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Fingerprint Recognition by Using Pores Extraction

A Thesis

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By

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Abstract

Fingerprints are the oldest and most broadly used form of biometric identification. Everyone is known to have unique, immutable fingerprints.

Fingerprint identification and recognition are considered popular technique in many security and law enforcement applications. Many systems rely on the matching of fingerprints using various methods and algorithms based on find position and orientation of ridge endings and bifurcations within the fingerprint image in both levels (level 2 and level 3). In this research, the sweat pores found in fingerprint image (level 3), their position and their type (open and closed) are detected. All they are considered as an important in matching phase by calculating number of pores found in the specified position. In addition, (level 2) we have focuses on another feature (bifurcation) which is found in detected ridges by applying a (3x3) mask to find bifurcation point. Also, the find distances between bifurcation point are found.

The numbers of samples were (10) for each person, five with light intensity and the other five with dark. 8 samples used as training samples.

The designed model has been trained and tested using a database consisting of (1000) image with selected fingerprint's images for (100) persons. Each person has 10 images with different contrast and moves. Results of fingerprints matching rate in level 3 is (100%) for pores by using Closet Point algorithm and in level 2, is (99.4%) for bifurcations points by using Iterative Closest Point algorithm.

The time consumed in level 2 for the whole image (320x240 pixels) matching process is obtain (2) minute, while it consumes (1) minute when it is performed within a selected window of size 160x120. In level3, the time consumed for 160x120 image matching in level 3 was (22) second while it is (47) seconds for the whole image.

List of content

List of Abbreviations

1-D	One dimension
AFAS	Automatic fingerprint Authentication System
AFIS	Automatic Fingerprint Identification System
DB	Data Base
Dist	Distance between bifurcation points
GIF	Graphic Interchange Format
HSV	Hue saturation and value
ICP	Iteration Closet Points
JPEG	Joint Photographic Experts Group
MSE	Mean Square Error
PFR	Finger Print Recognition
SIFT	Scale Invariant feature transform

Chapter One

General Overview

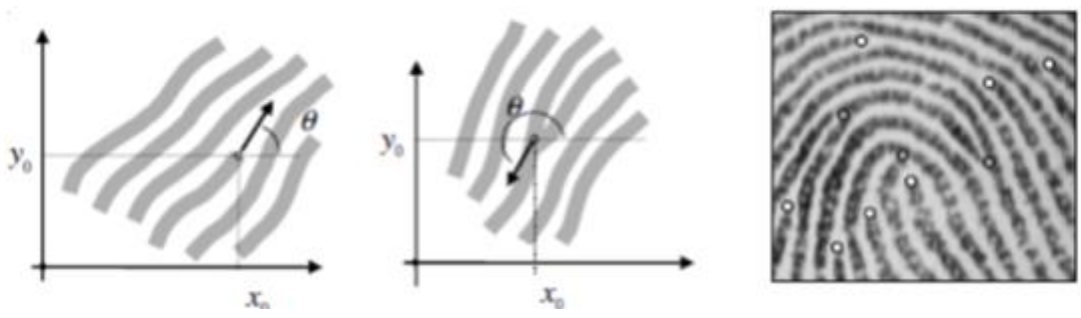
1.1 Introduction

Ridges present on the skin of hands and feet, are natural and their purpose is to prevent slippage in locomotion, and are often called friction ridges as a result. human has taken advantage of this feature by using them for personal identification[Gre84].

Everyone is known to have unique, immutable fingerprints. As most automatic fingerprint recognition systems are based on local ridge features known as minutiae, pattern minutiae accurately and rejecting false ones is very important. However, fingerprint images get degraded and corrupted due to variations in skin and impression conditions. Thus, image enhancement techniques are employed prior to minutiae extraction. A critical step in automatic fingerprint matching is to reliably extract minutiae from the input fingerprint images. The techniques are broadly classified as those working on binarized images and those that work on gray scale images directly [Rol11].

1.2 Fingerprint Concept

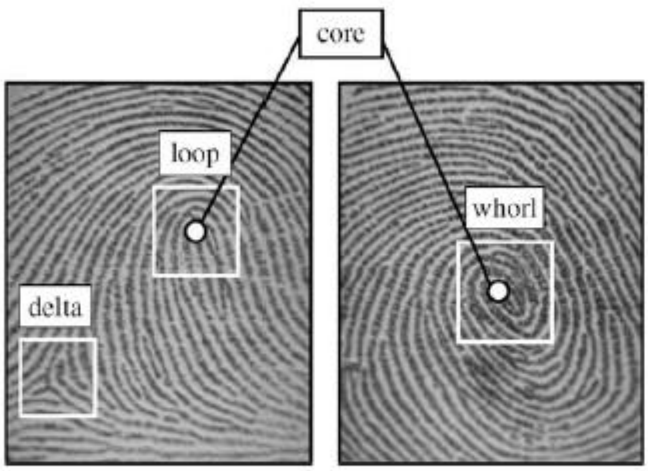
Fingerprints are the most important part in biometric for human identification. They are unique and stable from birth to death. So, fingerprints have been used for the forensic application and personal identification. Fingerprint has some unique points on the ridge which is known as minutiae point, the minutiae could be considered two main types of points which are termination point and bifurcation point [Bha13]. As shown in figure (1.1).



(a) (b) (c)

Figure (1.1) (a) A termination minutia (b) bifurcation minutia (c) termination [Tha10]

The fingerprint pattern contains one or more regions, where the ridge lines create special shapes. These regions may be classified into three classes: loop, delta, and whorl. Many fingerprint matching algorithms are pre-align fingerprint images based on a landmark or a center point which is called the core as shown in figure (1.2)[Tha10].



(a) (b)

Figure (1.2) Special regions white boxes and core points small circles in fingerprint image

.

These ridges and furrows present good similarities in each small local window, like parallel is mind average width **[**Kum10].

Fingerprints are not distinguished by their ridges and furrows, but by minutia, which are some abnormal points on the ridges (figure 1.2).

A typical young male has, on an average, 20.7 ridges per centimeter while a female has 23.4 ridges per centimeter [Lee01].

1.3 Fingerprint Representation

A representation of fingerprint is classified into three parts:

1.3.1 Global Level Representation: - This type of representation is known as pattern, which is an aggregate characteristic of ridges, and minutiae points [Pat13]. The global level structures consist of many ridges that form arches, loops, whirls [Kal11] as shown in figure (1.3).

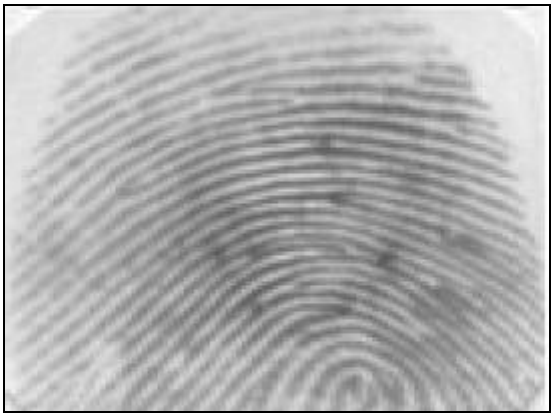


Figure (1.3) Global level representation

1.3.2 Local Level Representation: - Local representation consists of several components within a restricted region in the fingerprint which are unique features found within the pattern that is used for unique identification. In the local level, the ridges and valleys pattern can exhibit a particular shape called minutia. There are several types of minutiae, two types of minutiae are considered: ridge ending and ridge bifurcation as shown in figure (1.4) [Pat13].

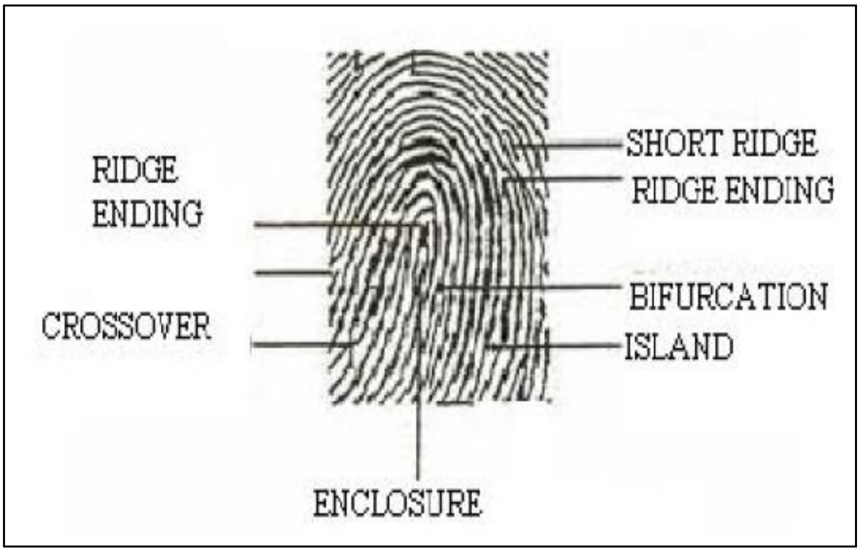


Figure (1.4) Local representation

1.3.3 Very Fine Level Representation: - A small point which is called pore is sometimes opening and closing in the skin as shown in figure (1. 5) [Pat13].

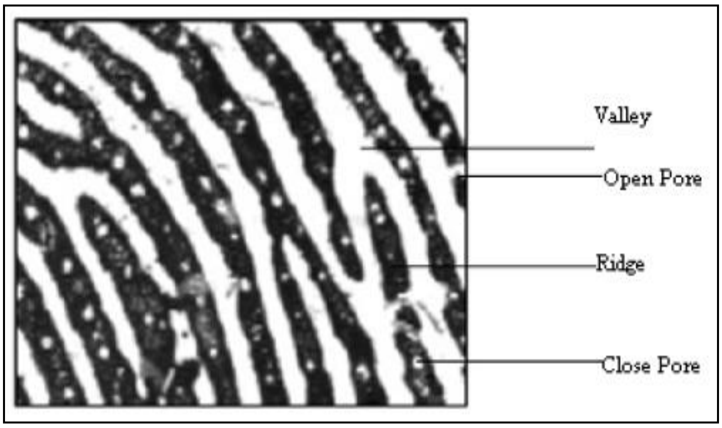


Figure (1.5) Very Fine Level Representation

1.4 Fingerprint Recognition

Fingerprint Recognition can be categorized into two sub domains fingerprint verification and fingerprint identification [Bar13]. Verification is the comparison of a claimant fingerprint against an enrollee fingerprint, where the intention is that the claimant fingerprint matches the enrollee fingerprint. To prepare for verification, a person initially enrolls his or her fingerprint into the verification system. A representation of that fingerprint is stored in some compressed format along with the person's name or other identity.

Identification and verification are both used to declare the identity of a user .Identification: In an identification system, an individual is recognized by comparing with an entire database of templates to find a match. The system conducts one-to-many comparisons to establish the identity of the individual. The individual to be identified does not have to claim an identity (Who am I?) In a verification system, the individual to be identified has to claim his/her identity (Am I whom I claim to be?) and this template is then compared to the individual's biometric characteristic The system conducts one-to-one comparisons to establish the identity of the individual . Before a system is able to verify/identify the specific biometrics of a person the system requires something to compare it with. Therefore, a profile or template containing the biometric properties is stored in the system. Recording the characteristics of a person is called enrollment.The processes of enrollment, identification, and verification are depicted graphically in figure (1.6) [Sra12].

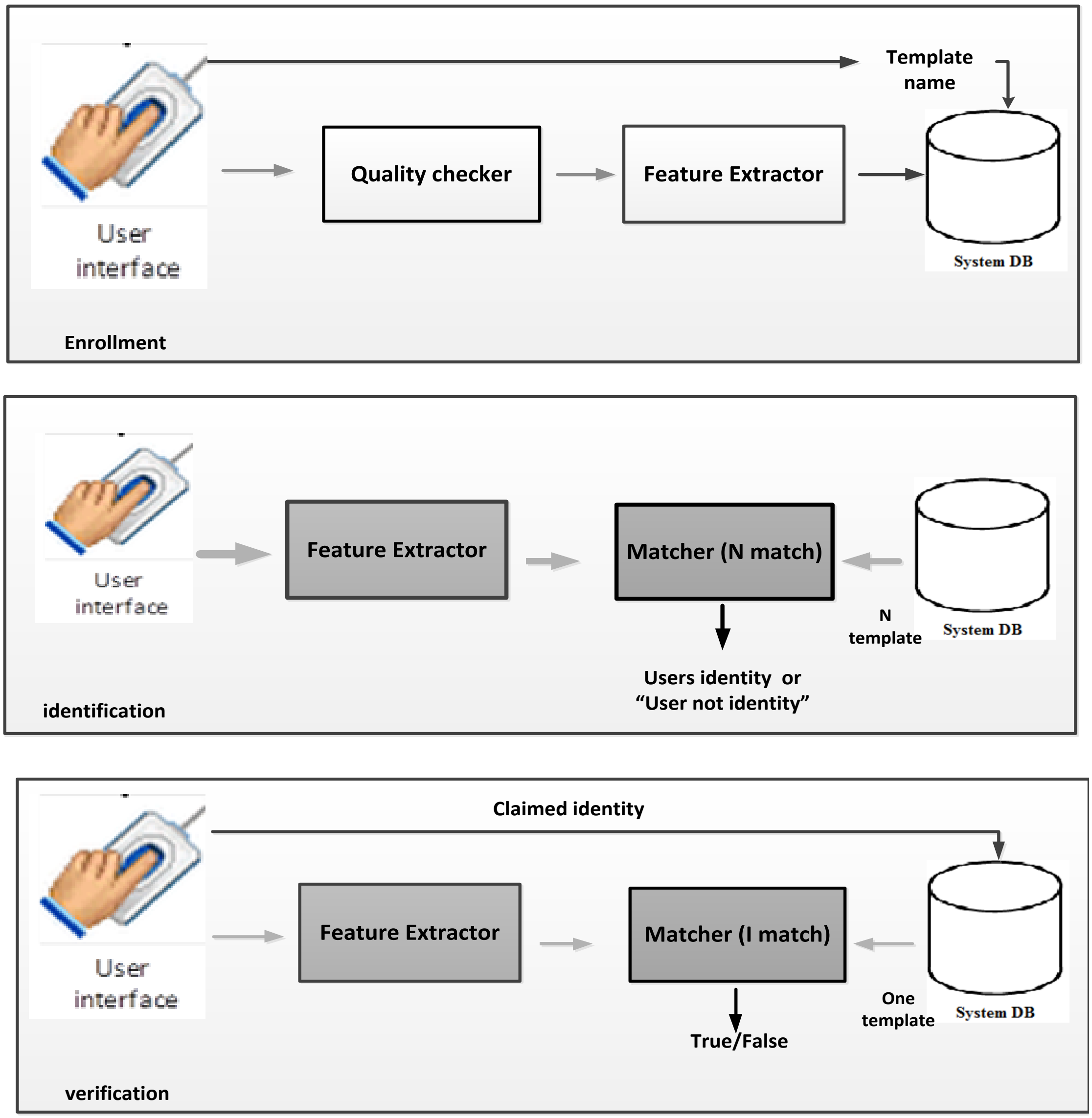


Figure (1.6) Enrollment, Identification and Verification system [Pro04]

Fingerprint verification is to verify the authenticity of one person by his fingerprint. The user provides his fingerprint together with his identity information like his ID number. The fingerprint verification system retrieves the fingerprint template according to the ID number and matches the template with the real-time acquired fingerprint from the user. Usually it is the underlying design principle of AFAS (Automatic Fingerprint Authentication System). [Sin09]

Fingerprint identification is to specify one person’s identity by his fingerprint(s). Without knowledge of the person’s identity, the fingerprint identification system tries to match his fingerprint(s) with those in the whole fingerprint database. It is especially useful for criminal investigation cases. And it is the design principle of AFIS (Automatic Fingerprint Identification System).

1.7 The Thesis Objective

The Objective of the thesis is to develop a fingerprint recognition system and to investigate the behavior of the recognition accuracy using two different phases. This is done by computing the distance between bifurcation points, and anther is by extraction of pores locations and determining their type (open, close) and calculating numbers of pores (open, close).

1.8 Literature Survey

Several researches have gone to develop the newest and best algorithms fingerprint recognition since the emergence of this concept at the first time.

- Kryszczuk et al. [Krz04] investigated the effect of pores in matching fragmentary fingerprints and they concluded that pores become more useful as the fragment size as well as the number of minutia decreases. But when the image resolution decreases or the skin condition is not favorable, this method does not give reliable results. In this proposal a comparison with the state-of-the-art minutia-based pore matching method is used this method can achieve more than 30% improvement on the recognition accuracy when using only pores. By fusing minutia and pore match scores, this method improves the recognition accuracy with respect to that of using only minutiae by 29.82% and 37.46% respectively

- Jea and Govindaraju [Jea05] presented an approach that uses localized secondary features derived from relative minutiae information. They showed that when fragmentary fingerprints with small fingerprint regions are given, it would be very possible that no sufficient minutia are available. The experiments show that using a neural network for generating similarity scores improves accuracy.

They've obtained 1.21% and 0.68% improvements on minimum total error rates of different databases.

- Jain et al .[Jai06] in this paper developed a matcher that utilizes Level 3 features, including pores and ridge contours, for 1000 dpi fingerprint matching. Level 3 features are automatically extracted using wavelet transform and Gabor filters and are locally matched using the (iteration close point) ICP algorithm. experiments on a median-sized database show that Level 3 features carry significant discriminatory information. EER values are reduced (relatively 20%) when Level 3 features are employed in combination with Level 1 and 2 features
- Jain et al. [Jai07] in this paper use advances in fingerprint sensing that is technology, many sensors equipped with dual resolution (500 ppi/1000 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. As a result, a systematic study to determine how much performance gain one can achieve by introducing level 3 features in AFIS is highly desired EER = 12% to 15% for pore matching.
- Qijun et al .[qij08] in This paper explaine that real pores are not always isotropic, To accurately and robustly extract pores, they proposed an adaptive anisotropic pore model, whose parameters are adjusted adaptively according to the fingerprint ridge direction and period. The fingerprint image is partitioned into blocks and a local pore model is determined for each block. With the local pore model, a matched filter is used to extract the pores within each block. Experiments on a high resolution (1200dpi) fingerprint dataset were performed and the results demonstrate that the proposed pore model and pore extraction method can locate pores more accurately and robustly in comparison with other state-of-the-art pore extractors. On the partial fingerprint image database, by fusing minutia and pore match scores it improves the recognition accuracy of using only minutiae by 34.86%

- Qijun Zhao et al. [Zha09] in this paper, propose a novel direct approach for matching fingerprint pores. It first determines the correspondences between pores based on their local features. It then uses the RANSAC (RANdom SAmple Consensus) algorithm to refine the pore correspondences obtained in the first step. A similarity score is finally calculated based on the pore matching results. The proposed pore matching method successfully avoids the dependency of pore matching on minutia matching results. Experiments have shown that the fingerprint recognition accuracy can be greatly improved by using the method proposed in this paper, Recognition accuracy with respect to that of using only minutiae is improved by 29.82% and 37.46% respectively in terms of EER and FMR1000.

- Abhyankar et al. [Abh10] in this study used fingerprint pores along the ridges for fingerprint matching. Wavelet based fingerprint enhancement techniques are implemented to ease detection of the level-3 features. Delaunay triangulation based alignment and matching of the fingerprints are performed. The pores are checked for the liveness by perspiration activity in the time series captures. The developed matching scheme was tested for the high resolution data (686 ppi) for 114 live and spoof fingerprint classes. ROC is plotted and EER of 2.97% is obtained.

- Nedia[Ned11] in this work, focuses on the problem of reducing the classification fingerprint features that has been entered to the neural network. An algorithm was introduced to work with a prepared codebook to code and normalize the input samples of the back-propagation method. The main advantages of preparing codebook are the simplicity of its idea and its high speed processing. This method has been tested on the FCV2002 fingerprint database. The recognition accuracy is 94% and the equal error rate (EER) is 2.1%.

- Chandra [Cha12] in this paper uses (Scale Invariant feature transform) SIFT algorithm. Firstly fingerprints of good quality are acquired by using optical scanner. Image normalization is done using Gaussian blurring and sliding window contrast adjustment. Pores are extracted and estimated. Using these estimated pores, matching is done from template database to stored database using SIFT algorithm. Scale Invariant Features Transform (SIFT) is an algorithm in computer vision to detect and describe local features in images. The features are invariant to image scaling and rotation. They are well localized in both the spatial and frequency domains the proposed level-3 feature extraction algorithm yields a verification accuracy of 94%.

- Mela [Mel13] in this work, develops a geometrically based method for fingerprint recognition and verification tasks; a set of partial local features extracted from fingerprint ridges, minutia, and pores attributes are used. The proposed system passes through two main phases: training phase and test phase. In the training phase, the system is trained using a set of low quality fingerprint images to select the best discriminating local features this can lead to best recognition rates. During the test phase, the system performance is examined to know the attained recognition rate is (100%) and verification with error rate of approximately (1.2%) at threshold value equal to (39.5). Using features based on local ridges attributes only can lead to near optimal recognition rate of (99.37%).

- Divyaloshini v. et al [div14] in this paper presents a unique verification system which is called fingerprint biometric authentication using Back Propagation Neural Network method The results of authentication has been compared with previously, implemented algorithm SVM. The mechanism has been tried with different sets of rotation and matching, Score at the end has been computed to 93% on an average with BPNN whereas the accuracy for SVM lies in the range from 70 to 80 %.

1.9 Thesis Organization

The remainder of the thesis is organized as follows:

- **Chapter 2:-*"Fingerprint Recognition"***

This chapter presents the background of the used biometric technologies and techniques for Fingerprint Recognition.

- **Chapter 3:-*" Proposed Fingerprint Recognition Model "***

This chapter covers the details of the developed AFRS; their stages and steps Also, a description for the implementation of each step is described. Also, some examples are given to illustrate the performance of the suggested methods to handle each system task and commonly used Algorithms in fingerprint recognition systems are also demonstrated.

- **Chapter 4:- " *Implementation Experimental and Results "***

This chapter presents the results of experimental analysis of some tests, Applied to define the best discriminating features, and the corresponding Recognition performance.

- **Chapter 5:-"*Conclusio ns and Future work"***

This chapter holds a list of some conclusions after implementing the Proposed model and it gives some suggestions for future work to enhance the presented system.

Chapter Two

Fingerprint Recognition

2.1 Introduction

Recently, forensic science has had many challenges in many different types of crimes and crime scenes vary from physical crimes to cyber or computer crimes. Accurate and efficient human identification or recognition have become crucial for forensic applications due to the large diversity of crime scenes, and because of the increasing need to accurately identify criminals from the available crime evidences.

Biometrics is an emerging technology that provides accurate and highly secure personal identification and verification systems for civilian and forensic applications. The positive impact of biometric modalities on forensic science began with the rapid developments in computer science, computational intelligence, and computing approaches. These advancements have been reflected in the biometric modality capturing process, feature extraction, feature robustness, and features matching. A complete and automatic biometric identification or recognition systems have been built accordingly [Awa 14].

2.2 Biometrics Definition

Biometrics is described as the science of recognizing an individual based on his or her physical or behavioral attributes. Biometric system broadly provides the three functionalities such as, identification, verification, [Wab13]. Since biometric characteristics are distinctive, and cannot be forgotten or lost, and the person to be authenticated needs to be physically present at the point of identification, biometrics is inherently more reliable and more capable than traditional knowledge-based and token-based techniques. Biometrics also has a number of disadvantages. For example, if a password or an ID card is compromised, it can be easily replaced. However, once a biometrics is compromised, it is not possible to replace it. Similarly, users can have a different password for each account, thus if the password for one account is compromised, the other accounts. Are still safe, however, if a biometrics is compromised, all biometrics-based accounts can be broken-in. Among all biometrics (e.g., face, fingerprint, hand geometry, iris, retina, signature, voice print, facial thermogram, hand vein, gait, ear, odor, keystroke Dynamics, etc.), fingerprint-based identification is one of the most mature and proven technique [Pra01].

2.3 Biometric Technology

Biometric technologies are defined as, "automated methods of verifying or recognizing the identity of a living person based on a physiological or behavioral characteristic". The term "automated methods" refers to three basic methods in concern with biometric devices [div14]:

1. A mechanism to scan and capture a digital or analog image of a living personal characteristic;
2. Compression, processing and comparison of the image to a database of stored images; and
3. Interface with applications systems.

2.4 Advantages of Biometrics

1. Biometric traits cannot be lost or forgotten (while passwords can).
2. Biometric traits are difficult to copy, share and distribute (passwords can be announced in websites).
3. They require the person being authenticated to be present at the time and point of authentication

Biometric systems of identification are enjoying a new interest. Various types of biometric systems are being used for real-time identification. The most popular are based on face recognition and fingerprint matching; however, other biometric systems use iris and retinal scans, speech, facial feature comparisons and facial thermograms, and hand geometry [div14].

2.5 A Brief Review of the Major Biometric Technologies

These technologies, fingerprint recognition, hand geometry recognition and iris recognition are most prevalent. Having said that, considerable time and effort is being invested in biometric technologies of the future, which include gait recognition (the way and manner in which somebody walks), earlobe recognition (examining the geometry of the earlobe) and DNA recognition [Rav06], (examining the unique strands found in DNA samples). Figure (2.1) represented deferent type of biometric technologies.

2.6 The Differences between Behavioral and Physical Biometrics

The biometric technologies fall in two categories: behavioral biometrics and physical biometrics. In general, behavioral biometrics can be defined as the non-biological or non- physiological features (or unique identifiers) as captured by a biometric system. As behavioral biometrics also covers any mannerisms or behavior displayed by an individual, this category includes signature as well as keystroke recognition.

Physical biometrics may be defined as the biological and physiological features (or unique identifiers) as captured by a biometric system. This category includes fingerprint recognition, hand geometry recognition, facial recognition, iris and retinal recognition, and voice recognition [Rav06].

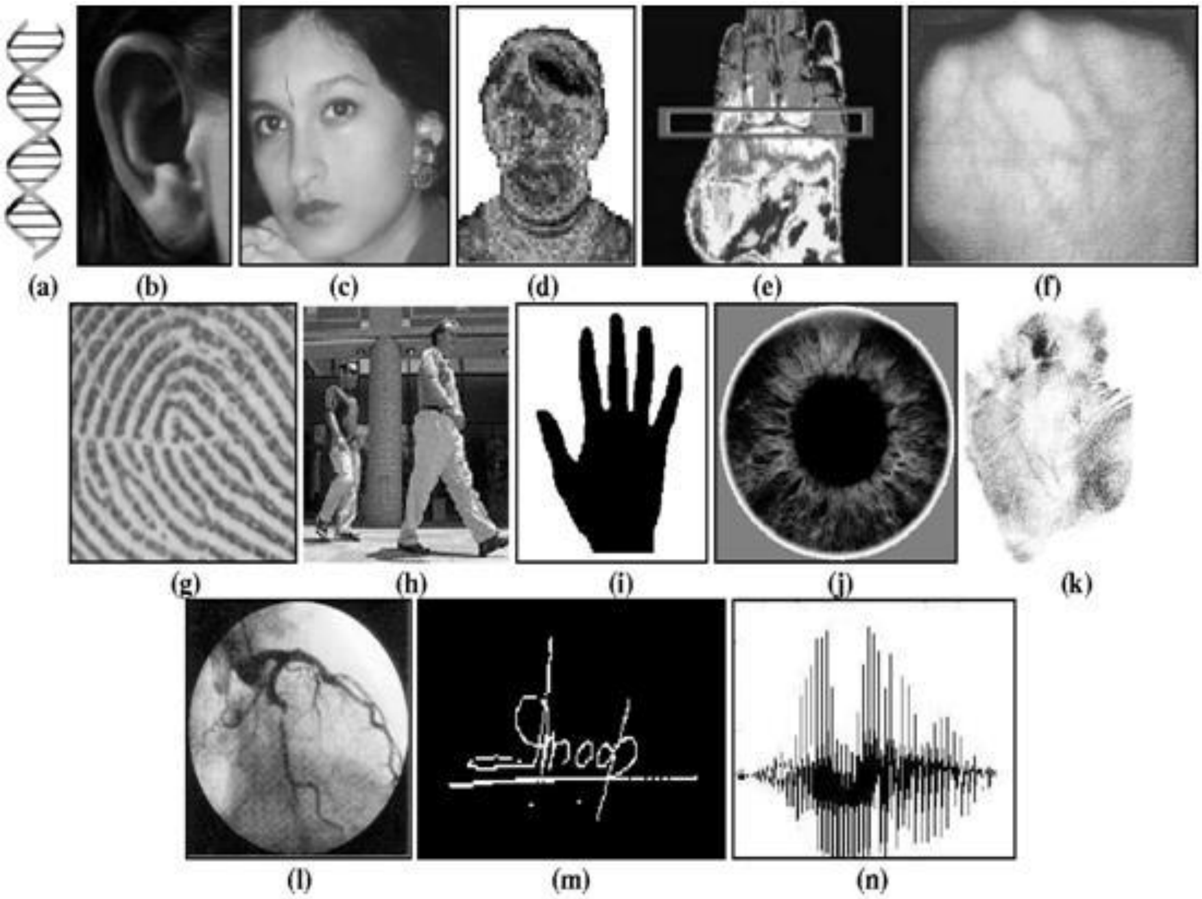


Figure (2.1): Examples of biometric characteristics: (a) DNA, (b) ear, (c) face, (d) facial thermo gram, (e) hand thermo gram, (f) hand vein, (g) fingerprint, (h) gait, (i) hand geometry, (j) iris, (k) palm print, (l) retina, (m) signature, and (n) voice

2.7 Techniques for Fingerprint Recognition

1- Minutiae Extraction based Techniques: Mostly accepted finger scan technology is based on Minutiae. Minutiae based techniques produce the fingerprint by its local features, like termination and bifurcation.

2- Pattern Matching or Ridge Feature based Techniques: Feature extraction is established on series of ridges as averse to different points which design the basis of pattern matching techniques over Minutiae Extraction.

3- Correlation based Techniques: Correlation is used to match two fingerprints, the fingerprints are adjusted and the correlation for each corresponding is computed pixel. They can match ridge shapes, breaks.

4- Image based Techniques: this technique attempt to do matching which is based on the global features of an all fingerprint images. It is an advanced and newly developed method for fingerprint recognition. A number of biometric characteristics are being used in various applications because of their universality, uniqueness, permanence, measurable [Bha13].

2.8 Classification of Fingerprints

Fingerprints are classified into three different levels: First level detail, second level detail and third level detail.

2.8.1 First Level

The need to classify fingerprints arose when large collections of fingerprints were to be stored in a suitable manner. As the fingerprints form definite patterns which may resemble in overall shape and design, they can be classified and this fact led Sir Edward Henry [Che07] to devise a classification system which is still in use today by the name of Henry's Classification System. Fingerprint patterns are classified into four groups [Che07].

1. Arches: - Arches constitute 5% of total fingerprint patterns. In this pattern, ridges enter from one side of the impression and they flow or tend to flow towards the other side of the impression with slight rise in the center like a small hill or a tent forming plain arches and tented arches respectively.

2. Loops: - Loops constitute 60-65% of fingerprint patterns. When one or more ridges enter from one side of pattern, they make a recurve and exit or tend to exit on the same side of the impression, they form loop pattern. Loop pattern is further subdivided into radial and ulnar loop depending on the slant of the loop ridges whether they are slant towards the ulna or radius (bones of fore-arm) i.e. little finger or thumb.

3. Whorls: - Whorls along with composites constitute 30-35% of the total fingerprint patterns. When ridges recurve in circular manner and at least one ridge makes a complete circle around the point of core, they form whorl pattern.

4. Composites: - When two or more patterns (arch, loop or whorl) combine to form a fingerprint pattern, that pattern is called as composite. The composites may be further subdivided into Central Pocket Loops, Lateral Pocket Loops, Twinned Loops and Accidentals.

a. Central Pocket Loop: - In this pattern, majority of ridges form loops and one or more ridges recurve at the core to form Pocket. In this pattern like whorl, at least one ridge makes a complete circle around the core and there are two deltas (point nearest to the Centre of divergence of ridges). Unlike whorl, the line joining two deltas doesn't touch any recurving ridge in the pattern area.

b. Lateral Pocket Loop (Double Loop): - In this pattern there are two separate overlapping loops with separate shoulders and two deltas. The core forming ridges of the loops open towards the same side of the deltas.

c. Twinned Loop (Double Loop): - It is the same pattern like Lateral Pocket Loop with the difference that the core forming ridges of the loops open towards either side of the deltas.

d. Accidental: - The pattern which is too irregular to be classified in any of the above patterns is called Accidental pattern.

This characteristic alignment of ridges in the center of the fingerprint is known as first level. First level detail serves as class characteristics. As shown in figure (2.2).

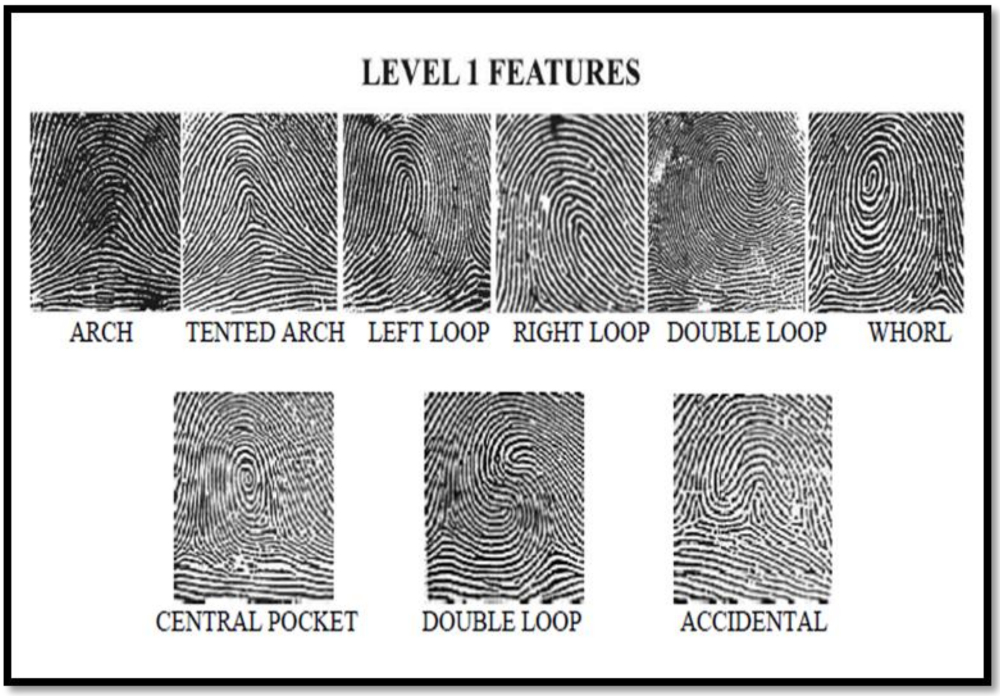


Figure (2.2) Fingerprint features at level 1

The term pattern interpretation is used in relation to giving names to these various patterns. The pattern area is the portion of fingerprint that is examined to determine the fingerprint pattern and this is usually the central portion of fingerprint, sometimes called the core. As this overall pattern is frequently repeated due to a fewer number of possible configurations, individual of fingerprints cannot be established on the basis of first level.

2.8.2 Second Level

Second level detail consists of ridge characteristics like ridge endings, bifurcations, enclosures, islands, short ridges, ridge breaks and trifurcations there may be more than 150 ridge characteristics in one full fingerprint. These ridge characteristics, also called minutiae, serve as individual characteristics. The two basic forms of minutiae generally considered are ridge endings and ridge bifurcations. The concept of 16 point standard (minutiae) in two fingerprints to establish the identity has been changed to non-numerical standards for personal identification. It has been established that a small portion of fingerprint (partial print) showing even fewer minutiae irrespective of their location on general pattern can provide great evidential contribution in making an identity .Database of most biometric systems consists of minutiae templates with salient features like core, delta and minutiae and not raw fingerprints image. These minutiae templates can reveal the class of fingerprint and even the ridge structure as shown in figure (2.3) [Abh08].

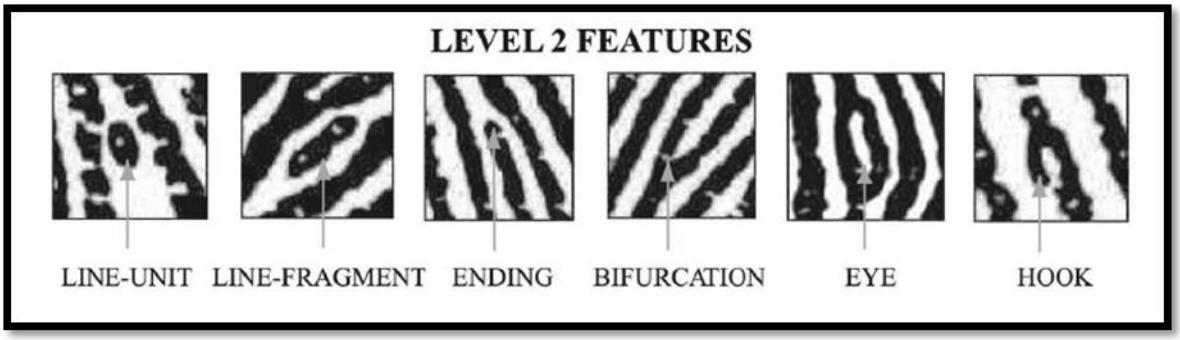


Figure (2.3) Fingerprint features at level 2

2.8.3 Third Level

Use of third level detail for personal identification began when identity could not be established using first and second level detail in some cases due to insufficient number of ridge characteristics. Identification based on the use of third level details is considered as an advanced identification technique. Study of third level detail is called Ridgeology and the term 'Ridgeology' was first coined in 1983 by David R. Ashbaugh [Abh08]. and he defined ridgeology as "The study of uniqueness of friction ridge structures and their use for personal identification". Ridgeology includes the study of pores and edge characteristics of ridges. The study of pores i.e. size, shape and relative position of pores on the ridges for the purpose of personal identification is called Poroscopy as shown in figure(2.4) [Abh08].

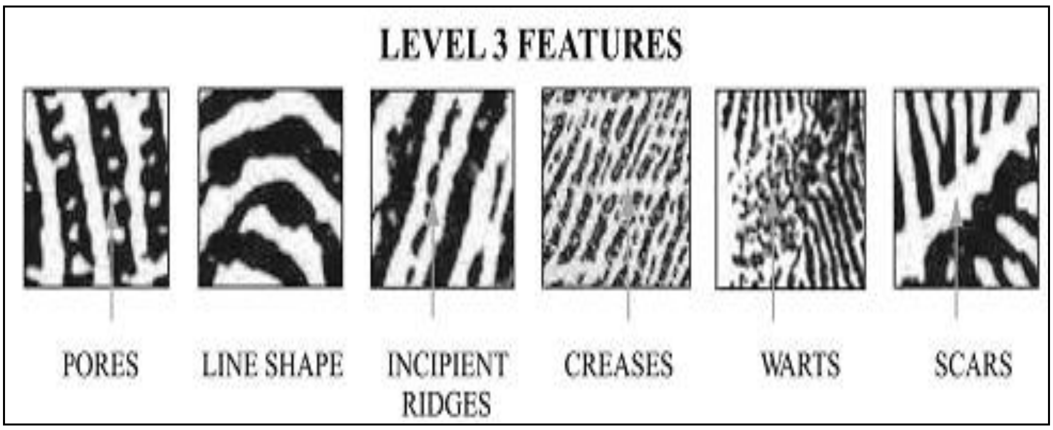


Figure (2.4) Fingerprint features at level 3

2.9 Pores

Sweat pores reside on finger ridges and may be either closed or open a closed pore looks like an isolated bright blob on the dark ridge, whereas an open pore, which is perspiring, is connected with its neighboring bright valleys. To investigate the spatial appearances of pores on fingerprint images, we manually marked and cropped hundreds of pores on many fingerprint images, including both open and closed pores as shown in figure(2.5) [Zha10].

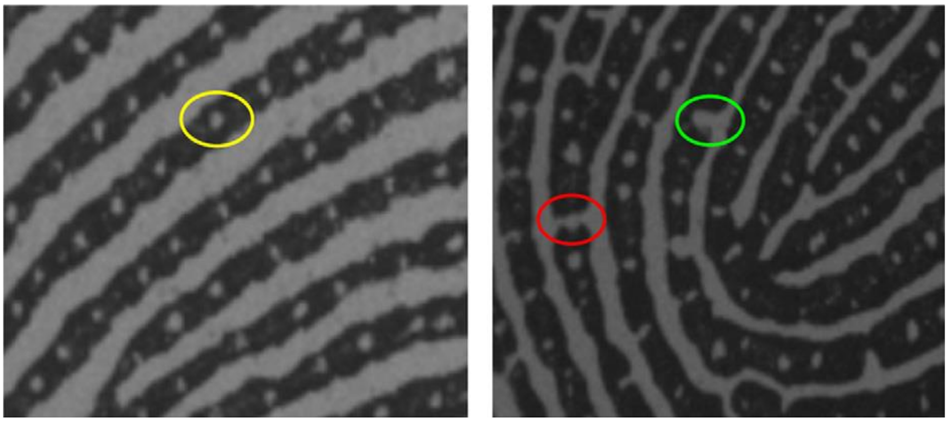


Figure (2. 5) Type of pores

(a) close pores (b) open pores

2.10 Pore Detection

Based on their positions on the ridges, pores can be divided into two categories: open and closed. A closed pore is entirely enclosed by a ridge, while an open pore intersects with the valley lying between the two ridges. However, it is not useful to distinguish between the two states for matching since a pore may be open in one image and closed in the other image, depending on the perspiration activity. One common property of pores in a fingerprint image is that they are all naturally distributed along the friction ridge. As long as the ridges are identified, the locations of pores are also determined, regardless of their being open or closed as show in figure(2.6) [Lee01].

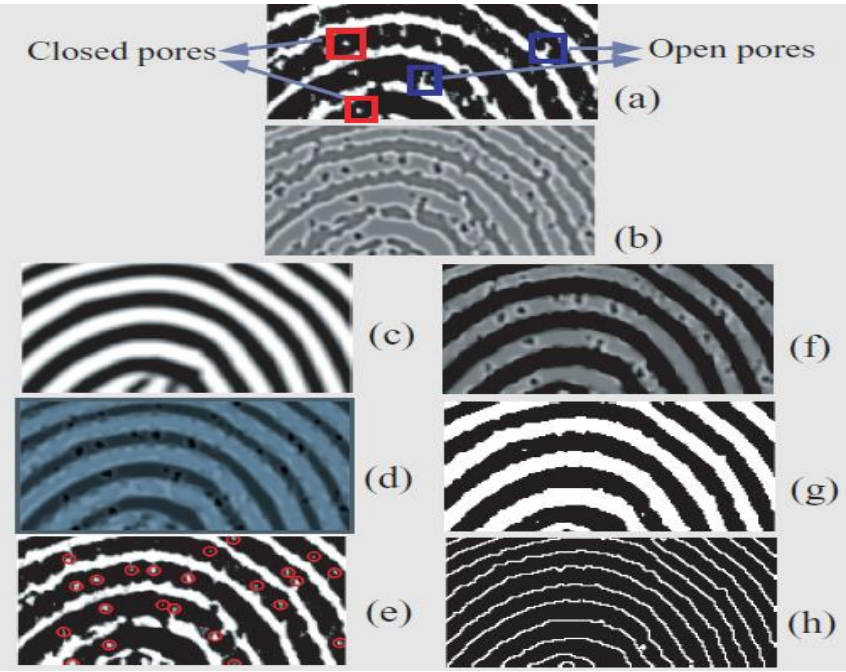


Figure (2.6). Pore extraction. (A) A partial fingerprint image at 1,000 ppi. (B) Enhancement of ridges (C) a linear combination of image in (a) and (b). (D) Wavelet response (s=1.32) of the image in (a). (E) A linear combination of image (d) and (b). (F) Extracted pores (red circles) after thresholding the image in (e) (h) Extracted ridge contours,

2.11 Image Pre-processing stages

These stages include several steps, these steps divided into two parts specific for level2 and level3.

2.11.1 Morphologies Operator (Dilation and Erosion)

Mathematical Morphology is a tool for extracting image components that are useful for representation and description. The technique was originally developed by Matheron and Serra at the school of mines in Paris [Kur94]. It is a set-theoretic method of image analysis providing a quantitative description of geometrical structures. (At the school of mines they were interested in analyzing geological data and the structure of materials), Morphology can provide boundaries of objects, their skeletons, and their convex hulls. It is also useful for many pre- and post-processing techniques, especially in edge thinning and pruning [Kur94].

Generally speaking most morphological operations are based on simple expanding and shrinking operations. The primary application of morphology occurs in binary images, though it is also used on grey level images. It can also be useful on range images.

The two basic morphological sets of transformations are erosion and dilation these transformations involve the interaction between an image A (the object of interest) and a structuring element B, called the structuring element.

Typically the structuring element B is a circular disc in the plane, but it can be any shape. The image and structuring element sets need not be restricted to sets in the 2D plane.

Let A and B be subsets of Z^2. The translation of A by x is denoted Ax and is defined as

$$A_x=\{c: c = a +x, \text{ for } a \in A\} \quad \textbf{(2.1)}$$

The complement of A is denoted Ac, and the difference of two sets A and B is denoted A - B.

The reflection of B, denoted, is defined as

$$B=\{x: x = -b, \text{ for } b \in B\} \quad \textbf{(2.2)}$$

These are the basic operations of morphology, in the sense that all other operations are built from a combination of these two.

2.11.2 Dilation

Suppose A and B are sets of pixels. Then the dilation of A by B, denoted$A \oplus B$, is defined as

$$A \oplus B = \bigcup_{x \in B} A_x \qquad \textbf{(2.3)}$$

What this means is that for every point $x \in B$, is translated A by those coordinates. Then take the union of all these translations.

An equivalent definition is that

$$A \oplus B = \{(x, y) + (u, v): (x, y) \in A, (u, v) \in B\} \qquad \textbf{(2.4)}$$

From this last definition, dilation is shown to be commutative; that

$$A \oplus B = B \oplus A \qquad \textbf{(2.5)}$$

An example of dilation is given in figure (2.7). In the translation diagrams, the grey squares show the original position of the object. Note that A $_{(0,0)}$ is of course just A itself. In this example, have

$$B = \{(0,0), (1,1), (-1,1), (1,-1), (-1,-1)\} \qquad (2.6)$$

and those are the coordinates by which translated A.

In general, $A \oplus B$ can be obtained by replacing every point (x,y) in A with a copy of B, placing the (0,0) point of B at (x,y). Equivalently, could replace very point (u, v) of B with a copy of A.

Dilation is also known as Murkowski addition; see Haralick and Shapiro [Rod97] for more information. As you see in figure (2.7), dilation has the effect of increasing the size of an object. However, it is not necessarily true that the original object A will lie within its dilation $A \oplus B$. Depending on the coordinates of B, $A \oplus B$ may end up quite a long way from which A is the same as in figure (2.8) B has the same shape but a different position. In figure (2.7),

$$B = \{(7,3), (6,2), (6,4), (8,2), (8,4)\} \qquad \textbf{(2.7)}$$

So that,

$$A \oplus B = A_{(7,3)} \cup A_{(6,2)} \cup A_{(6,4)} \cup A_{(8,2)} \cup A_{(8,4)} \qquad \textbf{(2.8)}$$

For Dilation, generally assume that A is the image being processed, and B is a small set of pixels. In this case B is referred to as a structuring element or as kernel [Kur94].

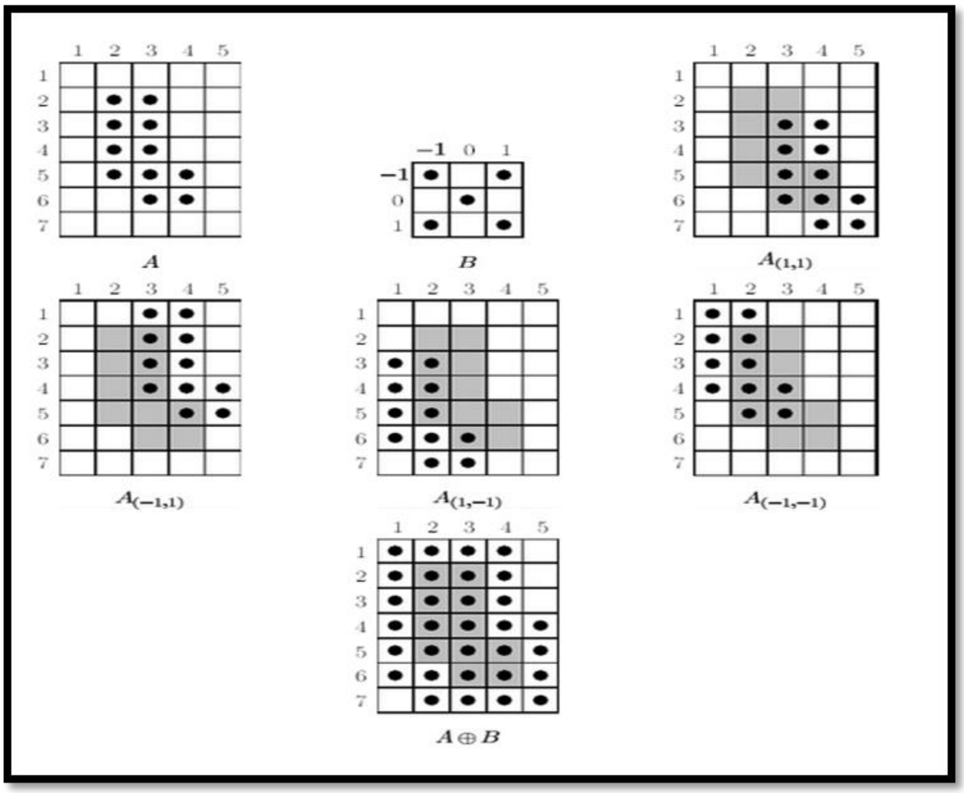


Figure (2.7) Dilation operator

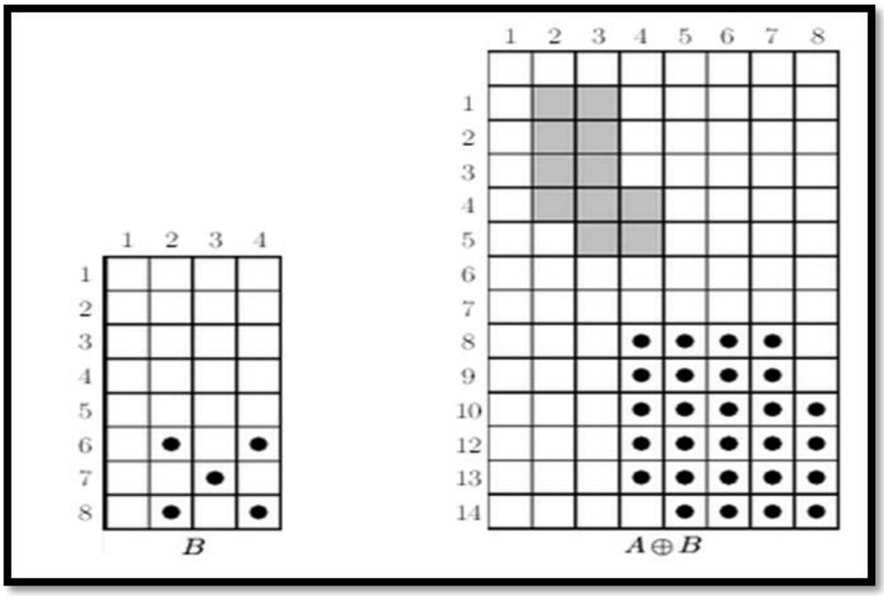


Figure (2.8) A dilation for which $A \oplus B$ [Kur94].

2.11.3 Erosion

Given sets A and B, the erosion of A by B, written $A \ominus B$, is defined as

$$A \ominus B = \{w : B_w \subseteq A\} \qquad \mathbf{(2.9)}$$

In other words the erosion of A by B consists of all points w=(x,y) for which B_w is in A. To perform an erosion, then moved B over A, and find all the places it will fit, and for each such place mark down the corresponding (0,0) point of B. the set of all such points will form the erosion. An example of erosion is given in figure (2.9).

Note that in the example, the erosion $A \ominus B$ is a subset of A. This is not necessarily the case; in depends on the position of the origin in B. if B contains the origin, then the erosion will be a subset of the original object. As shown in Figure (2.9) .

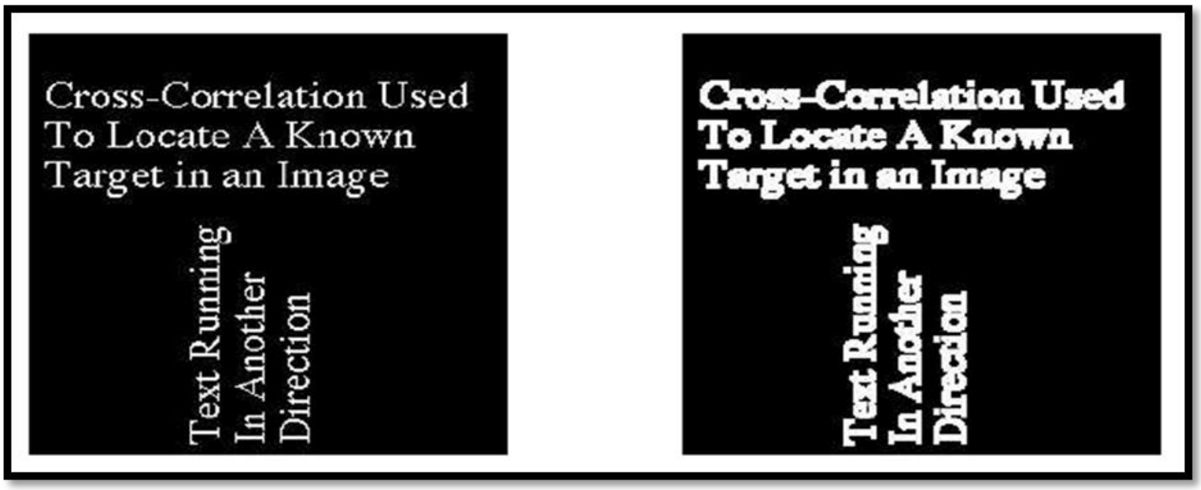


Figure (2.9) Applying dilation operator and erosion to binary image

For erosion, as for dilation, generally assume that A is the image being processed, and B is a small set of pixels: the structuring element or kernel.

Erosion is related to Minkowski subtraction: the Minkowski subtraction of B from A is defined as (2.10) [Par 98].

$$A - B = \bigcap_{b \in B} A_b \qquad (2.10)$$

2.11.4 Gray Level Thresholding

This is the simplest and the oldest of all thresholding processes. Hence GRAY color space is used for the study. The advantages of the gray level thresholding are that the algorithms are simple and easy to implement in real time. Xinwen[Uma05]. measured the geometric features of insect specimens using image processing.

Gray level thresholding suffers from serious drawback," Intensity Variation", because of which the intensity varies from time to time. Threshold values in gray level thresholding are fixed using only one parameter i.e. intensity.

This limitation led to the use of other thresholding techniques RGB, HSV thresholding commonly known as color thresholding [Uma05]. to binarize the filtered grayscale image, a local threshold method is used. The filtered image is decomposed into square blocks. The size of the blocks is set to 20 pixels, so that on average 3 ridges are present in one block, for each block. Pixels, whose value is below the threshold, are Converted to 0 (black) while others to 1 (white). Once we have obtained a binary image [Ots79]. Two types thresholding are:-

1- **Global threshold:** the surrounding fingerprint image area doesn't hold ridges and furrows; it should be discarded since it only holds background information. Then, the lines bounding the remaining effective area are marked out. This step is necessary to collect only the minutia data existing in the bounded region and to avoid the spurious minutiae that are wrongly detected in the surrounding bad background areas. A global threshold is determined by calculating average of gray pixels in the image multiplied by the value of inclusion parameter (α); this value depends on whether the image is too dark or too bright. Then each pixel value in the image smaller than the threshold will set 0, otherwise its gray value is kept without any change.

2- **Local thresholding:** method is adopted; it is based on the local characteristics of fingerprint image. The threshold assessment process is started with calculating the average intensity value in a large block surrounding certain area of the image Then, all the pixels which belong to a small block which lie within the central area of the large block are binarized by comparing its value with the determined threshold value to decide whether each pixel belong to ridge or background [Mel13].

2.11.5 Thinning Process

The Zhang-Suen algorithm (ZS algorithm) is a Fast Parallel Algorithm for Thinning Digital Patterns. A 3x3 window is moved down throughout the image and calculations are carried out on each ridge pixel, which has the value "1" and black color, to decide whether it needs to stay in the image or not. The iteration from one pixel to another used in this algorithm is clockwise [Ack08].

A. Odd sub-iteration flag a point P1 for deletion if all the following conditions :are satisfied

.a. Count with connectivity 1

$A(P_1) = 1$

b. Have a number of nonzero black neighbors, B(P1), between 2 and 6

$2 \leq B(P_1) \leq 6$

c. Have at least one of the following pixels in zero white: [x-1, y],

[y+1], [x+1, y]، [x

P2 * P4 * P6 = 0

d. Have at least one of the following pixels in zero white [x-1, y],

y] y], [x, y-1]، [x+1

$P4 * P6 * P8 = 0$

where *A (P1)* is total occurrences of 0-1 patterns (current pixel value 0 and next pixel value 1) in the ordered sequence P2, P3, P4, P5, P6, P7, P8, and P9, the "*" expresses logic "AND" operation, and the $B(P_1)$ function returns the number of nonzero black pixels in the structuring element.

$$B(P_1) = P_2 + P_3 + P_4 + P_5 + P_6 + P_7 + P_8 + P_9$$

For example:

$B(P_1) = 0 + 1 + 1 + 0 + 0 + 0 + 1 + 0$

$B(P_1) = 3$, and $A(P1) = 2$.

B. In even sub-iteration, only the condition items c. & d. in the first iteration are replaced, the following conditions would be applied:

a. Count with connectivity 1.

$A(P_1) = 1$

b. Have a quantity of nonzero black neighbors between 2 and 6 (Included).

$2 \leq B(P1) \leq 6$

c. Have at least one of the following pixels in white: [x-1,y], [x,y+1], [x,y- 1]

$P2 * P4 * P8 = 0$

d. Have at least one of the following pixels in white: [x,y+1], [x+1,y], [x, y-1]

$P2 * P6 * P8 = 0$

As previously expressed, iterations will go on as points are being eliminated (changed to zero) [Dav13].

2.11.6 Image Smoothing

The Gaussian filter is a two dimensional (2-D) convolution operator that is used to blur images and remove details and noise. An isotropic (i.e., circularly symmetric) Gaussian has the form:

$$g(x,y) = \frac{1}{\sqrt{2\,\pi\,\sigma^2}} e^{-(x^2+y^2)/2\sigma^2} \qquad \mathbf{(2.11)}$$

The idea of Gaussian smoothing is to use this 2-D distribution as a 'point-spread' function, and this is achieved by convolution. In image processing, a discrete representation of the Gaussian function is required for conducting the convolution. The image is stored as a collection of discrete pixels so needed to produce a discrete approximation to the Gaussian function before performing the convolution. The effect of Gaussian smoothing is to blur an image. The degree of smoothing is determined by the standard deviation of the Gaussian. Larger standard deviation requires larger convolution kernels in order to be accurately represented. In theory, the Gaussian distribution is nonzero everywhere, meaning an infinitely large convolution kernel. In practice, it is effectively zero more than about three standard deviations from the mean, so the kernels beyond this point can be truncated. Note that a constant scaling factor is multiplied to ensure that the output gray levels are in the same range as the input gray levels [Shi10].

2.11.7 Median Filter

The main concept of the median filter is to processed through the signal entry by entry, replacing each entry with the median of closest entries. The pattern of neighbors is called the "window" which is determined as kernel, which slides, entry by entry, over the entire signal. For 1D signal, the most obvious window is just the first few preceding and following entries, whereas for 2D (or higher-dimensional) signals such as images, more complex window patterns are possible (such as "box" or "cross" patterns). Note that if the window has an odd number of entries, then the median is simple to define: it is just the middle value after all the entries in the window are sorted numerically. For an even number of entries, there is more than one possible median, see median for more details [Ari09]. The median filter is a nonlinear filter, which can reduce impulsive distortions in an image and without too much distortion to the edges of such an image. It is an effective method that of suppressing isolated noise without blurring sharp edges [Aib06].

2.12 ICP Algorithm

ICP (Iterative Closest Point) algorithm is widely used for geometric alignment of three-dimensional models when an initial estimate of the relative pose is known. Many variants of ICP have been proposed, affecting all phases of the algorithm from the selection and matching of points to the minimization strategy, Enumerating and classifying many of these variants, and evaluating their effect on the speed with which the correct alignment is reached. In order to improve convergence for nearly-flat meshes with small features, such as inscribed surfaces, a new variant is introduced based on uniform sampling of the space of normal, concluded by proposing a combination of ICP variants optimized for high speed, demonstrated an implementation that is able to align two range images in a few tens of milliseconds, assuming a good initial guess. This capability has potential application to real-time 3D model acquisition and model-based tracking [Szy01], The Iterative Closest Point Algorithm has become established as one the most useful methods of range data. Processing given two sets of partially overlapping range data and an initial estimate of their relative positions, ICP is used to register the data sets by improving the position and orientation estimate. ICP is an essential step in model building, dimensional inspection, and numerous applications of range data processing. At each ICP iteration, correspondences are determined between the two data sets, and a transformation computed which minimizes the mean square error (MSE) of the correspondences. The iterations continue until either the (MSE) falls below some threshold values, the maximum number of iterations is exceeded, or some other stopping condition is satisfied, due to its fairly large computational expense, ICP is typically considered to be a batch or, at best, a user-guided online process where the user initiates and assists the process and then allows it to execute unsupervised for a number of minutes. An ICP which executes in real-time, or near real-time, would prove advantageous in several situations. One reason is that range data acquisition sensors are getting faster. The combination of real time range data acquisition with a real-time ICP forms the basis of a number of new and useful systems, such as geometric tracking and hand-held sensors. Furthermore, there are emerging applications such as environment modeling where the volume of data is large, and for which any improvement in the speed of ICP is desirable. There has been some previous work in developing efficient versions of ICP. Implemented efficient correspondence calculations based upon the k-d tree and decoupled acceleration for the rotation and translation components. Implemented and compared a variety of model representations and correspondence methods proposed a correspondence method which is specifically tailored to efficient ICP. A generic method for speeding up computations is parallelization. [Lan01].

2.12.1 Selection of Points

The effect of the selection of point pairs on the convergence of ICP was examined. The following strategies have been proposed:

- Always use all available points.
- Uniform subsample the available points.
- Random sample (with a different sample of points at each iteration).
- Select points with high intensity gradient, in variants that use per-sample color or intensity to aid in alignment [Szy01].

2.12.2 Euclidean Distance Equation

Euclidean distance is the distance between two points in Euclidean space. Euclidean space was originally devised by the Greek mathematician Euclid around 300 B.C.E. to study the relationships between angles and distances. This system of geometry is still in use today and is the one that high school students study most often. Euclidean geometry specifically applies to spaces of two and three dimensions. However, it can easily be generalized to higher order dimensions.

If the coordinates of the points (x, y) are given then we can calculate the distance using the formula,

$$d = \sqrt{((x2 - x1)^2 + (y2 - y1)^2)} \qquad \textbf{(2.12)}$$

Where x1 and y1 are the coordinates of one point and x2, y2 are coordinates of another point, and d is called the distance between the two points. The distance gives the numerical illustration of the location of the objects. Here we will see about the Euclidean equation to measure the distance.

Proposed Fingerprint Recognition System

(PFR)

3.1 Introduction

This chapter is devoted to present the design considerations, design requirements and the steps taken throughout the establishment of the proposed PFR system. The design steps are illustrated in detail.

The implemented PFR consists of three major stages: preprocessing, feature extraction, and post-processing. These three stages are executed sequentially. Figure (3.1) shows the main architecture of the proposed PFR system.

The preprocessing stage is considered as a necessary step in the reliable system since extraction and matching stages depend greatly upon the quality of the input fingerprint image. Therefore a preprocessing should cover four main steps.

The preprocessing is image noise elimination, the system used Gaussian filter for removing the image noise. A global binarization is applied on the gray level image; that is based on the minimum and maximum contrast.

Two approaches are used to process fingerprint image, level2 and level3. In level2 extracting bifurcation points and distances between the are calculated, while in level3 morphological operating (dilation and erosion) and pores features when extracted.

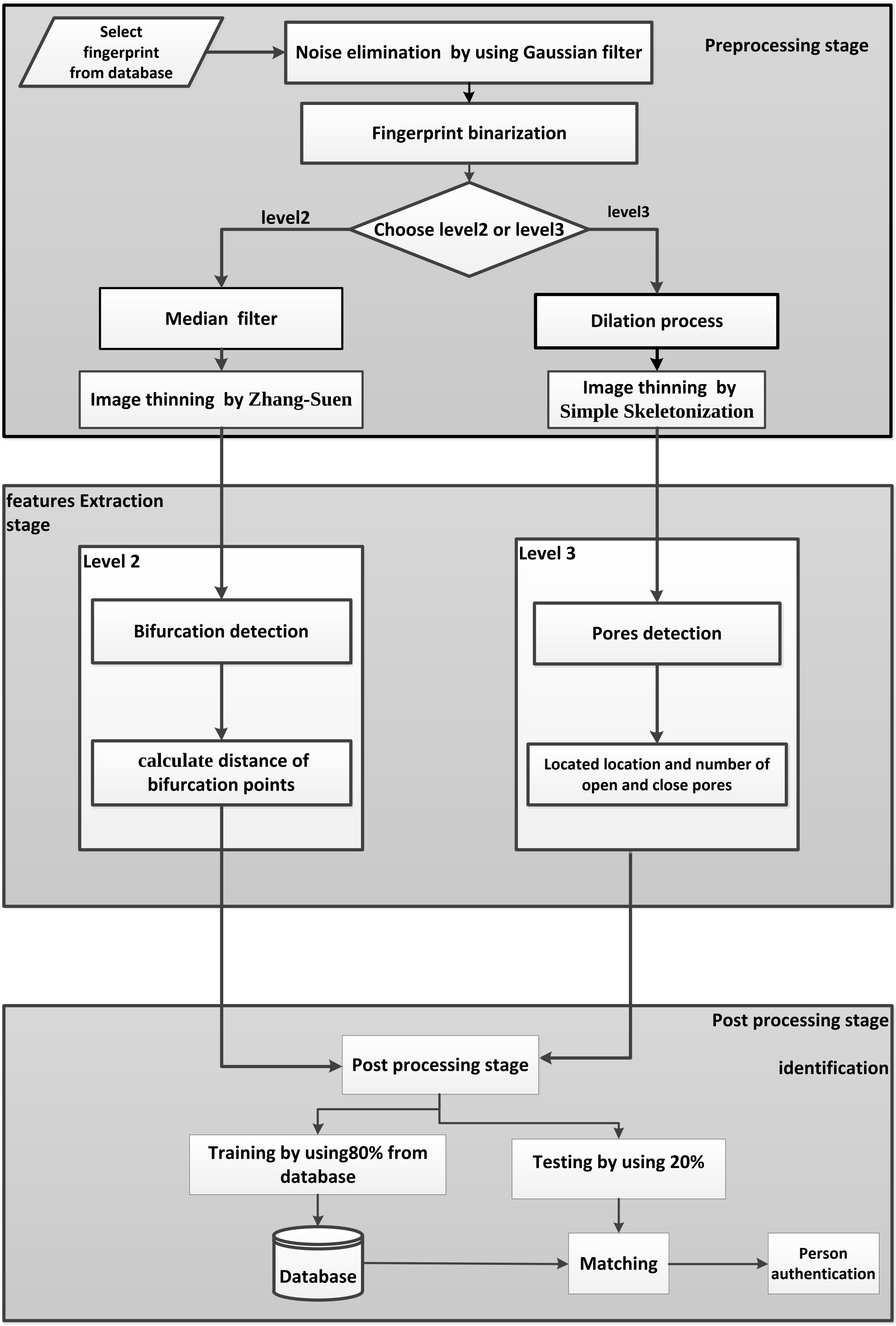


Figure (3.1) The Block Diagram of The Proposed Fingerprint Recognition

The middle stage of the model (i.e., feature extraction) includes two ways:-

a- Extract bifurcation points (level2) and calculate the distance among these bifurcation points.

b- Locate pores' positions (level3) and calculate the number of open and closed pores.

In the post-processing stage, bifurcation points were extracted and the distances between them were calculated. Also the numbers of open and closed pores were collected. These features matched with previous extracted vectors which listed in fingerprints database for recognition and identification purpose.

3.2 Preprocessing

The first phase which has been analyzed using various image preprocessing stages is shown in figure (3.1). Each step of this phase has been described in detail.

3.2.1 Select Fingerprint Image

The fingerprint image is served to the model as a (JPEG) image file. The image data is loaded from the database as a gray image.

3.2.2 Noise Removal

The most common method used to reduce the existing noise in the image is Gaussian filtering method with a mask size of (5x5) With the use of filter (5x5) as a result of the experiences attempted, algorithm (3.1) presents the implemented steps for Gaussian filter.

Algorithm Gaussian filter (3.1)

```
Input: grayscale image / GI,GIG = gray scale / sigma
Output: noise removing
stp1.  k= set size of kernel (5x5)
          read grayscale image
          for I = 0  to  GI.width-1
          for j = 0 to GI.height -1
          GIG(i,j)= GI(i,j)+ sigma
        Next j
   Next i
stp2.  //set standard deviation to 1.0//
              For i= 0 to GIG
              GIG(i) = 0.5 *sigma*sigma
              Sum(i) = sum(GIG(i))

Stp3   // generate 5x5 kernel//
            for x = -2 to 2  x++
            for y = -2 to 2  y++
            r(x,y) = sqrt (x*x + y*y)
            g(x+2)(y+2)= (exp(-(r*r)/s))/(M_PI * s)
            sum = g( [x + 2][y + 2])

Stp4  // normalize the Kernel//
              for i = 0 to  5 ; ++i
              for  j = 0 to  5; ++ j
              g Kernel [i][j] /= sum

Stp5.  End
```

3.2.3 Image Binarization

The conversion from gray-scale to black and white is performed by applying thresholding upon the fingerprint gray image. The selection of threshold value is either done manually by the user, or it is assessed Automatically. In our developed system the proper value of threshold is estimated automatically. Also, the global thresholding method is adopted; it is based on the local characteristics of fingerprint image. The threshold assessment process is started with calculating the average intensity value in a large block surrounding certain area of the image, this value is used as a global threshold value. As shown in algorithm (3.2).

Algorithm Binarization process (3.2)

Inputs: Gray() // array of Gray pixels values
Hgt // the height of the Image
Wid // the width of the Image

Output: *Glo()* // the array to convert from gray image to binary

***Stp*1** : **Initialize minimum (Min) and Max values**
Min ←Gray(0, 0); Max← Gray(0, 0);

***Stp*2** : **Compare each pixel with Min and Max**

all pixels in the image // x as row number, y as column number//
If Gray(x, y) < Min ***Then***
Min← Gray(x, y)
End If
If Gray(x, y) > Max ***Then***
Max← Gray(x, y)
End If
End For // x & y

***Stp*3** : Thr ← (Min + Max) / 2 // Calculate threshold//

Stp*4** : ***For all pixel in the image // x as row number, y as column number //
If Gray(x, y) ≥ Thr ***Then***
Glo(x, y) ← 1
Else
Glo(x, y) ← 0
End If
End For

***Stp*5** : **END**

3.3 Feature Extraction

In this stage, a set of features is extracted. So, an array of values for each feature over the whole image is obtained. Generally, this process includes extracting features from levels two and three.

3.3.1 Select Level2 Features

The distance between bifurcation points is extracted, this process is done using two steps:

3.3.2 Median Filter

The median filter is used in proposed model to reduce and remove the pores which are considered here as noise and unwanted feature. The filter is used to decrease impulse noise without blurring edges. It has neighborhood operation and its noise reducing effect depends on the size and figure of the filter mask, and method to find the median. The noisy value of digital image or sequence is replaced by the median of the filter mask. The pixels in the mask are ranked in the order of the gray value and the median of the mask is stored to replace the noisy value in the mask as shown in algorithm (3.3).

Median filter algorithm (3.3)
Input: binary image Output: smoothing image ***Stp*1** : Generation (3x3) kernel for x = -1 to 1 for y = -1 to 1 end for end for ***Stp*2**:calculate average g(i,j)/3 ***Stp*3** : camper current pixel with average / Im For x = 0 to width For y = 0 to height If Im(i,j)> average or Im(i,j)< average Calculate median of current pixel End for end for

end for

***Stp*4: End**

I. zhang-suen Process

PFR model used a compact representation called skeleton that is played in detail in (2.8.5, Thinning Process) in order to complete faster processing and smaller memory fingerprint. A thinning must preserve the structure of the shape but all redundant pixels should be removed. Algorithm (3.5) shows a thinning process.

Algorithm of thinning (3.5)

Input: binary image

Output: skeletonized image

Stp1. a [8]= kernel 3x3

Stp2. For image height and width do

ar= image data (0 and 1)

p1 = a [0] * a[2] * a[6]

p2 = a [0] * a[4] * a[6]

b = number of 1's in current window (mask)

Stp3. If ar=1 and b>=2 and b<=6 and p1=0 and p2=0

Y =1

Else y =0

Stp4. Set y to new image

***Stp*5. End**

I. Bifurcation Points Extraction

Bifurcations are points at which a single ridge splits into two ridges. A(3x3) mask is used to search the bifurcation points in a fingerprint image as described in algorithm (3.6) . To calculate the distances between one bifurcation point and all other bifurcation points,a Euclidean distance equation is used. The Euclidean distance measures, are used The equation compute the square root sum of the variances between corresponding points, as described in algorithm (3.7).

Algorithm of* bifurcation points *(3.6)

Input : skeletonized image
Output: detect bifurcation points
Step 1 : **Check the state of three bifurcation points in the same structure**
For all c = 0 → bi_counter - 1
Get the position of the three neighbors (x0, y0), (x1, y1), (x2, y2);
co←0; // initialize counter
step2:For each neighbor position
For all T = 0 → bi_counter – 1
Step3:Check ***If*** neighbor position in Bi() ***Then***
co ← co + 1;
End If
End for // T
End for
Step4:Check ***If*** co = 2 ***Then***
i ← Bi(c).h1; j ← Bi(c).v1; // bifurcation point position
//Define and get the following structure elements
p(0) ← lin(i - 1, j); p(1) ← lin(i - 1, j + 1); p(2) = lin(i, j + 1);
p(3) ← lin(i + 1, j + 1); p(4) ← lin(i + 1, j); p(5) = lin(i + 1, j - 1);
p(6) ← lin(i, j - 1); p(7) ← lin(i - 1, j - 1); p(8) = p(0);
p(9) = p(1); p(10) ← p(2); p(11) ← p(3);
p(12) ← p(4); p(13) ← p(5);
step5:For all i = 0 → 6
Check ***If*** p(i) = 1 And p(i + 2) = 1 And (p(i + 5) = 1) ***Then***
Remove the two neighbors from the Bi();
End If
End for // i
End for // c
Step6: End

Algorithm of **Euclidean distance** ***(3.7)***

Input: N: number of bifurcation points

Output: Distance between bifurcation points

Stp*1*. Given vector x1 and y1,each vector is coordinate in n dimension

Dist array of (x,y)

Dist =0

Stp*2*. For d = 1 to n // d= dimension

Dist[d] = Dist[d] + (x1[d]^2 – x2[d]^2)+ (y1[d]^2 – y2[d])^2)

Next

end for

Stp3. Return sqrt (Dist)

Stp*4*. End

III. Matching level2

Iterative Closest Point (ICP) is an algorithm working to minimize the difference between two closets of points. ICP is regularly used to re-form 2D or 3D surfaces from variance scans, to limit automatons and achieve optimal path.

The reference, or aim, is kept fixed, while the other one, the source, is transformed to best competition the reference. The algorithm iteratively rereads the alteration (combination of translation and rotation) needed to minimize the distance from the source to the reference points as shown in algorithm (3.8)**.**

presents the ICP steps Algorithm (3.8)
Input: feature record(distance between bifurcation points) **Output: matched sample from training with test sample** ***Stp1.*** MC= tested feature record Sdf1:Save the differences bifurcation point of the selected fingerprint image and saved records in tb1 For i= 0 to size(sdf1) For j=0 to length(tb1) MC[i,j]**= *sdf1 (i).Tb1(j)*** End for End for ***Stp2***. Do find matching or closest of current point in trained sample Find the closet distance in sdf1[] Current feature (cf) For i=0 to cf If MC[i] close to cf(i) then Closet(i) = MC[i] End if End for ***Stp3.*** For each record in Tb1 do weight=weighting base on compatibility of normal sum _ sq = (weight *weight) summation each set of training weight = n1*n2 ***Stp***4. Calculate MSE For i= 0 to length (closet) MSE= (close(i)) ***Stp5*. End**

3.3.3 Select Level3 Features

Extraction level3 (extraction level3 features) is done by two steps followed by post processing stage. These features discussed as below:

3.3.6 Morphological operation

Dilation and erosion are approach an the preprocessed image.

I. Image Dilation Process

The dilation process is performed by laying the window on the image and sliding it across the image, is used to thicken the edges in order to eliminate weak pores as shown in algorithm (3.9).

dilation process Algorithm (3.9)
Input: *Binarized Image* ***Output:*** *Dilated Image* ***Stp1***. Set a mask (3x3) ***Stp2***. ***For*** all pixels in the image ***For*** all pixels within the mask ***If*** any pixel within the mask = 0 ***then*** Convert each pixel in the image within the window to black ***End If*** ***End For*** ***End For*** ***Stp3 :*** END

II. Image Erosion Process

The erosion process is similar to dilation, but turns pixels to 'white', not 'black as shown in algorithm (3.10).

Erosion process Algorithm (3.10)
Input: *Dilated Image* ***Output:*** *Shrink edges in the Image* ***stp1.*** Set a window (3x3) ***stp2.*** ***For*** all pixels in the image ***For*** all pixels within the mask

If any pixel within the mask= 1 ***then***
Convert each pixel in the image within the window to white
End If
End For
End For

Stp3: END

III. Detecting The Pores

The proposed model detects the pore's location in all ridges within the selected area.

IV. Number of Pores

The pores divided into two types, closed and open. This step calculates number of open and close pores within the selected area suppose that the number of pixels the Surrounding of the pixel is10 points one as shown in algorithm (3.11).

pores detection Algorithm (3.11)
Input: skeleton image **Output: pores detection (closed and opened) number** ***Stp1*** all pixels in the image *(within the selected window)* ***Stp2. R = find ridge and put in array*** For each point in *R* Determine it's (x, y) coordinate P ← number of pixels in the ridge ***Stp3.*** **If P < 10 then** **Specify selected pores as open pore** ***Else*** **Specify it as close pore** ***End If*** ***Stp4.*** END

3.4 Matching level3

The closest algorithm has been used during matching phase to find the best matched of pores points and the feature pores points has depend on the location of these points (x and y) and number of pores as shown in algorithm(3.12) .

Closest point Algorithm (3.12)

Input: pores positions

Output: array of closest points

Stp1: initialization variables

X, y :first point coordinate x-axis and y-axis

Stp2: search closest

for each p : (x1,y1) in array

if first Point < p

first Point = p

Dist[]=sqrt ((x2 – x1)^^{2} + (y2 – y1)^^{2})

else

First Point = first Point

Stp3: return

Dist[] contains all closest for each point with others

Stp4: End

Chapter Four

Implementation Experimental and Results

4.1 Introduction

In this chapter, the results of some conducted tests are presented. A set of tests has been conducted in order to evaluate the performance of the established fingerprint verification system. Also, the results of the stage which was conducted to assess the discrimination capabilities of the extracted fingerprint features are illustrated. The developed system has been established using Microsoft Visual Studio (version 2010) programming language C#, and the tests have been conducted under the environment: Windows-7 operating system, laptop computer (processor: Intel(R) Core i5 CPU 1.60 GHz, and (8.00 GB) RAM.

The system focuses on analyzing pores number with their positions and distance between bifurcation points in a fingerprint image, several methods have been applied during the programming and testing the proposed system.

The fingerprint images are adopted from database names (sample fingerprint) loaded from (biometrics ideal test) web a JPEG 24 bit/pixel (bit depth), the size of each used image is 360×480 pixels with resolution 96 dpi. The number of fingerprint samples is for 100 people, 10 image for each person (i.e. 1000 sample were taken) are of different contrast (dark and light) and moves are belong to a specific person. Eight images are taken as training images and two are taken as testing images.

Two options were adopted in the proposed system; the first one is to find bifurcation points and their distance while the second stage is to find number of pores and their types. The elapse time has been calculated during the stages of the system process to evaluate the proposed system.

4.2 Preprocessing Stage

Fingerprint image enhancement is used to create the image clearer for easy advanced operations. Since the fingerprint images in the used data base attained from scanner or any other media are not assured with perfect quality, therefore enhancement methods are need .For increasing the contrast between ridges, valleys, and pores. This phase consists of three steps as shown.

4.2.1 Noise Removal

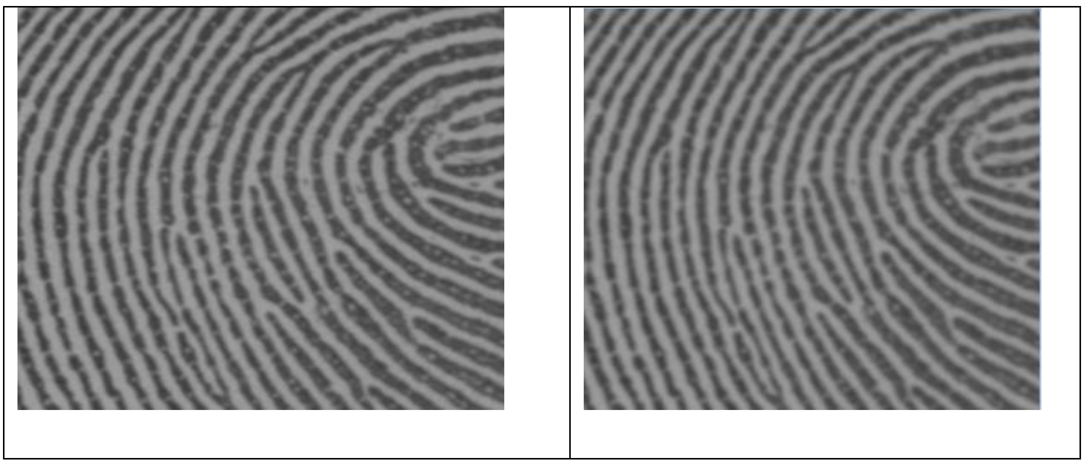
In the preprocessing phase, the Gaussian filter is used to smooth the image and to eliminate the Gaussian noises.

The process of Gaussian filter is done by convolving each point in the input image (browsed image) with a Gaussian mask (5x5) the mask size filter(3x3) and (7x7) gave undesired result . and then summing them all to produce the output image, Besides applied Gaussian filter with different rates of sigma and during, our experimental work it is noted that the best sigma is (0.5) as shown in figure (4.1).

4.2.2 Image Binarization

The fingerprints in the database are all gray images. A global threshold is determined. The threshold value depends on brightness of the image. Then each pixel is smaller than the threshold will be set to zero, otherwise will set to 1 figure (4.2) shows it all

The purpose of binarization is to extract the pixels from image which represent an object.



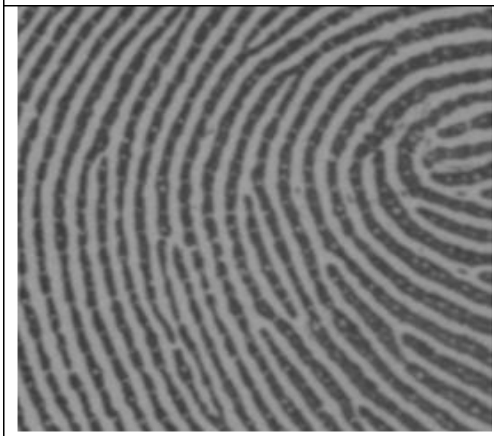
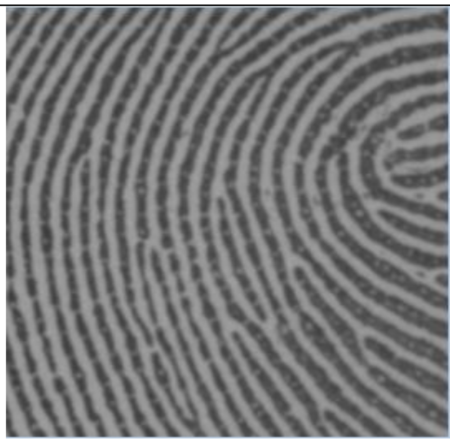
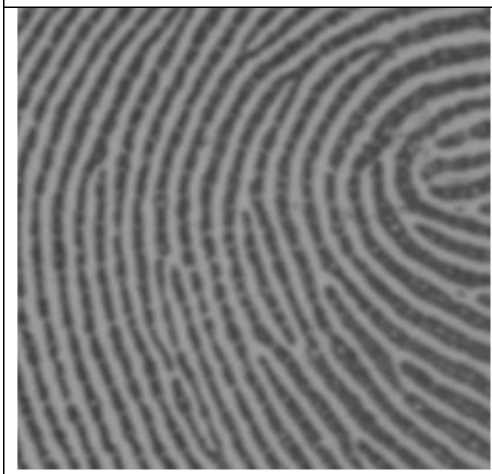
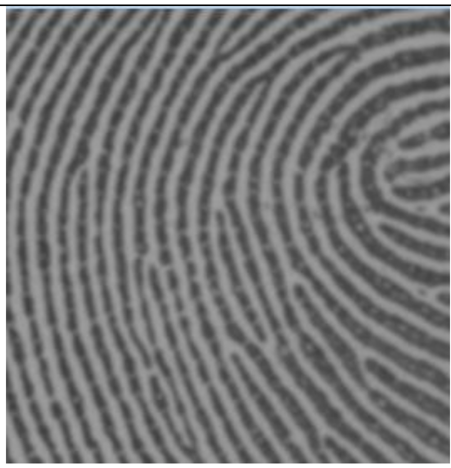
(a)	(b)
	
(c)	(d)
	
(e)	(f)

Figure (4.1) Gaussian filter with different rate of sigma. (a) σ=0.1, (b) σ=0.2, (c) σ=0.3, (d) σ=0.4, (e) σ =0.5, and (f) σ=0.6

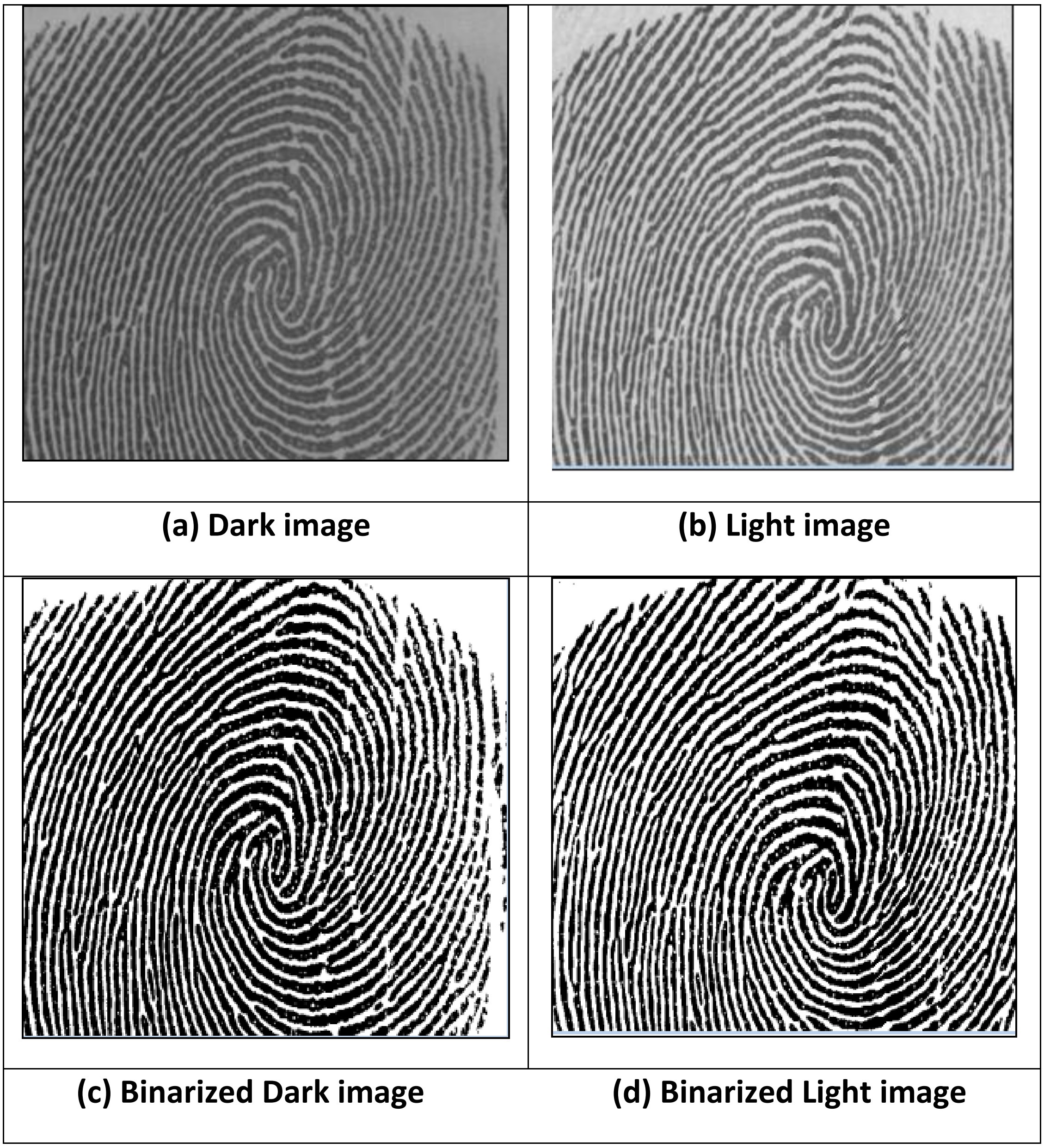


Figure (4.2) Binarization with different contrast

4.2.3 Median Filter

Level2 stage is used to find the bifurcation point, so there is a need to reduce and eliminate the pores in the ridges which are considered here as noise and unwanted features, size of median filter is used for this process was equal to 6 as shown in figure (4.3) and figure (4.4).

Before

After

Figure (4.3) Applying medial filter

4.2.4 Thinning Process (Zhang-Suen)

The filter builds simple objects' skeletons by thinning them until they have one pixel wide "bones" horizontally and vertically. The filter uses "Background" and "Foreground" colors to distinguish between object and background. As shown in figure (4.5).

Figure (4.5) Zhang-Suen process

4.3 Stage of Feature Extraction

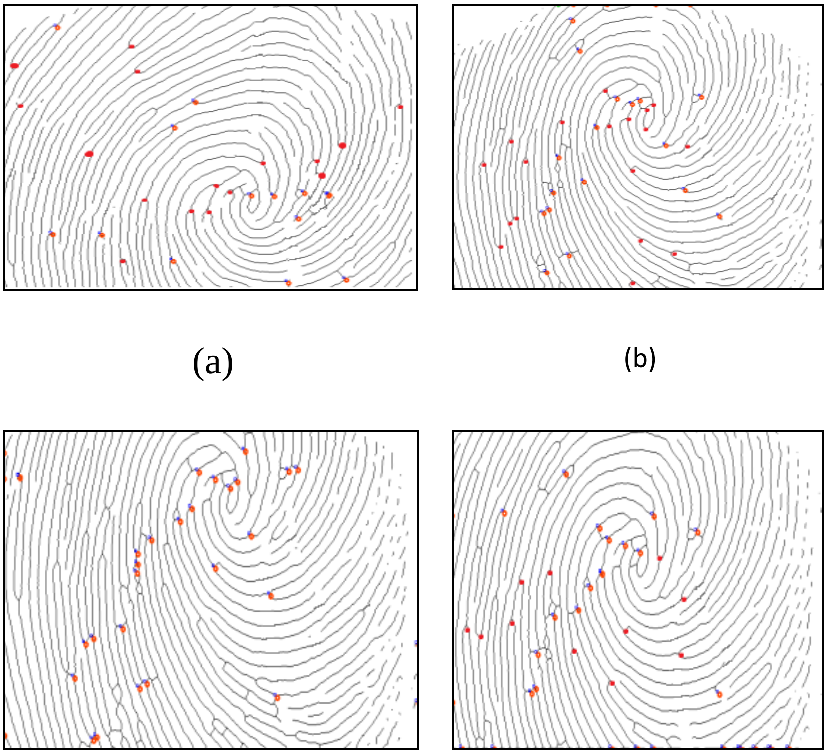
The proposed methods implemented to perform fingerprint feature extraction from two levels (level 2 and level 3) have been discussed follows.

4.3.1 Level2 Features Extraction

To extract level2 features, the implemented method is based on following criteria:

I. Bifurcation Point Extraction

In level2, the bifurcation points were extracted from the whole digital image of size (320 x 240) is shown in figure (4.6), the number of extracted bifurcation points is (29) as in figure(4.5)(a) and the consumed time for this process is (20) seconds. To speed up the PFR system, a centered window of size (160 x 120) is determined as shown figure (4.7, the number of extracted bifurcation points is (20) and the consumed time is (7) second.



(a) (b)

(c) (d)

Figure (4.6) Bifurcation point of whole image

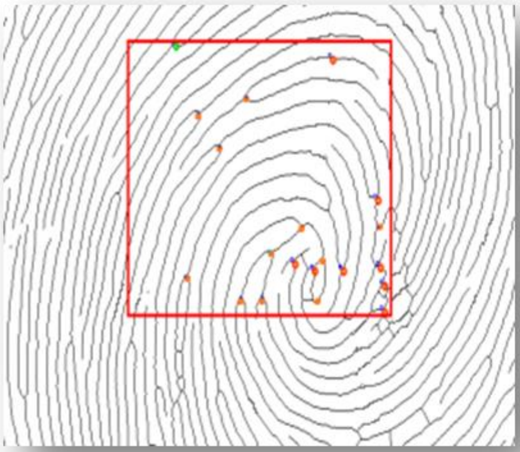


Figure (4.7) Bifurcation point within the selected window

Figure (4.8) shows different detected number of bifurcation points on the same person on different contrast and moves.

II. Calculate Minimum Distance

In this step, the distances between the detected bifurcation points are calculated, the Euclidian distance is used between the extracted bifurcation point to the others is shown in table (4.1).

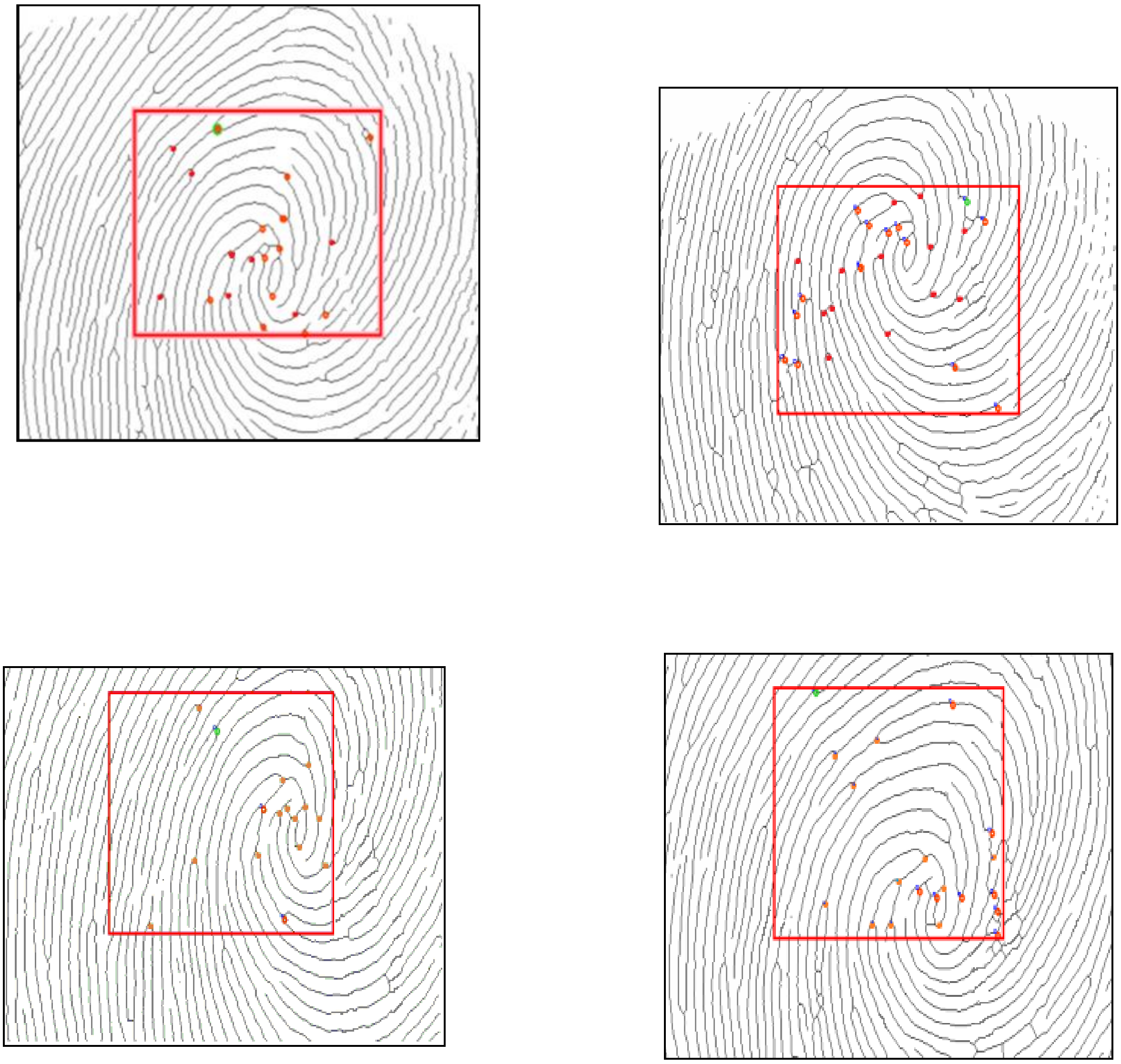


Figure (4.8) Sample of extracted bifurcation points during level 2

Table (4.1) shows Distances between bifurcation point for image (5_2_5)

Table (4.1) the distance between bifurcation points

(x,y)	(186,137)	(160,210)	(184,233)	(186,219)	(216,179)	(238,359)	(244,324)	(252,426)	(281,416)	(271,288)	(278,313)	(284,337)	(286,338)	(316,278)	(321,265)	(338,408)	(339,424)	3(65,380)
(356,380)	308.5	258.7	225.5	227.0	244.4	120.8	124.3	112.4	100.3	124.6	103.6	83.0	82.7	109.6	129.5	32.2	46.8	0.0
(339,424)	335.6	279.0	246.0	250.5	274.1	121.8	137.9	87.0	78.5	152.1	127.6	102.9	103.2	148.0	170.0	18.2	0.0	
(338,408)	318.8	263.4	230.3	234.2	256.8	110.5	123.2	86.1	75.5	134.7	110.7	86.4	86.6	129.7	151.7	0.0		
(321,265)	195.6	167.2	138.8	131.0	129.6	134.3	103.4	183.5	170.9	59.9	73.4	90.0	88.6	23.8	0.0			
(316,278)	205.9	169.3	138.5	133.7	140.0	113.2	84.6	159.9	147.3	45.1	52.4	66.6	65.3	0.0				
(286, 338	253.2	195.3	162.3	167.6	193.5	49.0	54.6	72.9	60.0	73.3	24.7	23.0	0.0					
(284,337)	232.7	177.5	144.3	147.8	172.0	52.8	42.1	93.6	81.3	50.7	25.3	0.0						
(278,313)	208.1	155.1	121.9	124.1	146.8	61.0	33.8	114.5	103.1	25.5	0.0							
(271,288)	184.5	135.7	102.9	102.7	122.1	79.2	45.0	138.3	127.4	0.0								
(281,416)	294.1	228.5	197.6	206.8	240.3	61.3	92.6	13.5	0.0									
(252,426)	300.9	233.9	203.7	213.7	248.6	67.9	101.3	0.0										
(244,324)	203.0	141.6	109.0	115.9	147.7	35.9	0.0											
(238,359)	233.1	167.3	136.3	145.9	181.1	0.0												
(216,179)	66.1	64.0	62.8	45.2	0.0													
(186,219)	87.3	36.1	17.8	0.0														
(184,233)	97.9	33.2	0.0															
(160,210)	73.2	0.0																
(186,137)	0.0																	

4.3.2 Level3 Features Extraction

The PFR technique implemented to perform fingerprint recognition on level3 features is shown in the following processes.

I. Dilation Process

The filter assigns maximum value of surrounding pixels to each pixel of the result image. Surrounding pixels, which should be processed, are specified by (3x3) window, the filter is especially useful for gray image processing as shown in figure (4.9).

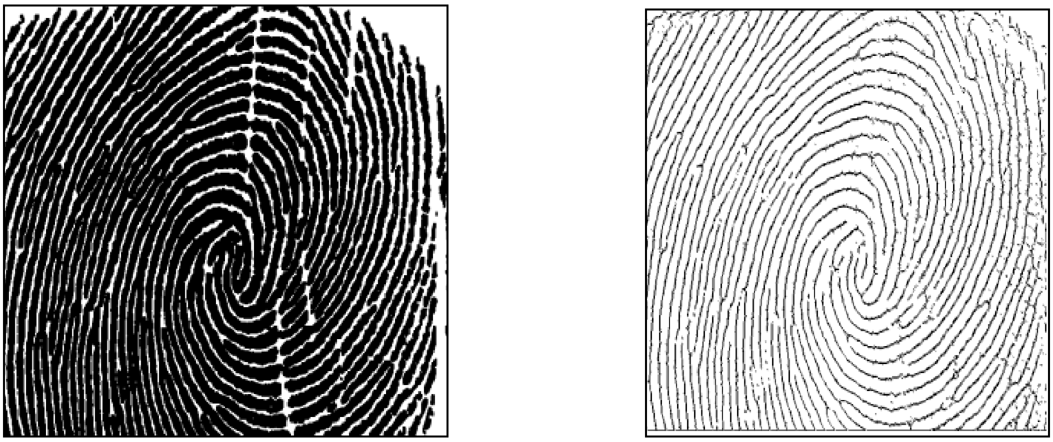
(a)

(b)

Figure (4.9) Dilation process

II. Simple skeleton Process

The filter builds simple objects' skeletons by thinning them until they have one pixel wide "bones" horizontally and vertically. The filter uses "Background" and "Foreground" colors to distinguish between object and background. As shown in figure (4.10) (b).



(a) Before (b) after

Figure (4.10) Simple skeleton process

III. Pores extraction

Level 3 feature's type is based on pores found on ridges of fingerprint image, the number of both types of pores (closed and opened) is calculates. Figure (4.11) shows a sample of result after extracting these pores.

Two types of extracted pores app ears, they are closed and open pores. In this thesis, red color is used to represent closed pores, while blue colored represent open pores.

In order to extract the pores, two different ways are tried to conclude better results the effect of adding erosion:

1- Dilation then thinning (simple skeleton): The number of open pores that is extracted by this method is (77) and the closed pores is (286) which is shown in Figure (4.11. a).

2- Dilation, Erosion then Thinning: The number of open pores that is extracted from this method is (104) and closed pores is (730) which are shown in figure (4.11.b).

Image1

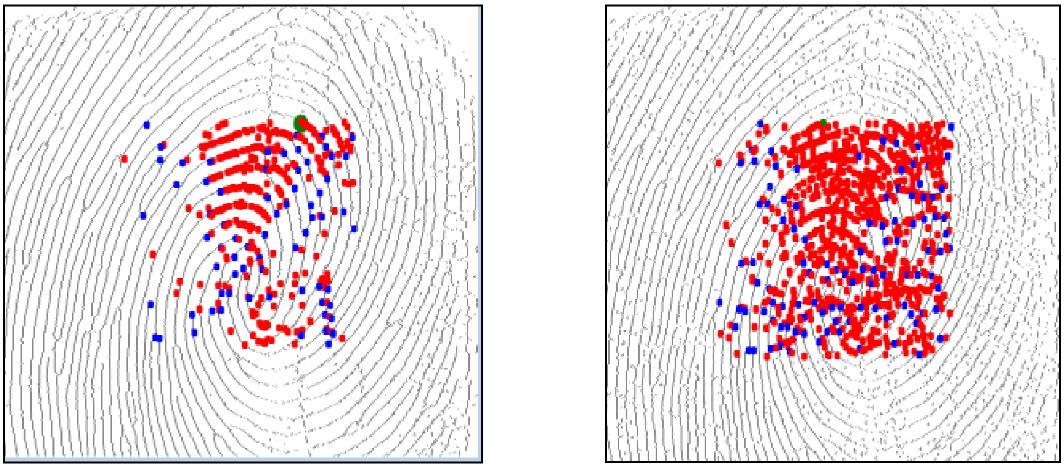
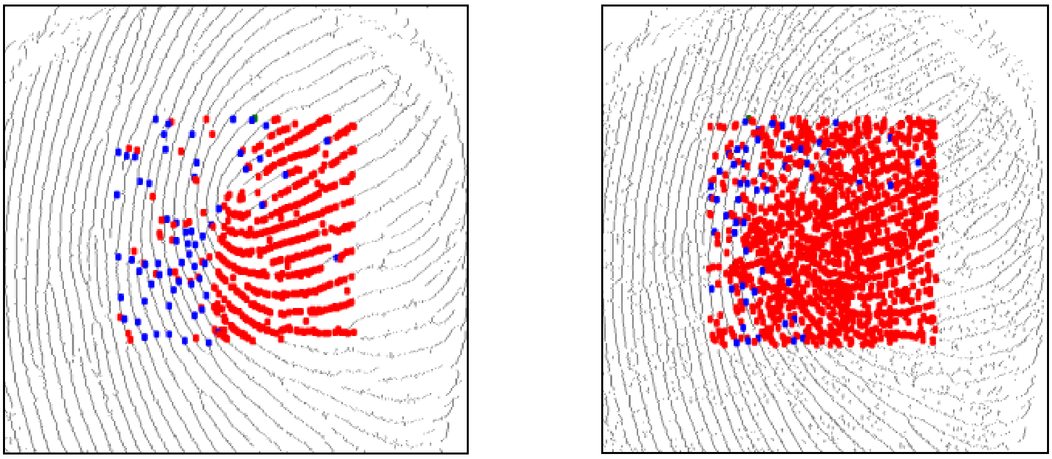


Image2



(a) (b)

After dilation process — After dilation then erosion process

Figure (4.11) The detected pores found in fingerprint image

While the result of extracted pores when applying median filter followed by zhang –Sue algorithm is shown in figure (4.12).

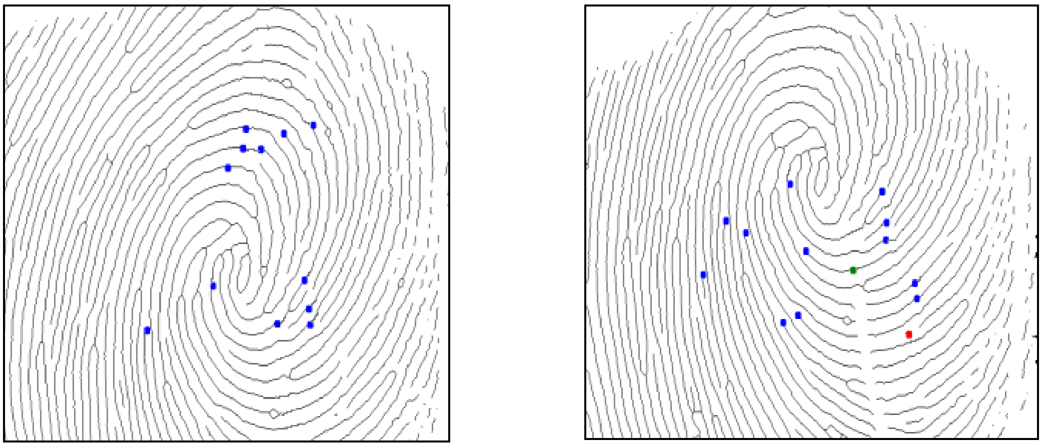
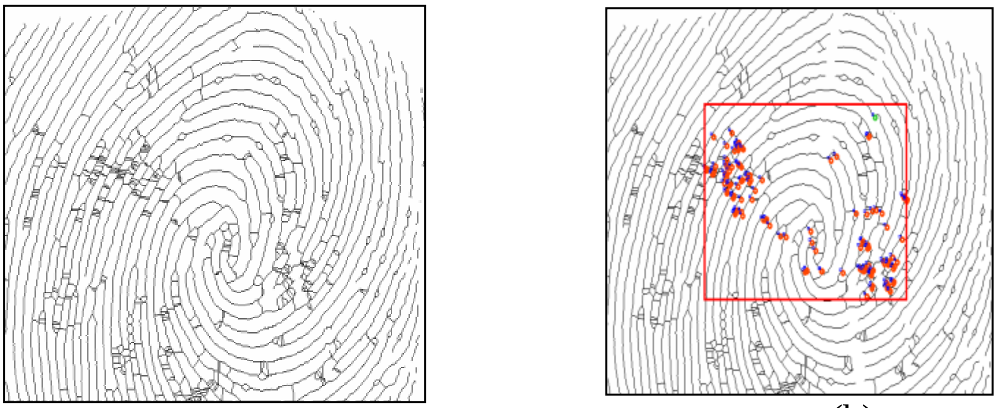


Figure (4.12) pores extraction after applying median filter

Bifurcation points was tried to be extracted after applying dilation process followed by Zhang-Suen algorithm, for example, The number of bifurcation points in figure(4.13) equal to 125.

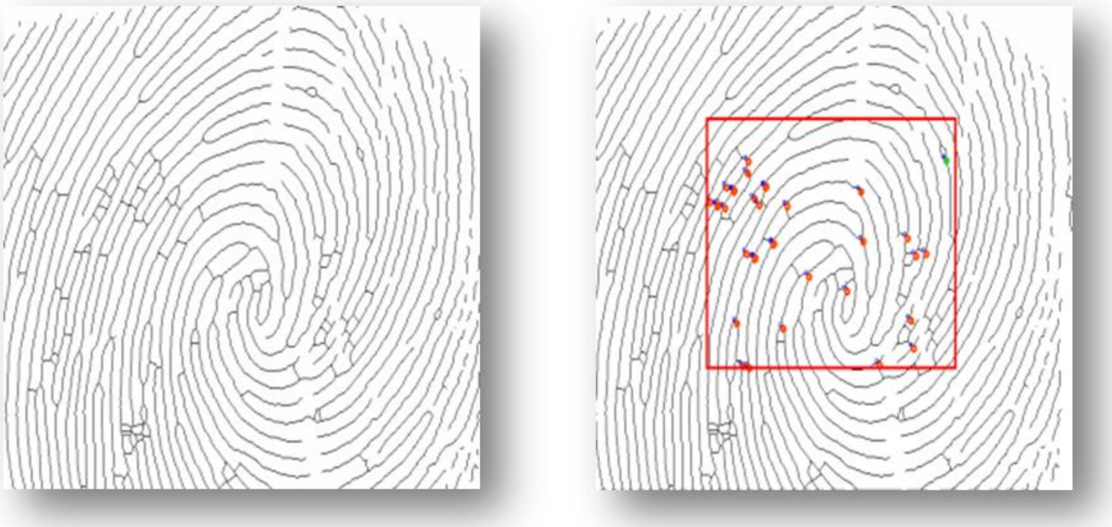
The numbers of extracted bifurcation points after applying dilation, erosin and thinning were (32) points as shown in figure(4.13).



(a) (b)

Figure (4.13) Level 2 (a) after applying dilation and Zhang-Suen

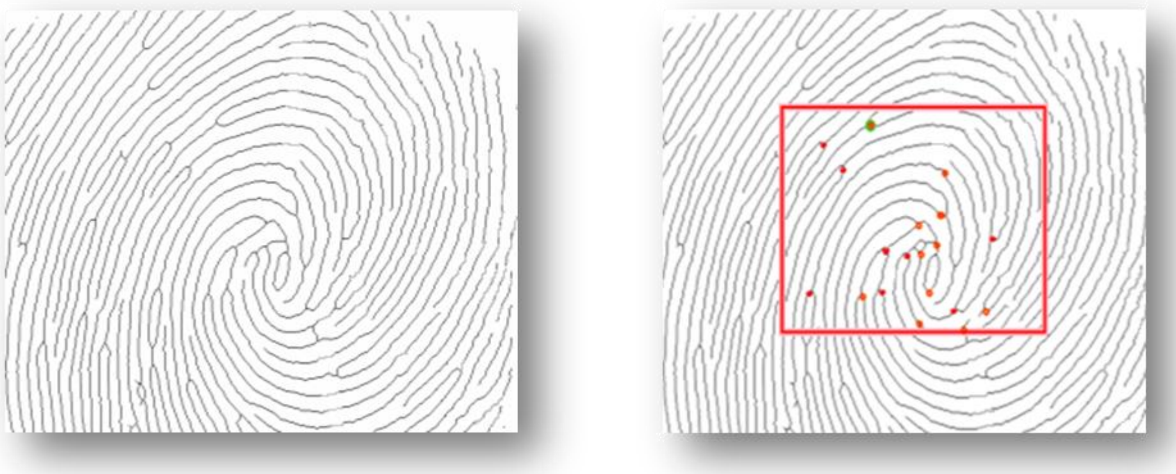
(b) Number of extracted points resulted after processes applied in (a).



(a) (b)

Figure (4.14) Level2 results after applying (a) dilation, erosion and Zhang-Suen thinning algorithm, (b) number of extracted points resulted after processes applied in (a).

The result after applying median filter followed by Zhang-Suen for exmaple, the number of bifurcation points in figure(4.14) is equal to 18.



((b

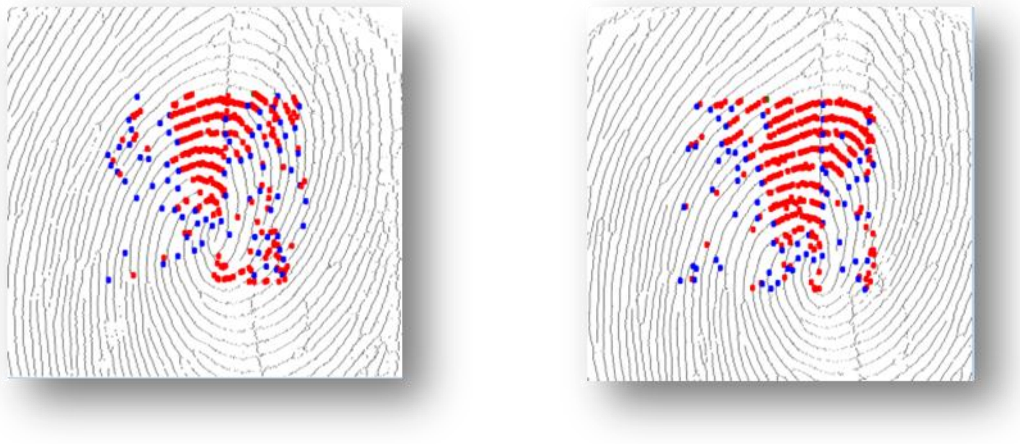
a))

Figure (4.15) Level2 features after (a) applying median filter followed by Zhang-Suen algorithm (b) number of extracted points resulted after processes applied in (a).

When applying the filter on the same person with different contrasts is shown in figure (4.16).

- Number of open pores for dark image (77), and of closed pores (268).

- And number pores for light image are open pores (73), close pores   (347).



(a) dark image (b) Light image

Figure (4.16) Pores extraction

4.4 Post-Processing

There are two procedures in this phase, training and test. Below is each these phases discussed in detail.

4.4.1 Training stage

In this phase, 80% of the samples are selected and processed and then features number of open pores and close pores and distance between bifurcation points are extracted. Images used for training was (5_1_1, 5_1_2, 5_1_3, 5_1_4,5_2_1, 5_2_2, 5_2_3,5_2_4,).

4.4.2 Testing stage

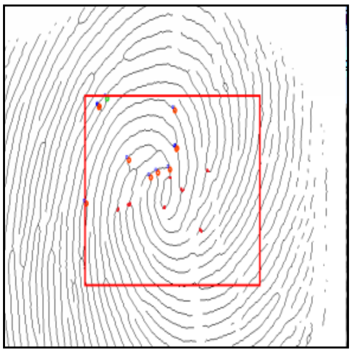
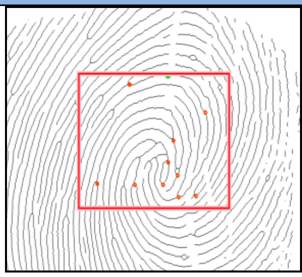
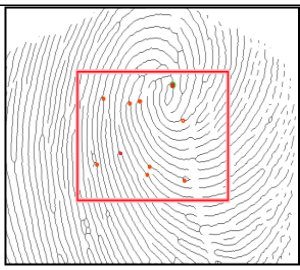
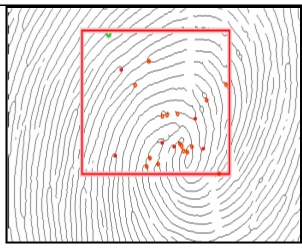
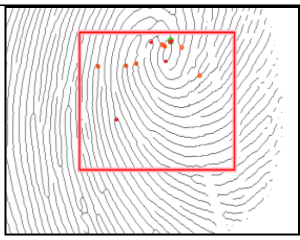
After that, the remaining 20% of the samples are processed to extract their features and matched with the saved features. Image used for this stage (, 5_1_5, 5_2_5).

I. Iteration closet point Algorithm

The ICP algorithm has been used to find the matched features of bifurcation of current sample and each feature of trained samples, the process of the ICP is shown in algorithm (3.3).

The result of tested sample (5-2-5) with trained sampled found in database during extracted bifurcation points and after applying (median filter and Zhang-Suen) for processing step and ICP algorithm for matching step is best matched with sample (5-2-2) which is displayed in table (4.2).

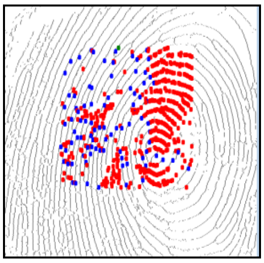
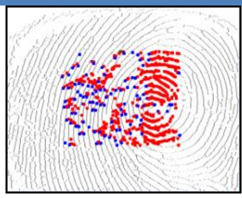
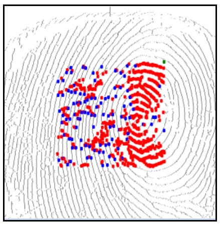
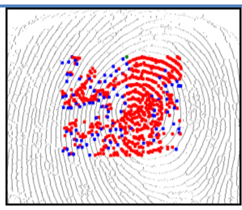
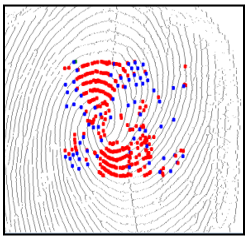
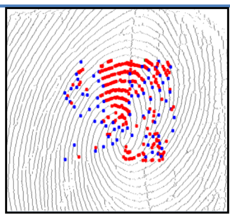
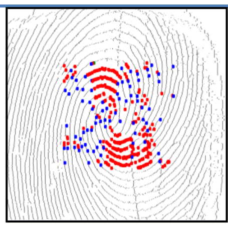
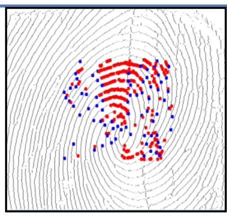
Table (4.2) Result of matching of bifurcation points

Image test	**Id**	**Image**	**Rate of dark**	**mse**
5-1-5  dark	5-1-1		98.48	1.69 E-08
	5-2-5		96.70	1.61 E-07
	5-2-1		99.38	3.87 E-09
	5-2-2		99.63	3.12 E-09

II. Closest Algorithm

The closest algorithm has been used in matching phase to find the best matched pores points depend on type of pores (opens, closes) and the number of pores as described in table (4.3).

Table (4, 3) Result of level3

Id	imaged	Test image		open	close
1	1_1_2	1_1_5 		103	505
2	1_1_3			103	555
3	1_2_4			102	658
7	5_1_3	1_2_5 		80	372
8	5_1_4			80	280
9	5_1_1			77	268

Chapter Five
Conclusions and Suggestions

5.1 Conclusions

In the previous chapters, the establishment of recognition and identification system based on a combination of fingerprint bifurcation and pores extraction was presented, and the effect of system parameters on its performance have been illustrated. Several conclusions have been deduced from the obtained test results. Some of these conclusions are summarized in the following points:

1. The experimental results which use part of an image (160X120) are better than using an image (320x240) as a whole in time, where the time of matching for pores (level 3) in case window 320 x 240 are about double the time required to extract bifurcation points in the whole image. In level 2 matching, the time required for bifurcation point in the whole image is about 3 times than the time required to extract bifurcation points within a specific area.
2. The proposed PFR use dilation process to get the stronger pores instead dilation followed by erosion which gives strong and poor pores.
3. Using median filter in level2 to extract bifurcation points are better than using dilation in the same level, such that when dilation process is applied in level2, the number of bifurcation points are 125 and the recognition rate is (86.7%), While the number of bifurcation points are 18 when using median filter and the recognition rate is 99.4%.
4. In level 3 using dilation only followed by thinning gives (100 %) recognition rate for the biometrics ideal test database often the match through closed and open pores.

5.2 Future Work Suggestions:

This work can be extended in different directions. Below are some suggested ideas:

1. Using another matching method instead of ICP algorithm such as neural network algorithm which may increase the discriminating power of the system.
2. Intelligent techniques may apply during matching phase such as fuzzy logic.
3. An electronic device could plug to monitor system for real-time recognition or identification.
4. Testing different types of database especially for damaged fingerprint such as wet fingerprint or engaged.

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