ridges and valleys in the direction orthogonal to the ridge. O'Gorman and Nickerson were the first to propose the use of contextual filtering.

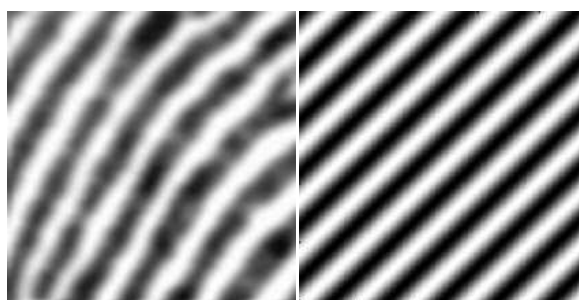


Figure 3.7 (a) Local region in a fingerprint image (b) Surface wave approximation of (a).

By assuming that the ridge frequency remains constant across an entire fingerprint image, 16 bell-shaped filters are pre-computed. The filter whose direction best fits the sub region's orientation is selected and then convolved on every point of the sub region.

### 3.5 Different Level of Fingerprint

A fingerprint can be looked at from different levels.

1. The global level
2. The local level
3. The very fine level.

In the global level, you find the singularity points, called core and delta points. These singularity points are very important for fingerprint classification, but they are not sufficient for accurate matching. Figure 3.8 shows the core and delta points of two fingerprint's pattern loop and whorl. Loops have one delta, whorl have two.

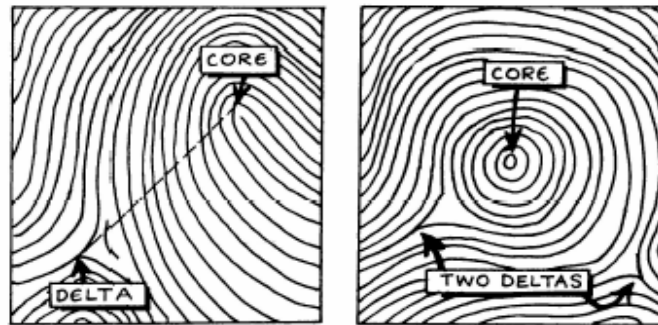


Figure 3.8 Core and delta points

### 3.6 Quality of Fingerprints

The performance of a fingerprint feature extraction and matching algorithm depend heavily upon the quality of the input fingerprint image. While the quality of a fingerprint image cannot be objectively measured, it roughly corresponds to the clarity of the ridge structure in the fingerprint image. A good quality fingerprint image has high contrast and well defined ridges and valleys. A poor quality fingerprint is marked by low contrast and ill-defined boundaries between the ridges and valleys. There are several reasons that may degrade the quality of the fingerprint image.

1. The ridges are broken by presence of creases, bruises or wounds on the fingerprint surface
2. Excessively dry fingers lead to fragmented ridges
3. Sweaty fingerprints lead to bridging between successive ridges

The quality of fingerprint encountered during verification varies over a wide range See Figure 3.9. It is estimated that roughly 10% of the fingerprint encountered during verification can be classified as poor. Poor quality fingerprint lead to generation of spurious minutiae. In smudgy regions, genuine minutiae may also be lost, the net effect of both leading to loss in accuracy of the matcher.



Figure 3.9 Fingerprint images of different quality. The quality decreases from left to right. (a) Good quality image with high contrast between the ridges and valleys (b) Insufficient distinction between ridges and valleys in the centre of the image (c) Dry print

The robustness of the recognition system can be improved by incorporating an enhancement stage prior to feature extraction. Due to the non-stationary nature of the fingerprint image, general-purpose image processing algorithms are not very useful in this regard but serve as a pre-processing step in the overall enhancement scheme. Furthermore pixel oriented enhancement schemes like histogram equalization mean and variance normalization wiener filtering improve the legibility of the fingerprint but do not alter the ridge structure. Also, the definition of noise in a generic image and a finger print are widely different. The noise in a fingerprint image consists of breaks in the directional flow of ridges. In the next section, we will discuss some filtering approaches that were specifically designed to enhance the ridge structure.

### **3.7 Requirement for Fingerprint**

In order to aid forensics in criminal identification, authentication in civilian applications and for preventing unauthorized there is a need to develop a finger print recognition and analysis system.

### **3.7.1 Statement of the Hypotheses**

The hypothesis of the study was that by making use of efficient feature extraction and matching techniques a fingerprint system can be made more robust and reliable.

### **3.7.2 The Delimitations**

The delimitations of the study were that the rate of fingerprint capture and feature extraction were not considered, although in a real world scenario this is an important factor. Further studies on this topic could address the issue of speed pertaining to image and feature extraction.

### **3.7.3 The Limitations**

This study was limited to the extent that only 200 fingerprints are being considered. Furthermore the physical conditions of the finger (dry, wet, wrinkle) are being overlooked.

### **3.7.4 The Definitions of Terms**

**Minutiae:** A ridge structure which differs from the usual (normal) continuous and non-diverging flow, examples are ridge branches (bifurcations) and ridge ends.

**Normalization:** It is done on the image to increase the dynamic range of the gray scale between ridges and valleys of the image

**Thinning:** To reduce the widths of ridges down to a single pixel for minutiae detection.

**Minutiae Extraction:** The minutiae from the thinning image are extracted.

**Inked fingerprint:** An image of the fingerprint resulting from applying ink to the surface of the finger and then rolling the finger on paper results in a rolled fingerprint impression unlike a live scan fingerprint.

**FAR:** False Accept error Rate: Fraction of attempts for which the system allows access to an imposter or invalid user.

**FRR:** False Reject error Rate: Fraction of attempts for which a fingerprint system denies access to a valid user.

### 3.8 Types of Fingerprint Recognition Devices

A fingerprint verification system consists of three major components.

1. Collection of database
2. Match processor.
3. Sensor

#### 3.8.1 Collection of data base

Firstly we collect different fingerprint Database. For this purpose we used USB finger key hamster by NITGEN which is a USB interface shown in figure 3.10.



Figure3.10. Finger key hamster with USB connector

There is an optical surface, finger in put on this surface during Scanning process. There is a typical (USB) cable pin that comes with the scanner. Specification of this scanner is as shown in the Table 2

<b>S.No.</b>	<b>ITEM</b>	<b>DESCRIPTION</b>
1	Interface Type	USB
2	External Interface Type	USB 1,1
3	Fingerprint Sensor	CPU 01M
4	Resolution (DPI)	500 DPI
5	Dimension (mm)	25.3 (W) × 40.7 (L) × 67.7 (H)(mm)
6	DB	Window 98/ ME/ 2000/ XP Window 98 SE/ MR/ NT4.0/ 2000
7	Operating Temperature (°C)	0~40 (°C)
8	Operating Voltage (V)	5 V
9	Authentication	MIC, CE, FCC, WHQL

Table 2 Fingkey hamster specification

### **3.8.2 Match Processor**

Such a system can be categorized as either of two types of fingerprint verification devices stand-alone and PC-based. A stand-alone device consists of a fingerprint sensor and a match processor, while a PC-based system is a fingerprint sensor connected to a personal computer (PC). The PC serves as the match processor. Examples of stand-alone systems include automotive products, access control systems, and automatic teller machines. Figure 3.10 shows a TRW access control device and Figure 3.11 TRW automotive fingerprint matching device. Examples of PC-based applications include logons, workflow management, enterprise security, and E-commerce. Figure 3.12 shows a PC-based system.



Figure 3.10. TRW Fingerprint Verification Device for Access Control

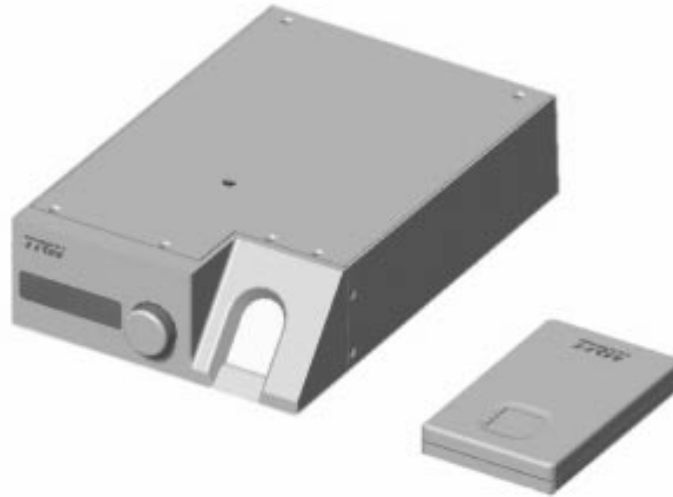


Figure 3.11. TRW Fingerprint Verification Evaluation Unit for Automotive Applications left and a Key Fob or a Badge right

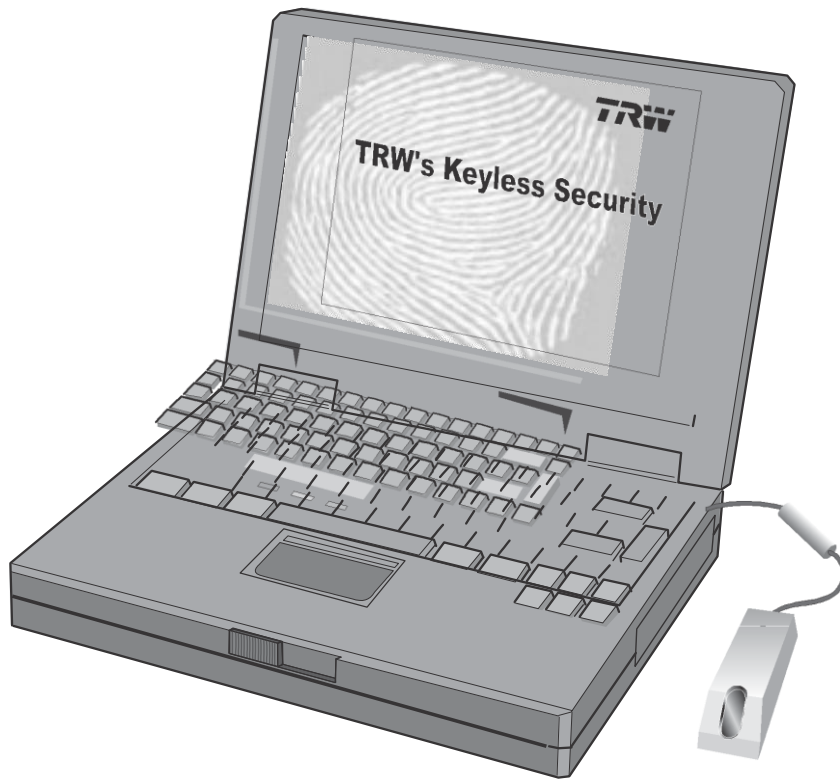


Figure3.12. A Fingerprint Verification Device for Computer Applications

### **3.8.3 Sensors for Verification Systems**

Different types of fingerprint sensors are optical, capacitive, thermal, silicon sensor, electric field, ultra sound and electro optical sensor are currently available. The most popular sensors are optical and capacitive.

#### **3.8.3.1 Optical Sensor**

Optical sensors use commercial video charge coupled device (CCD) cameras to capture fingerprints. However ridges and valleys on a finger do not have an inherently strong contrast. To enhance the contrast, a finger is pressed against a glass prism.

When the prism is illuminated from within, the fingerprint's ridges return a total reflection to the camera while valleys do not. This produces enhanced fingerprint images. A typical optical sensor is 1 x 1 x 3 inches in size and currently costs close to 4700 rupees.

The finger touches a glass prism and the prism is illuminated with diffused light. The light is reflected at the valleys and absorbed at the ridges. The reflected light is focused onto a charge coupled device (CCD) sensor. Optical fingerprint sensors provide good image quality and large sensing area but they cannot be miniaturized because as the distance between the prism and the image sensor is reduced, more optical distortion is introduced in the acquired image.

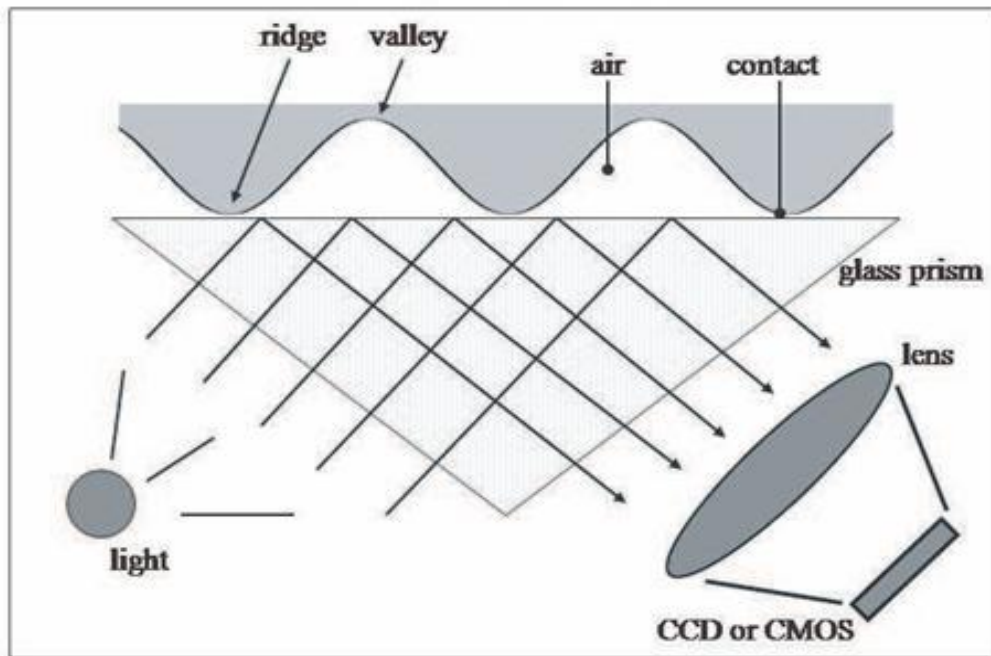


Figure 3.13 Optical sensor

**Optical fibers:** the finger is in direct contact with the upper side of the platen; on the opposite side, a charge coupled device (CCD) tightly coupled with the platen, receives the finger residual light conveyed through the glass fibers.

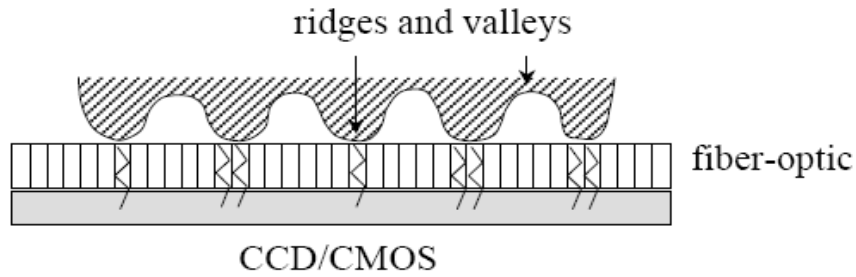


Figure 3.14 Optical fiber sensing

**Electro-optical:** constituted of two main layers light emitting polymer and photodiode array. As ridges touch the polymer and the valleys do not, the potential is not the same across the surface when a finger is placed on it and the amount of light emitted varies, thus allowing luminous representation of the fingerprint pattern to be generated and acquired by the photodiode array.

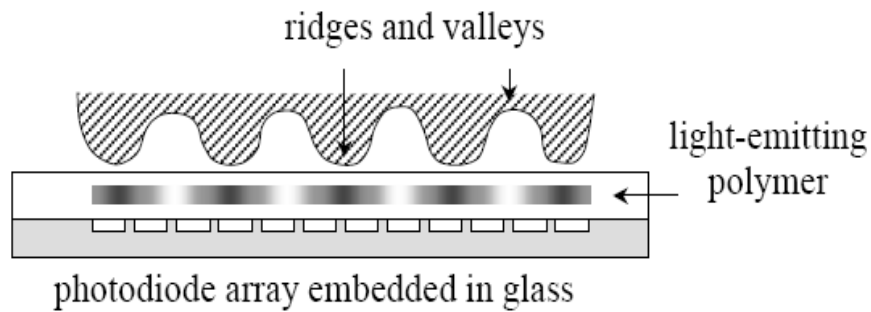


Figure 3.15 Electro-optical sensing

**Direct reading:** uses a high-quality camera to directly focus the fingerprint. The finger is not in contact with any surface, but the scanner is equipped with a mechanical support that facilitates the user in presenting the finger at a uniform distance.

### 3.8.3.2 Capacitive Sensor

Capacitive sensors consist of a large array of tiny capacitors etched on a finger-sized piece of silicon. As a finger is pressed against the silicon, the ridges and valleys, being of different distances to the ground plane, produce different amounts of capacitance. The capacitance is measured by the time to discharge the capacitors with a constant current source. A typical capacitive sensor is 1 x 1 x 1/8 inch in size and costs approximately 3150 rupees. In

comparing the two types of sensors, we find that optical sensors have been used for fingerprint applications in general, produce a superior quality image. However, capacitive sensors are much smaller and cheaper to manufacture and promise a bright future.

**Capacitive:** is a two-dimensional array of micro--capacitor plates embedded in a chip. The other plate of each micro-capacitor is the finger skin itself. Small electrical charges are created between the surface of the finger and each of the silicon plates when a finger is placed on the chip. The magnitude of these electrical charges depends on the distance between the fingerprint surface and the capacitance plates.

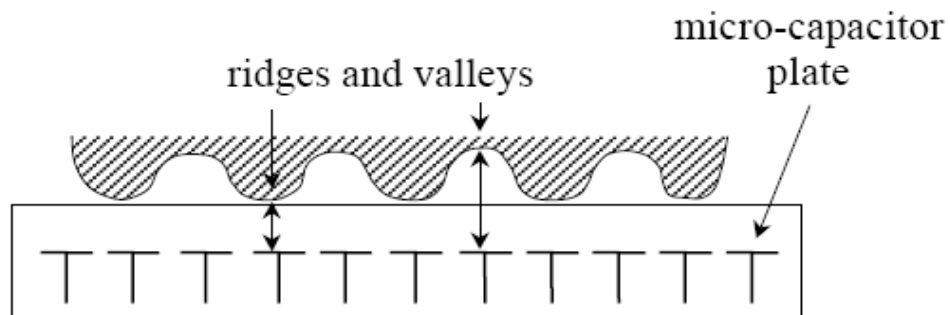


Figure 3.16 Capacitive sensor

### 3.8.3.3 Silicon Sensor

These consist of an array of pixels, each pixel being a sensor itself. Users place the finger on the surface of the silicon, and four techniques are typically used to convert the ridge/valley information into an electrical signal: capacitive, thermal, electric field and piezo-electric. Since solid-state sensors do not use optical components, their size is considerably smaller and can be easily embedded. On the other hand, silicon sensors are expensive, so the sensing area of solid-state sensors is typically small.

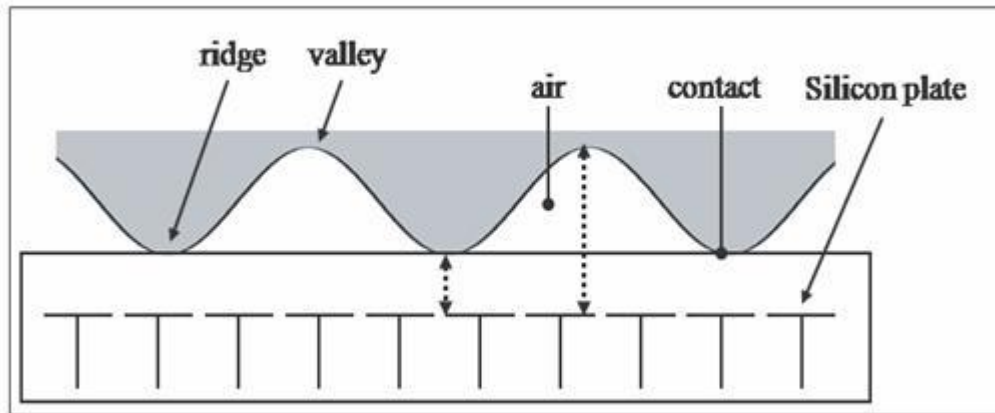


Figure 3.17 Silicon sensor

Image quality is essential for acceptable accuracy involving widespread applications for millions of people. In this regard, both types of fingerprint sensors still have plenty of room for improvement. When a finger is dry, it does not couple very well with the glass prism of an optical sensor. A similar problem exists with the capacitive sensor. Sensor manufacturers are developing better automatic gain control and sensitivity adjustment to improve image quality.

#### 3.8.3.4 Ultra-sound Sensors

Ultrasound technology is perhaps the most accurate of the fingerprint sensing technologies. It uses ultrasound waves and measures the distance based on the impedance of the finger, the plate, and air. These sensors are capable of very high resolution. These sensors tend to be very bulky and contain moving parts making them suitable only for law enforcement and access control applications.

Ultrasound sensing may be viewed as a kind of echo graph. It is based on sending acoustic signals toward the fingertip and capturing the echo signal. The echo signal is used to compute the range image of the fingerprint and, subsequently, the ridge structure itself.

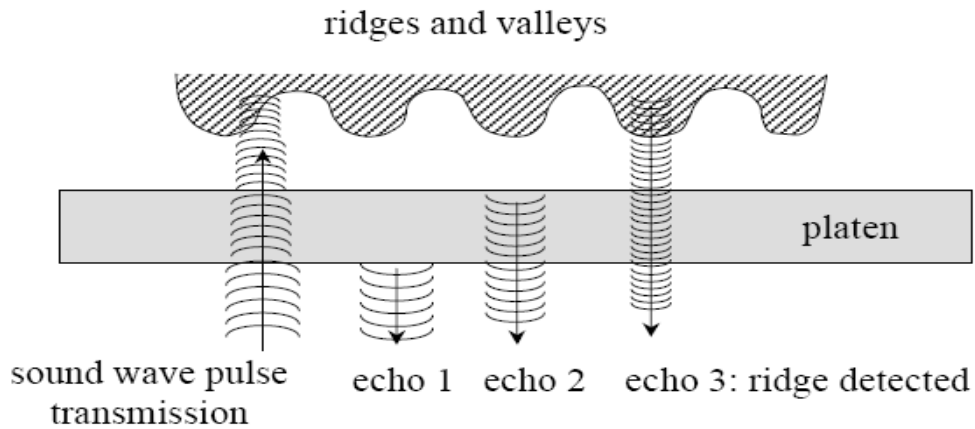


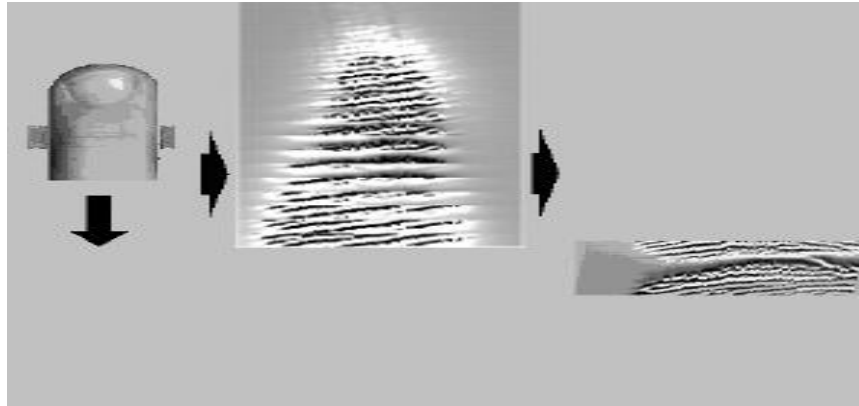
Figure 3.18 Ultra-sound sensor

### 3.8.3.5 Thermal Sensor

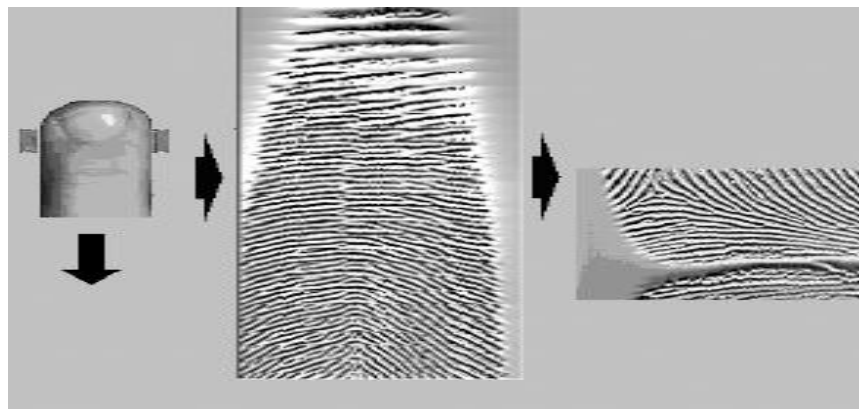
These are made up of pyroelectric materials whose properties change with temperature. These are usually manufactured in the form of strips. As the fingerprint is swiped across the sensor, there is differential conduction of heat between the ridges and valleys that is measured by the sensor.

### 3.8.3.6 Sweeping Sensor

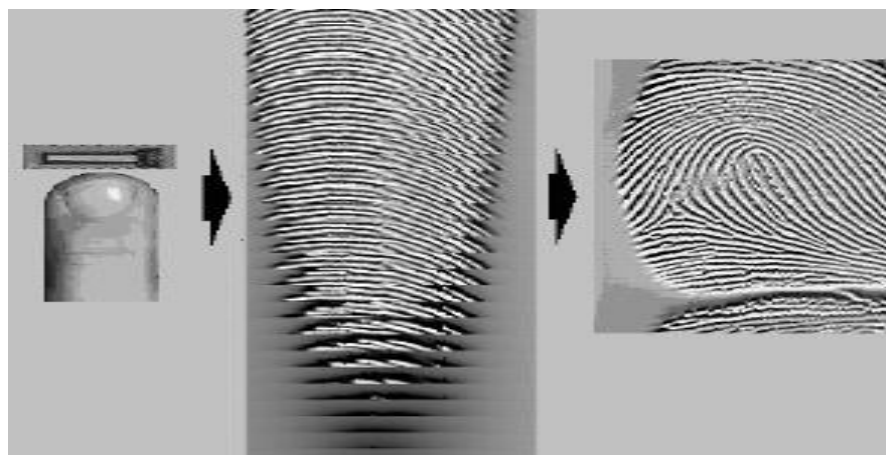
The sensor surface is a small rectangle, whose width is larger than the finger, but whose height is just few pixels. As the user sweeps her finger on the sensor, the sensor delivers new image slices, which are combined into a two-dimensional image as shown in figure 3.19.



(a)



(b)



(c)

Figure 3.19 Sweeping sensor

These figures 3.19 Sweeping sensor a, b and c shows the working of sweeping sensor

## **4.1 Fingerprint Matching**

Matching fingerprint images is an extremely difficult problem, mainly due to the large variability in different impressions of the same finger i.e. large intra-class variations. The main factors responsible for the intra-class variations are displacement, rotation, partial overlap, non-linear distortion, variable pressure, changing skin condition, noise, and feature extraction errors. Therefore, fingerprints from the same finger may sometimes look quite different whereas fingerprints from different fingers may appear quite similar. A three class categorization of fingerprint matching approaches.

1. Correlation-based matching
2. Minutiae matching
3. Ridge feature-based matching

### **4.1.1 Correlation-Based Matching**

Two fingerprint images are superimposed and correlation at the intensity level between corresponding pixels is computed for different alignments e.g. various displacements and rotations.

### **4.1.2 Minutiae Matching**

Minutiae are extracted from the two fingerprints and set of points in the two-dimensional plane. Minutiae matching essential consists of finding are alignment between the template and the input minutiae set the results in the maximum number of minutiae pairings.

### **4.1.3 Ridge Feature-Based Matching**

Minutiae extraction is difficult in very low quality fingerprints images, whereas other features of the fingerprints ridge pattern e.g. Local orientation and frequency, ridge shape, texture information may be extracted more reliability then minutiae. Even through their distinctiveness is generally lower the approaches belonging to this family compare fingerprints in terms of features extracted from the ridge pattern.

### **4.2 Pattern-Based Matching**

Pattern based algorithms compare the basic fingerprint patterns arch, whorl and loop between a previously stored template and a candidate fingerprint. This requires that the images be aligned in the same orientation. To do this, the algorithm finds a central point in the fingerprint image and centres on that. In a pattern-based algorithm, the template contains the type, size, and orientation of patterns within the aligned fingerprint image. The candidate fingerprint image is graphically compared with the template to determine the degree to which they match.

Given a complex operating environment, it is critical to identify a set of valid assumptions upon which the fingerprint matcher design could be based. Often there is a choice between whether it is more effective to exert more constraints by incorporating better engineering design or to build a more sophisticated similarity function for the given representation. For instance, in a fingerprint matcher, one could constrain the elastic distortion altogether and design the matcher based on a rigid transformation assumption or allow arbitrary distortions and accommodate the variations in the input images using a clever matcher. In light of the operational environments mentioned above, the design of the matching algorithm needs to establish and characterize a realistic model of the variations among the representations of matched pairs.

### **4.3 Implementation Technique**

In this work concentration is on implementation of minutiae based method. In particular only two of the most important minutia features i.e. Ridge Ending and Ridge bifurcation are as considered as shown in figure 4.1

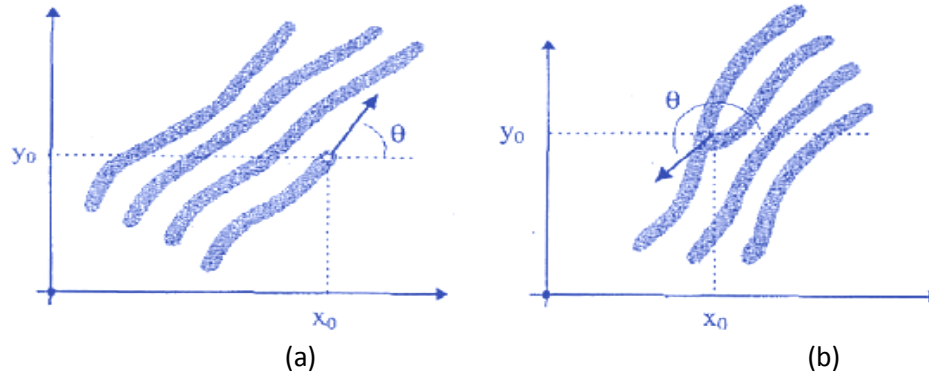


Figure 4.1 (a) Ridge ending, (b) Ridge bifurcation

### 4.3.1 Design Description

A fingerprint recognition system constitutes of fingerprint acquiring device, minutia extractor and minutia matcher as shown in figure 3.2

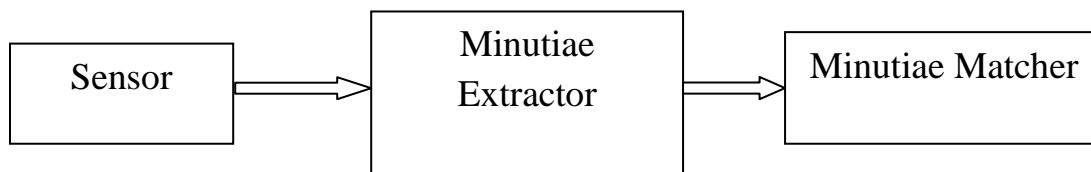


Figure 4.2 Simplified fingerprint recognition system

For fingerprint acquisition, optical or semi-conduct sensors are widely used. They have high efficiency and acceptable accuracy except for some cases that the user's finger is too dirty or dry. The minutia extractor and minutia matcher modules have been explained in detail in the next part for algorithm design and other subsequent sections.

### 4.3.2 Algorithm Level Design

To implement a minutia extractor, a three-stage approach is widely used by researchers. They are preprocessing, minutia extraction and post processing stage as shown in figure 4.3.

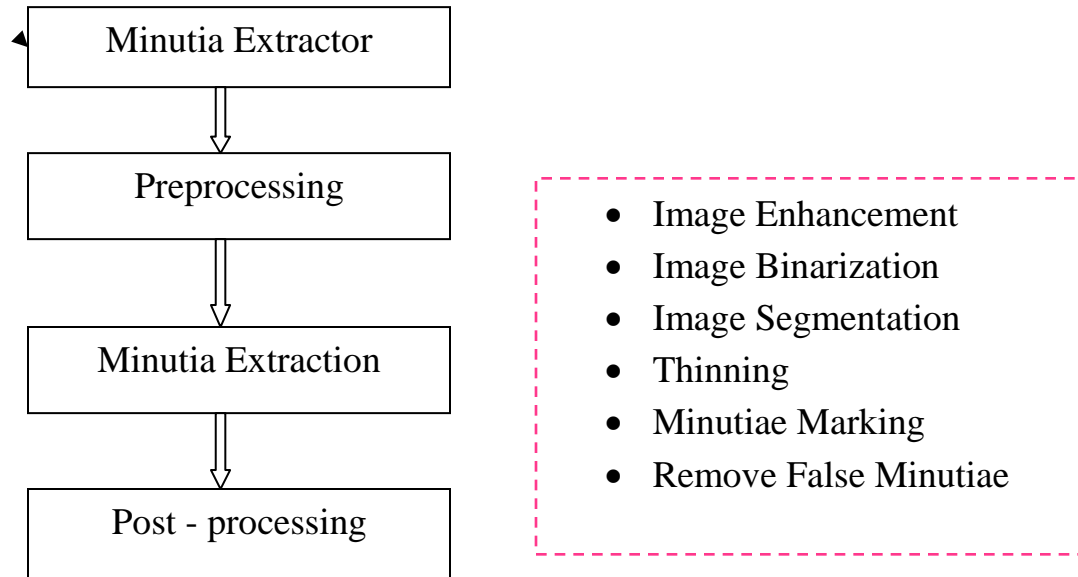


Figure 4.3 Minutia extractor

For the fingerprint image preprocessing stage, Histogram equalization and Fourier transform have been used to do image enhancement. And then the fingerprint image is binarizing using the locally adaptive threshold method. The image segmentation task is fulfilled by three-step approach block direction estimation, segmentation by direction intensity and region of interest extraction by morphological operations.

For minutia extraction stage, iterative parallel thinning algorithm is used. The minutia marking is a relatively simple task. For the post processing stage, a more rigorous algorithm is developed to remove false minutia. Also a novel representation for bifurcations is proposed to unify terminations and bifurcations.

## Minutia Matcher

- Ridge correlation to specify reference minutia pair
- Align two fingerprint images
- Minutiae match

Figure 4.4 Minutia matcher

The minutia matcher chooses any two minutiae as a reference minutia pair and then matches their associated ridges first. If the ridges match well, the two fingerprint images are aligned and matching is conducted for all remaining minutia.

### **4.3.3 Fingerprint image enhancement**

Fingerprint Image enhancement is to make the image clearer for easy further operations. Since the fingerprint images acquired from sensors or other medias are not assured with perfect quality, those enhancement methods, for increasing the contrast between ridges and furrows and for connecting the false broken points of ridges due to insufficient amount of ink are very useful for keep a higher accuracy to fingerprint recognition. One method is adopted for image enhancement stage the first one is histogram.

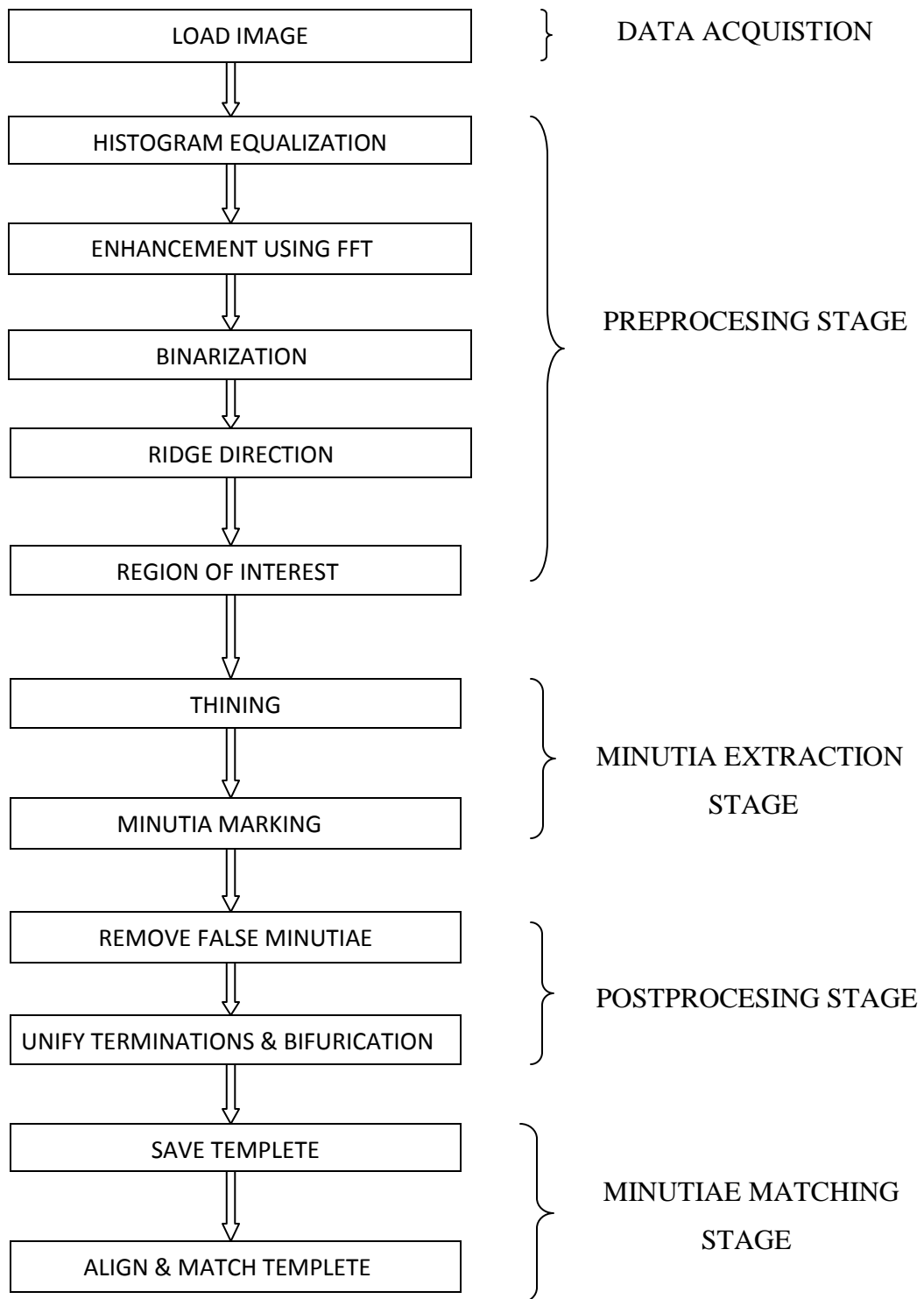


Figure 4.5 Steps involved in Fingerprint Recognition Algorithm

### 4.3.3.1 Histogram Equalization

Histogram equalization is to expand the pixel value distribution of an image so as to increase the perception information. The original histogram of a fingerprint image has the bimodal type as shown in Figure 4.6 the histogram after the histogram equalization occupies all the range from 0 to 255 and the visualization effect is enhanced as shown in Figure 4.7.

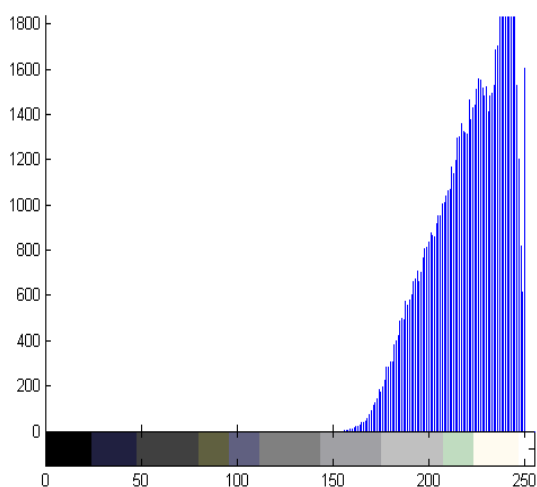


Figure 4.6 the Original Histogram of a image

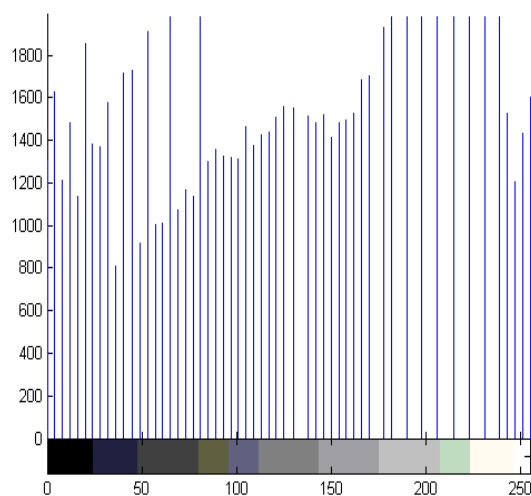


Figure 4.7 Histogram after fingerprint histogram equalization

### 4.3.3.2 Fingerprint enhancement

In a fingerprint image, ridges and valleys flow smoothly in a locally constant direction ideally. There are certain factors that affect the quality of a fingerprint image as shown in figure 4.8. As wetness or dryness of the skin, noise of the sensor, temporary or permanent cuts in the skin, variability in the pressure against the sensor, etc. Several enhancement algorithms have been proposed in the literature with the aim of improving the clarity of ridges and valleys. The most frequently used fingerprint enhancement techniques use a contextual filter, which means changing the filter parameters according to the local characteristics of image. Filters are tuned to the local ridge orientation or frequency, thus removing the imperfections also preserving the ridges and the valleys as shown in figure.4.9.



Figure 4.8 Fingerprint images with different quality. From left to right: high, medium and low quality, respectively



Figure 4.9 Examples of original and enhanced fingerprint images

#### 4.4 Fingerprint Image Binarization

Fingerprint Image Binarization is to transform the 8-bit Gray fingerprint image to a 1-bit image with 0-value for ridges and 1-value for furrows. After the transformation, ridges in the fingerprint are highlighted with black colour while furrows are white. Locally adaptive binarization method is performed to binarize the fingerprint image. Mechanism of transforming a pixel value to 1 if the value is larger than the mean intensity value of the current block (16x16) to which the pixel belongs comes under the application of this method.



Figure 4.10 Binarization and thinning of fingerprint images using contextual filters

#### 4.5 fingerprint Segmentation

Fingerprint segmentation consists of the separation of the fingerprint area i.e. fore - ground from the background. This is good to avoid subsequent extraction of fingerprint features in the background, which is the noisy area. Global and local thresholding segmentation methods are not very effective. So that more robust segmentation techniques are frequently.

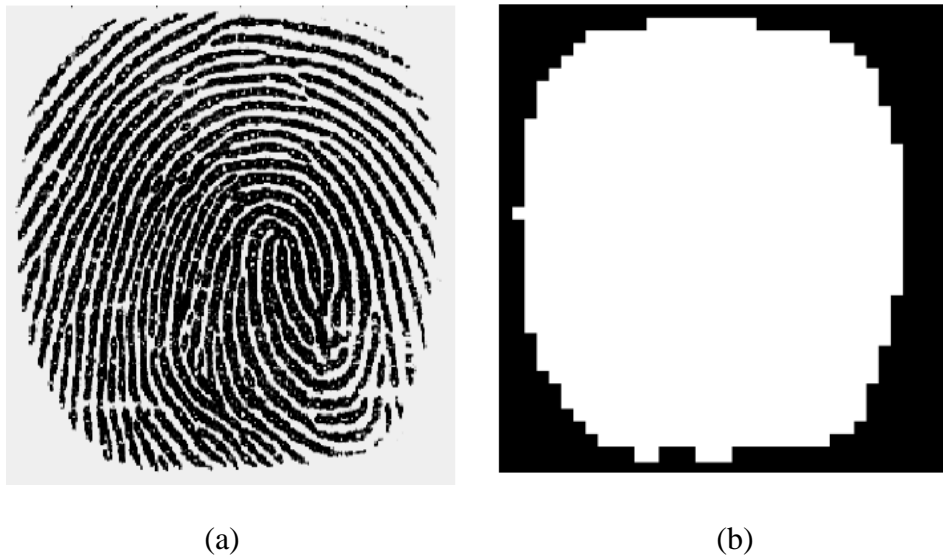


Figure 4.11 Segmentation of fingerprint images (a) Original image and (b) Segmentation mask

## 4.6 Minutiae Extraction

The image is enhanced and segmented area is minutiae extraction is done in steps operations

1. Ridge Thinning
2. Minutiae Marking
3. False Minutiae Removal
4. Minutiae Representation.

### 4.6.1 Fingerprint Ridge Thinning

Ridge Thinning is done to eliminate the redundant pixels the ridges are brought to a level of just one pixel wide. An iterative, parallel thinning algorithm is used for this purpose in each scan of the full fingerprint image. This the algorithm marks down redundant pixels in each small image window of size 3x3. And finally removes all those marked pixels after several scans. The thinned ridge map is filtered with the help of three morphological operations H breaks, isolated points and spikes.



Figure 4.12 (a) Image before,



Figure 4.12 (b) Image after thinning

#### 4.6.1.1 Binarization Approach

The gray scale image is converted into a binary image before minutiae detection in binarization approach. While algorithms differ in several implementation aspects, they have the certain common stages as shown in Shown in figure 4.13.

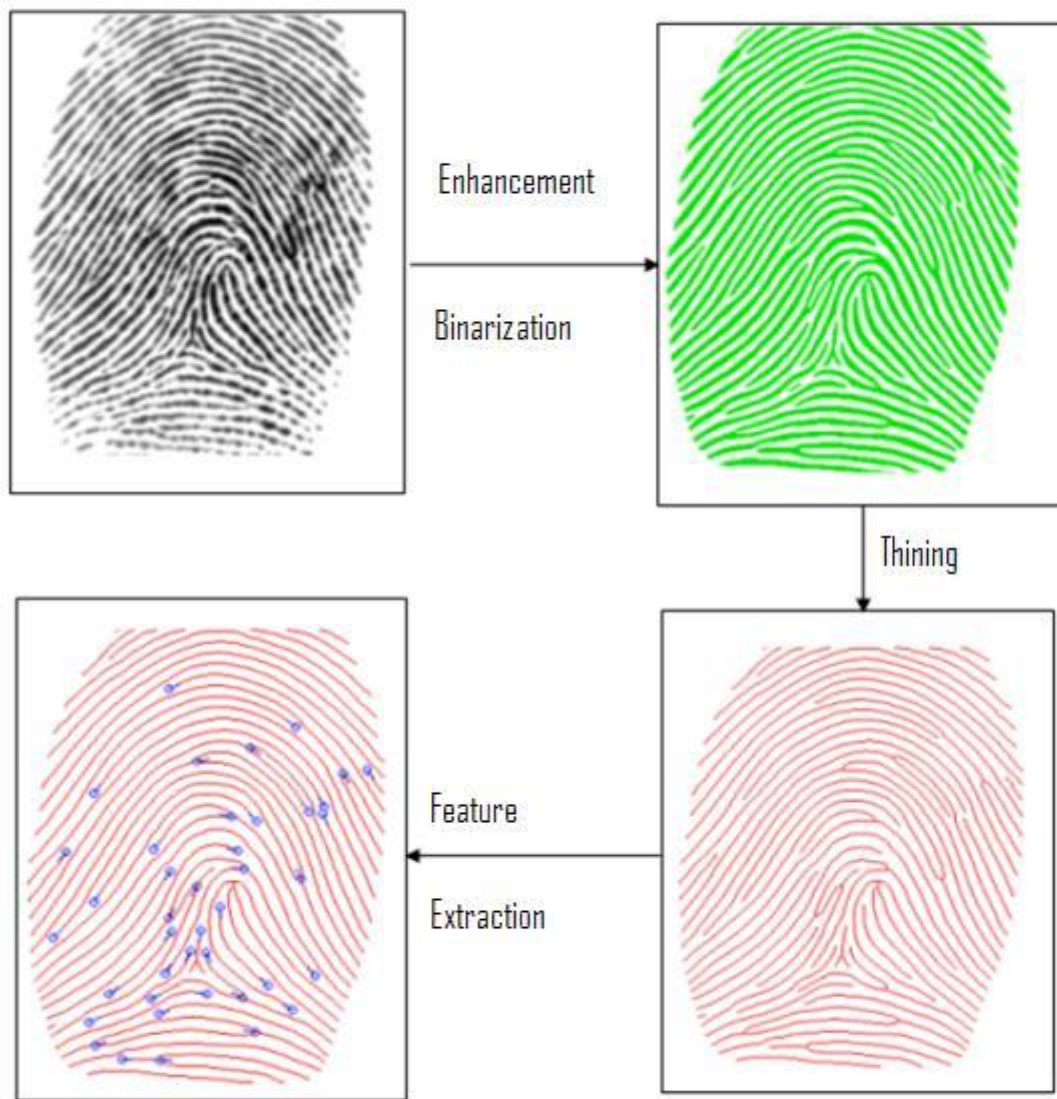


Figure 4.13 Different stages in a typical feature extractor change the binarization approach

#### 4.6.1.2 Segmentation/Binarization

The gray scale image is converted to a binary image with the help of process of simple thresholding and adaptive binarization. The quality of the binarization output is improved if the gray scale image is enhanced prior to this process. This step is also commonly called as segmentation. But one must not confuse with segmentation of the fingerprint foreground from the background during region mask generation.

#### 4.6.1.3 Thinning

The resulting binary image is thinning by an iterative morphological process. This results in a single pixel wide ridge map.

#### 4.6.1.4 Minutiae Detection

The problem of minutiae detection is trivial & then this theory is used. The resulting pixel wide map is scanned sequentially and minutiae points are identified based on its neighbourhood. Ridge endings are characterized by single neighbour and bifurcations are identified by locating pixels with three or more neighbours.

#### 4.6.2 Minutiae Marking

A minutia marking is now done using templates for each 3 x 3 size pixel window as follows. If the central pixel is 1 and has exactly 3 one-value neighbours, then the central pixel is a ridge branch as shown in figure 4.14

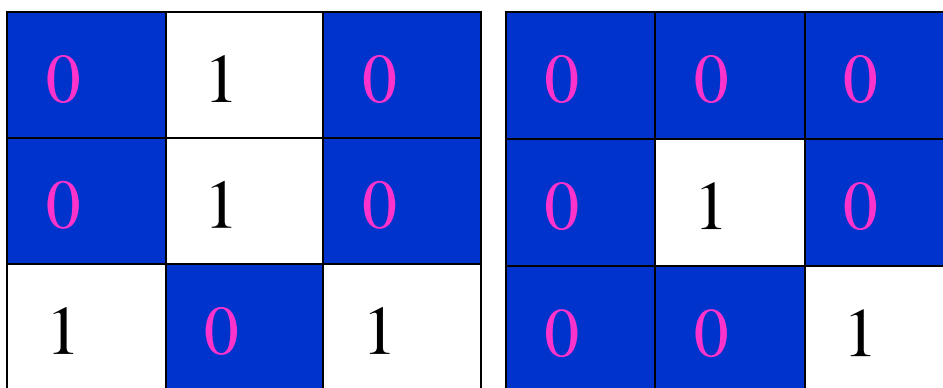


Figure 4.14 (a) and (b) Minutiae marking

0	1	0
0	1	1
1	0	0

Figure 4.15 Triple counting branches

Figure 4.15 illustrates a special case that a genuine branch is triple counted. Suppose both the uppermost pixel with value 1 and the rightmost pixel with value 1 have another neighbour outside the 3x3 size window, so the two pixels will be marked as branches too. But actually only one branch is located in the small region. So a check routine requiring that none of the neighbours of a branch are branches is added.

Also the average inter-ridge width  $D$  is estimated at this stage. The average inter-ridge width refers to the average distance between two neighbouring ridges. The way to approximate the  $D$  value is to scan a row of the thinned ridge image and sum up all pixels in the row whose value is one. Then divide the row length with the above summation to get an inter ridge width. For more accuracy, such kind of row scan is performed upon several other rows and column scans are also conducted, finally all the inter-ridge widths are averaged to get the  $D$ . Together with the minutia marking, all thinned ridges in the fingerprint image are labelled with a unique ID for further operation. The labelling operation is realized by using the Morphological operation.

### 4.6.3 Minutiae Post - processing

#### 4.6.3.1 False Minutia Removal

The preprocessing stage does not totally heal the fingerprint image. For example, false ridge breaks due to insufficient amount of ink and ridge cross-connections due to over inking are not totally eliminated. Actually all the earlier stages themselves occasionally introduce some artifacts which later lead to spurious minutia.

These false minutiae will significantly affect the accuracy of matching if they are simply regarded as genuine minutia. So some mechanisms of removing false minutia are essential to keep the fingerprint verification system effective. Seven types of false minutia are specified in following diagrams

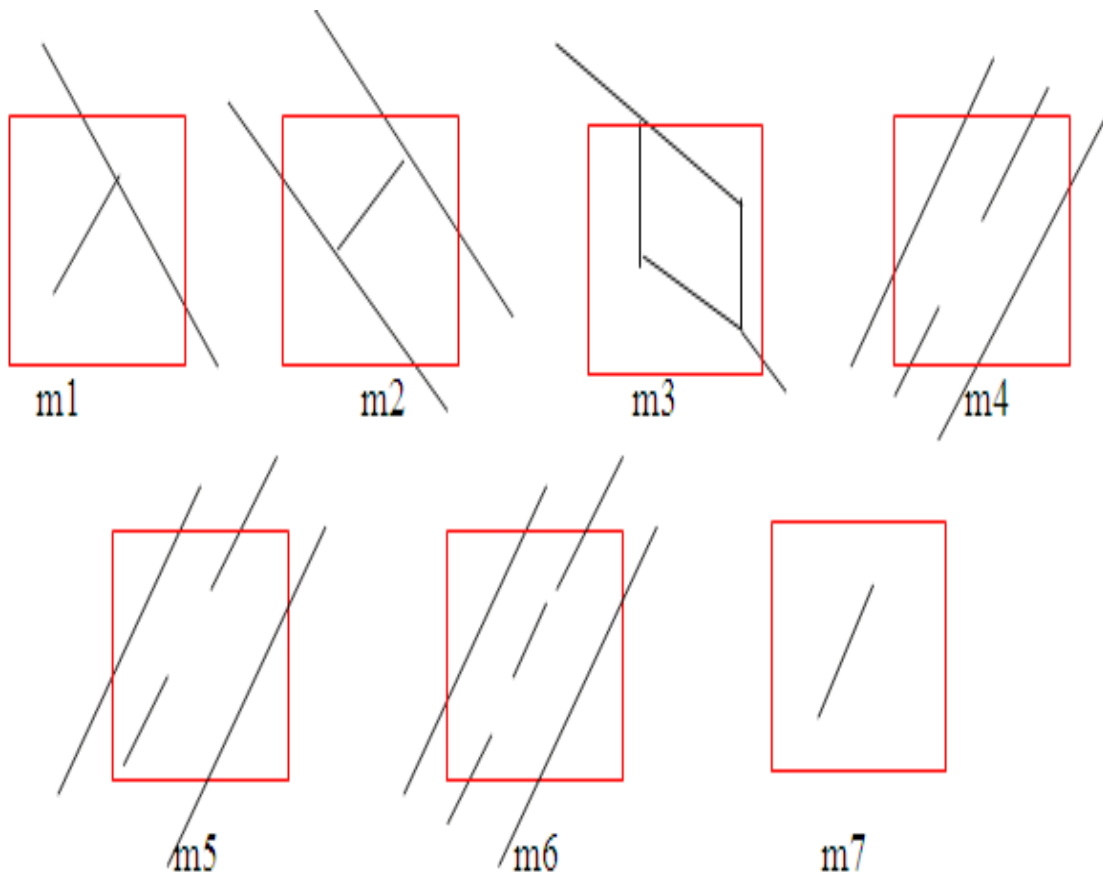


Figure 4.16 False minutia structures.

m1 is a spike piercing into a valley. In the m2 case a spike falsely connects two ridges. m3 has two near bifurcations located in the same ridge. The two ridge broken points in the m4 case have nearly the same orientation and a short distance. m5 is alike the m4 case with the exception that one part of the broken ridge is so short that another termination is generated. m6 extends the m4 case but with the extra property that a third ridge is found in the middle of the two parts of the broken ridge. m7 has only one short ridge found in the threshold window.

The procedure for the removal of false minutia is

1. If the distance between one bifurcation and one termination is less than  $D$  and the two minutia are in the same ridge (m1 case), both of them are removed. Where  $D$  is the average inter-ridge width representing the average distance between two parallel neighbouring ridges.
2. If the distance between two bifurcations is less than  $D$  and they are in the same ridge, the two bifurcations are removed. (m2, m3 cases).
3. If two terminations are within a distance  $D$  and their directions are coincident with a small angle variation. And they suffice the condition that no other termination is located between the two terminations. Then the two terminations are regarded as false minutia derived from a broken ridge and are removed. (case m4,m5, m6).
4. If two terminations are located in a short ridge with length less than  $D$ , remove the two terminations (m7).

#### **4.6.4 Fingerprint Matching**

In the matching step, features extracted from the input fingerprint are compared against those in a template which represents a single user retrieved from the system database based on the claimed identity. The result of such a procedure is either a degree of similarity also called matching score or an acceptance /rejection decision.

There are fingerprint matching techniques that directly compare gray scale images or sub images using correlation-based methods so that the fingerprint template coincides with the gray scale image. One of the biggest challenges of fingerprint recognition is the high variability commonly found between different impressions of the same finger. This variability is known as interclass variability and is caused by several factors, including (a) displacement or rotation between different acquisitions (b) partial overlap, specially in sensors of small area (c) skin conditions, due to permanent or temporary factors (cuts, dirt, humidity, etc.) and (d) noise in the sensor for example, residues from previous acquisitions and (e) nonlinear distortion due to skin plasticity and differences in pressure against the sensor. Fingerprint matching remains as a challenging pattern recognition problem due to the difficulty in matching fingerprint affected by one or several of the mentioned factors.

They can be classified into two types

- (1) correlation-based approaches
- (2) minutiae-based approaches

#### **4.6.4.1 Correlation-based Approach**

In the correlation-based approaches the fingerprint images are superimposed and the gray scale images are directly compared using a measure of correlation. Due to nonlinear distortion, different impressions of the same finger may result in differences of the global structure, making the comparison unreliable. In addition, computing the correlation between two fingerprint images is computationally expensive. To deal with these problems, correlation can be computed only in certain local regions of the image, which can be selected following several criteria. Also, to speed up the process, correlation can be computed in the Fourier domain or using heuristic approaches, which allow the number of computational operations to be reduced.

#### **4.6.4.2 Minutiae-based Approach**

This is the most popular and widely used methods for fingerprint matching, since they are analogous with the way that forensic experts compare fingerprints. A fingerprint is modelled as a set of minutiae.

Which are usually represented by its spatial coordinates and the angle between the tangent to the ridge line at the minutiae position and the horizontal or vertical axis. The minutiae sets of the two fingerprints to be compared are first aligned, requiring displacement and rotation to be computed some approaches. Compute scaling and other distortion-tolerant transformations. A minutia point is defined as the point where a fingerprint ridge ends or splits. Normally finger has 30 to 60 minutia points. The location and orientation of these points are unique to each finger, and they do not change over a person's lifetime. The minutia algorithm matches the location and orientation of these minutia points. Figure 4.17 shows the minutia points on a fingerprint. The green Y indicates the location where a ridge splits and the black Y shows where a ridge ends.

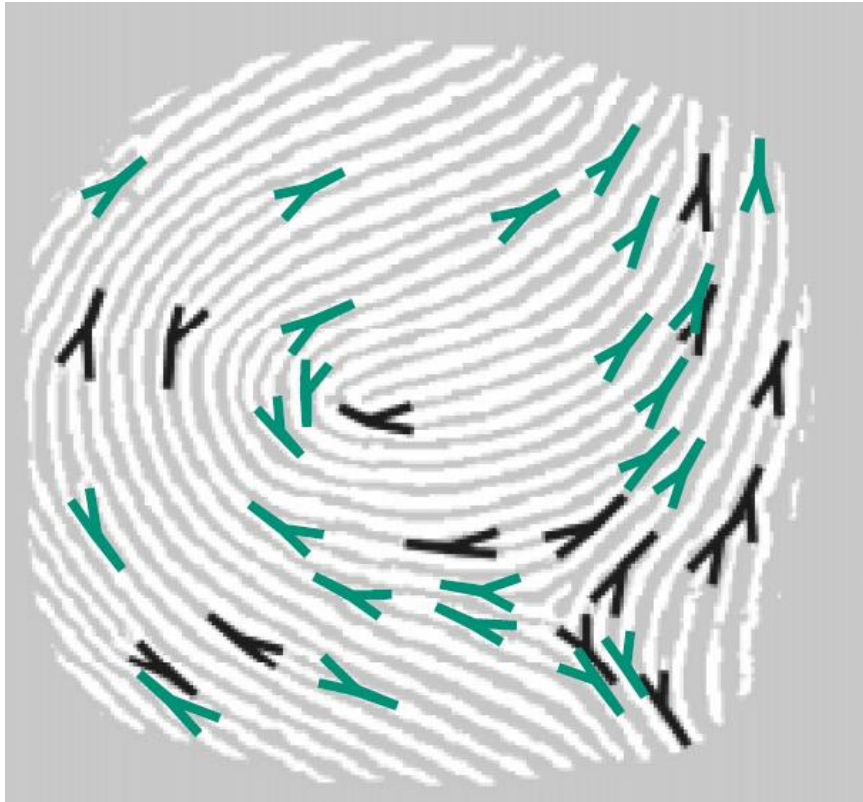


Figure 4.17 Minutiae are the points of interest on a fingerprint

This alignment involves a minimization problem, the complexity of which can be reduced in various ways. Once aligned, corresponding minutiae at similar positions in both fingerprints are looked for. A region of tolerance around the minutiae position is defined in order to compensate for the variations that may appear in the minutiae position due to noise and distortion. Likewise, differences in angle between corresponding minutia points are tolerated.

#### 5.1 Minutiae Based Fingerprints matching results

In the fingerprint recognition and analysis by minutiae extraction technique we get these results of fingerprint images as shown in the Fig. 5 shows fingerprint images from the MATLAB after complete the iteration of 0 to 30 times and the output of our fingerprint images are shows after fig.5.1 5 times iteration fig.5.2 10 times iteration fig.5.3 15 times iteration fig.5.4 20 times iteration fig.5.5 25 times iteration fig.5.6 30 times iteration. Based on the findings the minutiae Based matching method proved reliable with a high level of accuracy.



(a)

(b)

Figure 5.1 (a) Original image sample (b) Image after 5 times iteration



(c)



(d)

Figure 5.2 (c) Original image sample (d) Image after 10 times iteration



(e)



(f)

Figure 5.3 (e) Original image sample (f) Image after 15 times iteration



(g)



(h)

Figure 5.4 (g) Original image sample (h) Image after 20 times iteration



(i)



(j)

Figure 5.5 (i) Original image sample (j) Image after 25 times iteration



(k)



(L)

Figure 5.6 (k) Original image sample (L) Image after 30 times iteration

## 5.2 Enhancement Result



(m)



(n)

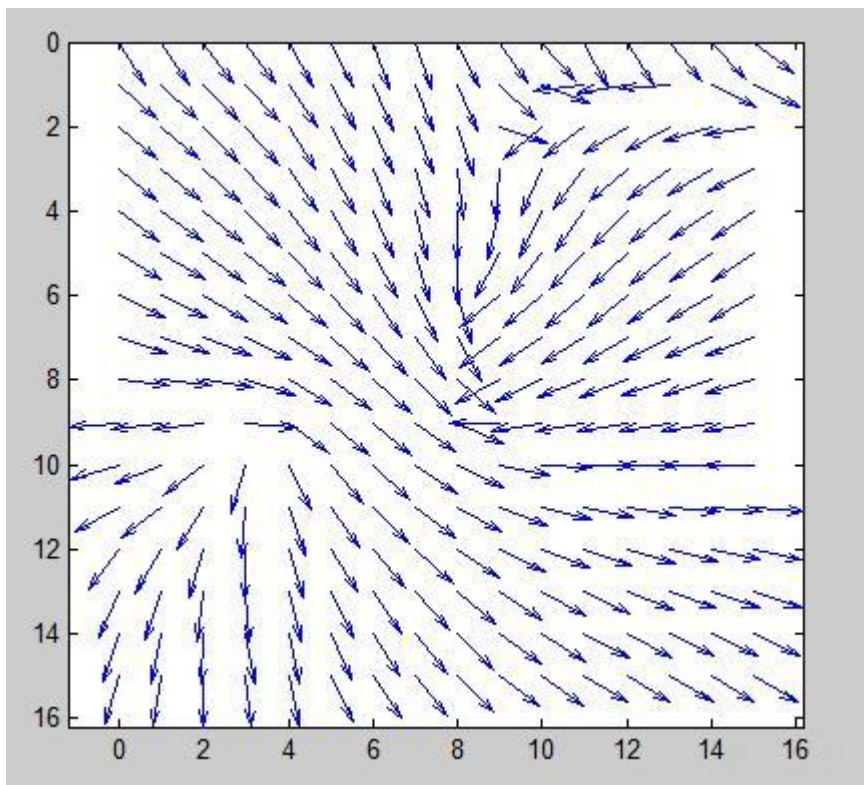
Figure 5.7 (m) Original fingerprint image sample (n) Enhancement image

### 5.3 Orientation Result



(q)

Figure 5.8 (o) Original image of fingerprint



(R)

Figure 5.8 (p) Orientation image of fingerprint

Among the many current biometric technologies, fingerprint verification is most popular method widely used in different commercial and security application. To accelerate the process, in my thesis pursue the solution using smaller fingerprint images region to extract the minutiae. The relationship between the number of matching minutiae and the verification accuracy in order to find relatively small sub regions of the captured images for use in the matching process is deeply investigated. I have revealed that our system identifies the most of minutiae present in the original acquired image. However note that the final numbers of minutiae obtained depend heavily of the acquired system used and the pre-processing stage applied.

### 6.1 Conclusion

The reliability of any automatic fingerprint system strongly relies on the precision obtained in the minutiae extraction process. A number of factors are detrimental to the correct location of minutia. Among them, poor image quality is the most serious one. In this thesis, Minutiae based fingerprint matching is studied in detailed and implemented in MATLAB and I have combined many methods to build a minutia extractor and a minutia matcher. The following concepts have been used- segmentation using Morphological operations, minutia marking by specially considering the triple branch counting, minutia unification by decomposing a branch into three terminations and matching in the unified x-y coordinate system after a 2-step transformation in order to increase the precision of the minutia localization process and elimination of spurious minutia with higher accuracy. The proposed alignment-based elastic matching algorithm is capable of finding the correspondences between minutiae without resorting to exhaustive research.

### 6.2 Future Work

The work in this thesis suggests that future enhancement can be carried out to further improve the design to achieve better performance or a more complete operation. The image processing stage result can be improved by using adaptive threshold values for image segmentation and binarization process. In the improvement of the feature extraction stage false minutiae points are extracted because the ridges are out of scanner bounds or due to image segmentation process. This can be improved by checking the angle of ending minutiae that are close to the background image. If the direction of the minutiae is opposite to the background, the minutiae are discarded.

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