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A NONINVASIVE METHOD OF EVALUATING INVARIANT BASAL CELL LAYER FINGER PRINT FEATURE IDENTIFICATION USING MINUTIAE MATCHING TECHNIQUE

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Abstract
Human physiological and behavioral characteristics are considered to be more reliable biometric parameters which are utmost protected and authenticated tool for recognizing human identity. Currently, biometric recognition system uses fingerprints as standard parameter and most extensively it act as backbone for human identification. The proposed identification method practices certain details marked on the fingers called minutiae which are the end and crossing points of the ridges rather than using all selective features available in fingerprints. In this work we tried to explore the methods that improve identification accuracy with minutiae matching algorithm using both its local and global structures. Before being evaluated the fingerprint image has been preprocessed using image enhancement as well as histogram equalization method for improving the image quality. In order to have post processing of fingerprint image we have used Fast Fourier Transformation (FFT), binarization, image segmentation, thinning and removal of false minutiae. For fingerprint verification and identification an extensive model and system has been developed using minutiae extraction and matching techniques. An orientation and alignment based minutiae matching algorithm has been used which is proficient in finding correspondence correlation between the input and stored minutiae templates. The proposed model generates the simple, reliable and unique system to identify the person as it uses morphological operations, triple branch counting, decomposing of branch and X-Y coordinate system in matlab which can easily be used to recognize the fingerprint of a person.
Keywords: Dactyloscopy, basal cells, Biometric, Fingerprints, Minutiae

Introduction

Fingerprints comprise of inimitable impression of the friction ridges, arches, furrows, loops, valleys, whorls and various minutiae points which are the end and crossing points of ridges on all part of a finger. Since these patterns are formed in basal cell layer which is the innermost layer of the epidermis and it maintain the uniqueness of fingerprint features as any damage to the surface layer will not alter the fingerprints. Biometric systems possess an ability to deliver an truthful and exact validation in comparison with the conventional recognition methods that include PINs, passwords, and ID cards which resulted in great implementation of these systems in private and public work spaces for authentication and attendance purposes. Compared to the currently available biometric features fingerprint based recognition system has been considered to be most established practice which has largest share in criminal investigation and civilian applications. In spite of the advancements in fingerprint identification techniques matching of fingerprints has developed as a key challenge which need to be addressed. Although latest compact silicon chip-based sensors has attained a significant attention as it capture only a portion of the fingerprint and has made it an important problem from a commercial perception. The processing of partial and latent fingerprints obtained at crime scenes also requires a considerable interest as finger prints obtained here are hidden prints, which are taken as proof for the forensic science to probe the criminals for past few decades. These hidden fingerprint images are matched with the available database templates using automated finger print identification system to curtail the manual work. The recognition and verification of these hidden fingerprints waste lot of time and is not an easy task as quality of image may get deteriorated [1]. The lot of work has been done on fingerprint recognition technology but still there exist a scope of further improvement in terms of accuracy, good quality acquisition and fast response time. The major feature of fingerprint image is minutiae which determine the uniqueness of fingerprint image. An excellence quality fingerprint image can have 25 to 80 minutiae based on adequate resolution of fingerprint scanner and location of finger on the sensor. In minutia fingerprint matching system the recognition and verification of minutia require small size, high processing speed, cost effectiveness, stability, accuracy, fast recognition rate, uniqueness and extraordinary grade of security for minutiae matching due to their generous discriminating and reliable features[2-4].The fundamental features of minutia based finger print identification system are coordinates, minutia type and the tangential (orientation) angle.

The enquiry and reference finger points are the key points on which minutiae matching depend and it generate the higher yield similarity scores which are required for more minutiae matching. Genuine and fraud finger prints are certainly identified by using the large number of matched minutiae. The guidelines of forensic science enumerate that minimum of 12 minutiae matching are compulsory required to consider that these minutiae belong to the same finger of one person[5]. The minutiae matching single-handedly doesn't help in the exact identification and verification of a person but coinciding zones of the finger prints and the distance between the minutiae are also considered to be significant in the verification and identification process of a person[6]. Fingerprint recognition system is being used extensively in our day to day life for individual authentication. The fingerprints like ridges and furrows face major challenge of differentiation due to the bad fingerprint image quality. The image gets degraded as a result of injury, skin variations, dirt, humidity, Impression conditions and non-uniform contact with scanning device. These problems are addressed by identifying, verifying and matching some abnormal points and discontinuities known as minutiae that are found on finger surface like ridge ending, bifurcation, dots, islands, ponds and lakes, spurs, bridges and crossovers. The Federal Bureau of Investigation (FBI) uses local features of minutiae as ridge ending (termination) and ridge splitting (bifurcation) as the two eminent kinds of minutiae. [7].

The skin of finger exhibit properties more like a rubber and it decreases skin contact area with object one holds and hence reduces the friction and our ability to grasp objects. The exceptional and irreversible finger print templates are stored as data base which result in loss of information about ones identify based on bad quality of finger print. Therefore these biometric physiological features plays significant role in developing a finger print recognition system[8]. The biological crypto system and cancelable biometrics are the two main categories of the biometric pattern/template security[9]. Many historians have reported that earlier in ancient China thumbprints were being used as unique identification futures on clay seals. In 1858 for the first time recorded fingerprints were used for identification. Fingerprints present highly distinctive patterns which act as excellent base for recognition purposes such as stable, exclusivity, robust, size and individuality[10]. Regardless of many features that can be extracted from fingerprints for the verification and identification, minutiae are considered to be broadly used for identity recognition purpose. Identification and verification of a person is a cumbersome, expensive and time consuming process which comprises of computation work and search hence restricted size of template database is current requirement. So, Algorithms are continuously being developed generally based on their computational speed using set of local discontinuities extracted from the fingerprint minutiae[11]. A person's recognition is a vital issue which can be addressed using two different approaches. First is the verification which targets to evaluate similarity between two images correspond to the same fingerprint. Second approach is identification in which matching of a given input fingerprint is done with the available stored template fingerprint database[12, 13] . The matching of fingerprint encounter image quality related problems like image falsifications, pattern information loss, and the high dimensionality of the representation space. Hence, identification and verification of fingerprint experiences a great complexity[14,15]. Furthermore, identification process is basically found to be more complex than verification, as it involves manifold comparisons among identities. Numerous methods associated with different techniques such as classification [11] and indexing[16] have been proposed to overcome these difficulties of identification and verification of fingerprints. In many fingerprint computational intensive problems High Performance Computing (HPC) is widely used to speed up the response time by splitting the calculations among a set of computers and processors[17]. It allows a parallel search through the template database that reduces the identification time [18-21]. HPC systems can be used to pro- vide data redundancy and high availability[22, 23] . To accelerate this computational time and for better matching accuracy an angle orientation and alignment based algorithm is proposed which includes MATLAB based enhancement and segmentation of image, extraction and verification of minutiae points as main themes of fingerprint matching. The penetration of Biometric/ Convergence of market forces in biometric authentication system is rapidly gaining momentum in lieu of code and password based systems as these traits are always under user's possession. Biometric authentication system is a high future potential wave that has boom the market such as health care, retail and commerce, banking and financial institution and the consumer electronics. Global market uses various physiological and biological human traits such as fingerprint scan, facial scan, middleware, hand scan, iris scan, voice scan, signature scan and keystroke scan for identification and verification process.

2. Background

Fingerprint recognition is associated with statistically unique friction ridge patterns which are considered as external characteristic in human recognition process. Fingerprint recognition system mainly encounters with two major problems such as fingerprint verification and fingerprint identification. Figure1 describes the block diagram representing the fingerprint recognition system. Firstly it includes enrollment process also called registration process which generates and stores templates in the database with the help of keyboard to enter the name or some other ID like PIN in the system. The reader captures the fingerprint of a person and the feature extractor process accordingly to gather the pattern of interest like minutiae from the captured image and convert it into an expressive compact size image. Secondly the feature extractor fed its output to the matcher where 1:1 matching is done for verification to authenticate person's identity and a quick response is obtained. In verification system 1:1(one to one) comparison is conducted to seek the confirmation about the specificity of a person. Here the system checks and evaluate the person biometric trait with the one that is already stored in database and result in faster and accurate. Verification is basically a valid claim of person's identity. Thirdly the identification process uses one to many (1: N) match method as it seeks to identify the unknown person. It is a time consuming process as each stored template in database is compared with new fingerprint to seek the identity of a person. The earlier used manual approaches for fingerprint recognition was time consuming and was not error free. So Automatic Fingerprint Recognition which is programmed base system that addresses the problems faced during verification and identification process and it have made fingerprint identification a highly automated technique in the current scenario.

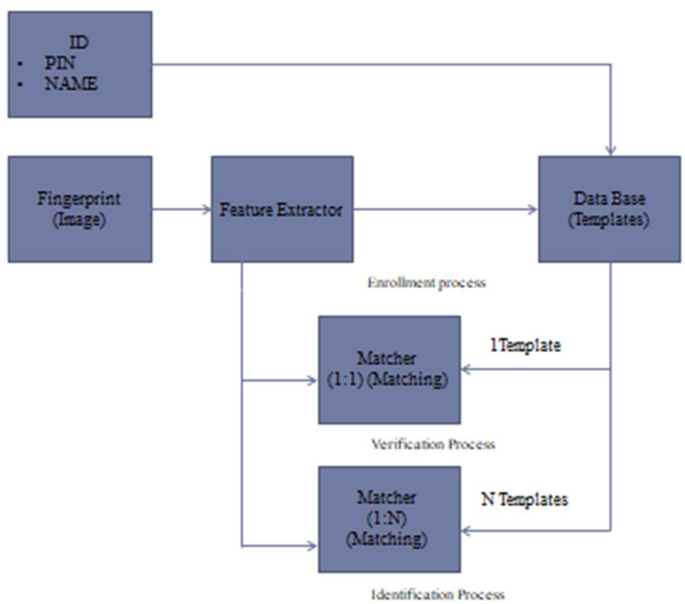


Figure1 Basic Block diagram representation of fingerprint pattern recognition system

Here in this paper we have initially discussed the approach and implementation techniques for fingerprint image enhancement and minutiae extraction and matching. Experiments using an available database of real fingerprint images are then conducted to evaluate the performance of the implemented techniques. In combination with these techniques, preliminary results on the statistics of fingerprint images are then presented and discussed. The key contributions of this work are:

a) A methodology to extract rare basal cell features and extract information from minutiae
b) A specific algorithm to align the latent minutiae pattern and the ten print minutiae pattern using rare minutiae.
c) Experimental demonstration of the performance improvement of minutiae-based matchers when incorporating information from rare features.

d) Proposed algorithm to modify and improve the efficiency in identification and verification process to get fast and accurate results.

There are two approaches followed by fingerprint recognition system. The first is the minutia-based approach which uses local features of fingerprint like terminations and bifurcations. Minutia based approach has been intensively studied which act as the key feature and backbone of the currently available fingerprint recognition applications.

The second approach is an advanced and newly emerging method which uses the global features of an acquired fingerprint image. This approach is useful in solving some intractable problems faced by the first approach like person's recognition and verification. We are aiming at first approach which is minutia based.

2.3.1 Design description and Implementation

A fingerprint recognition system comprises of basic building blocks such as which a sensor which act like source for acquiring fingerprints, minutia extractor and minutia matcher as shown in figure 2. As we are focusing on termination and bifurcation we are using the minutia based matching process.

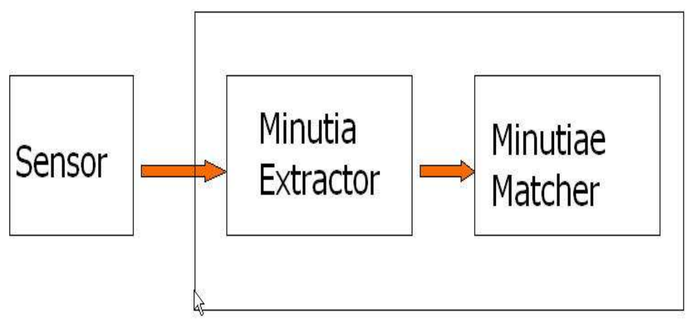


Figure 2. Simplified Fingerprint Recognition System

The Sensor is an optical or semi-conductor acquisition device which acquires fingerprint images with efficiency and great accuracy provided finger should not be dry or dirty. Fingerprint verification competition 2002 was used to avail database.

2.3.2 Structure Level Design

A three-stage approach consisting of preprocessing, minutia extraction and post processing is extensively adopted by many researchers for extracting the minutia parts from fingerprint template as shown in figure 3.

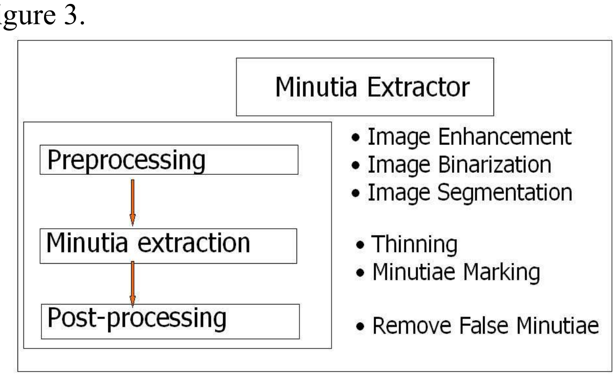


Figure 3 Minutia Extractor

The preprocessing stage includes image enhancement, image binarization as well as image segmentation. Histogram Equalization and Fourier Transform are adopted for image enhancement. The locally adaptive threshold technique is used for Image binarization. Block direction estimation, segmentation by direction intensity and Region of interest (ROI) extraction by morphological operations is the three step methodology adopted to complete the image segmentation

For minutia extraction stage, three thinning algorithms are tested and the Morphological thinning operation is finally bid out with high efficiency and pretty good thinning quality. The minutia marking is a simple task as most literature reported but one special case is found during my implementation and an additional check mechanism is enforced to avoid such kind of oversight.

As fingerprint templates are associated with presence of false minutia so a more rigorous algorithm is developed to get rid of these false minutias in post processing stage. A novel representation for bifurcations is proposed to unify terminations and bifurcations. The minutia matcher selects any two minutiae as a reference minutia pair and then matches their related ridges first during the post processing stage. If the ridges match well, two fingerprint images are aligned and matching is conducted for all remaining minutia as shown in Figure 4

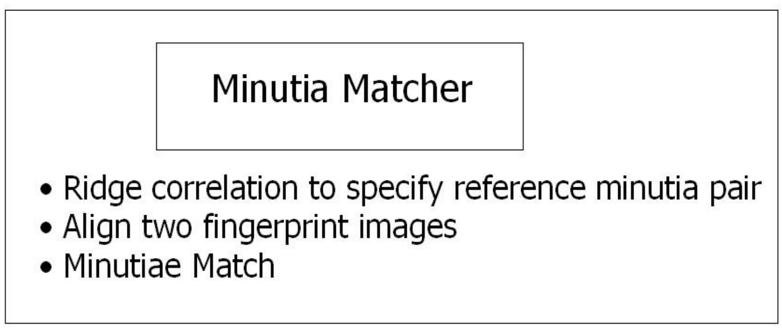


Figure 4 Minutia Matcher

For the post processing stage, the minutia matcher chooses any two minutiae as a reference minutia pair and then matches their associated ridges first. If the ridges match well, two fingerprint images are aligned and matching is conducted for all remaining minutia as shown in Figure 4

2.4 IMAGE PREPROCESSING

2.4.1 Fingerprint Image Enhancement

Fingerprint Image enhancement technique make the image more pure. Fingerprint always encounter with image quality related problems like image falsifications, pattern information loss, and the high dimensionality of the representation space so enhancement approaches such as histogram equalization and fourier transform are adopted to address these issues. As a result contrast between ridges and furrows is increased to make a connection between false broken points of ridges and furrows which make fingerprint highly detailed and accurate one.

2.4.2 Histogram Equalization:

In Histogram equalization approach contrast between ridges and furrows is improved by expanding the image pixel value distribution and adjusting the intensity distribution on a histogram. This results in increased perceptional information. In this approach of image processing quality of image is adjusted by allowing low contrast area to occupy higher contrast and with identical distribution of regular intensity values of the template. Figure 5 (a) the image of original histogram and histogram after equalization which indicates enhanced visual effect where histogram occupies the range between 0 to 255.

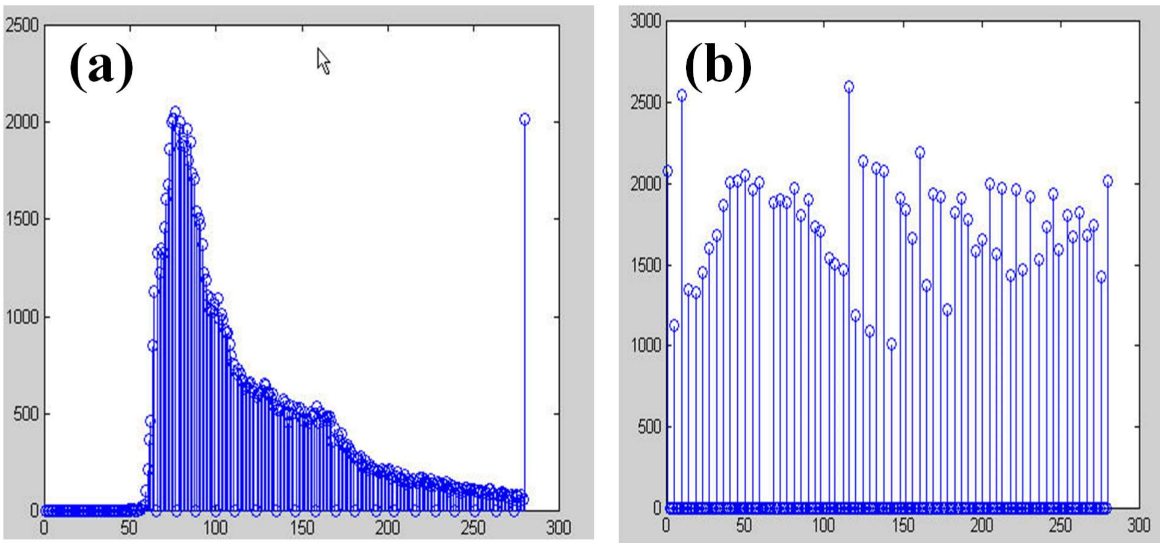


Figure 5(a) represents the original histogram of a finger print image and (b) histogram after the histogram equation

The right side of the following figure 6 is the output after the histogram equalization.

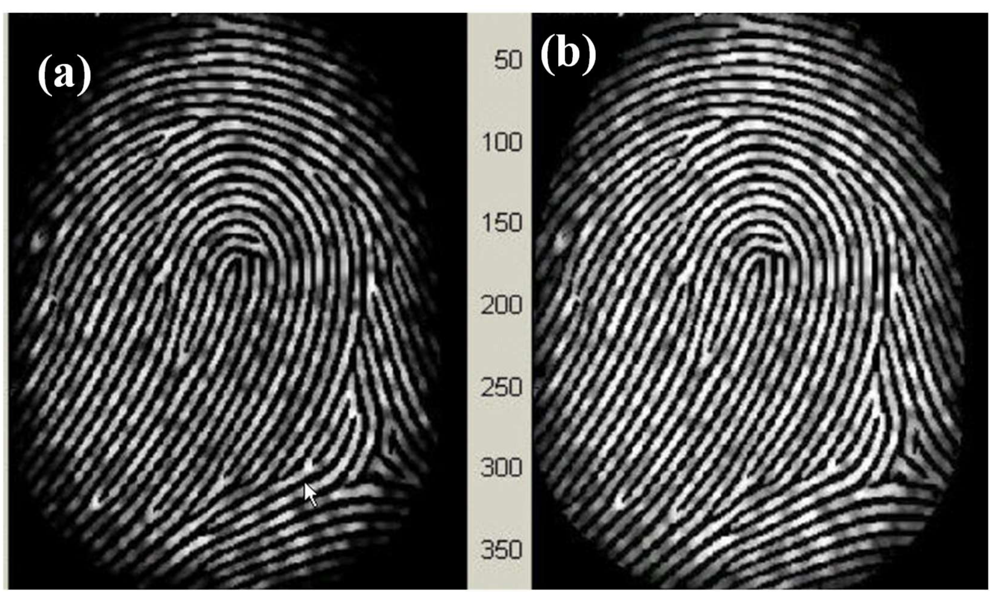


Figure 6 Histogram Enhancement of (a) original and (b) enhanced image

2.4.3 Fingerprint Enhancement by Fourier Transform

We divide the image pixel into small processing blocks of size 32 by 32 to implement the Fourier transform on the image based on following equation:

$$F(u,v) = \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y) \times \exp\left\{-j2\pi \times \left(\frac{ux}{M} + \frac{vy}{N}\right)\right\} \tag{1}$$

For u = 0, 1, 2, ..., 31 and v = 0, 1, 2, ..., 31.

In order to enhance a specific block by its dominant frequencies, we multiply the FFT of the block by its magnitude a set of times. Where the magnitude of the original FFT = abs(F(u,v)) = |F(u,v)|.

Get the enhanced block according to

$$g(x,y) = F^{-1}\left\{F(u,v) \times \left|F(u,v)\right|^{K}\right\} \tag{2}$$

where $F^{-1}(F(u,v))$ is done by:

$$f(x,y) = \frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} F(u,v) \times \exp\left\{j2\pi \times \left(\frac{ux}{M} + \frac{vy}{N}\right)\right\} \tag{3}$$

for x = 0, 1, 2, ..., 31 and y = 0, 1, 2, ..., 31.

The k in formula (2) is an experimentally determined constant, which we choose k=0.45 to calculate. While having a higher "k" improves the appearance of the ridges, filling up small holes in ridges, having too high a "k" can result in false joining of ridges. Thus a termination might become a bifurcation. Figure 7 presents the image after FFT enhancement.

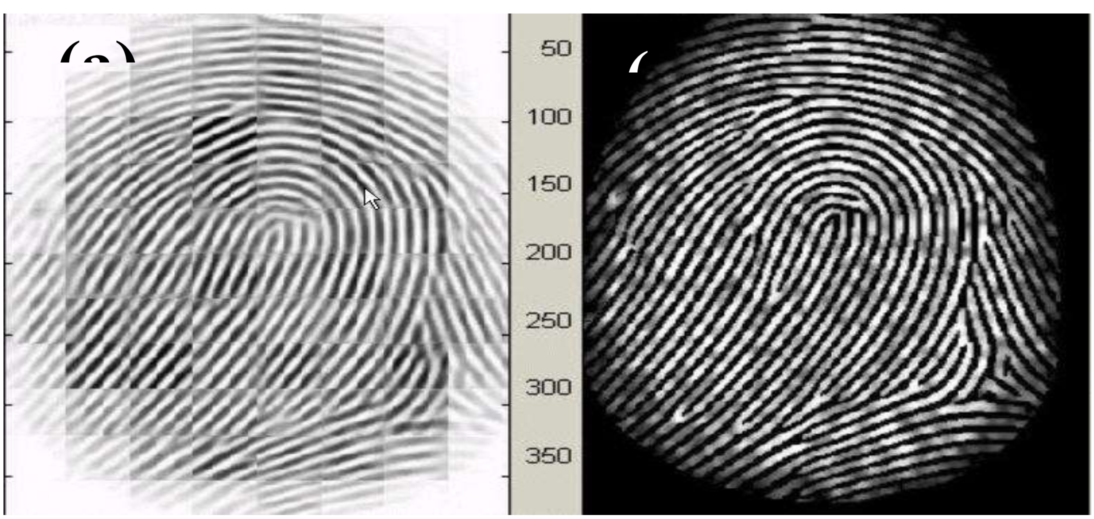


Figure 7 Fingerprint Enhancement by (a) enhanced image and (b) original image

The enhanced image after FFT has the improvements to connect some falsely broken points on ridges and to remove some spurious connections between ridges. The shown image at the left side of figure 3.1.2.1 is also processed with histogram equalization after the FFT transform. The side effect of each block is obvious but it has no harm to the further operations because we found the image after consecutive binarization operation is pretty good as long as the side effect is not too severe.

2.4.4Fingerprint 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 operation, ridges in the fingerprint are highlighted with black color while furrows are white.
A locally adaptive binarization method is performed to binarize the fingerprint image. Such a named method comes from the 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 a shown in Figure 8

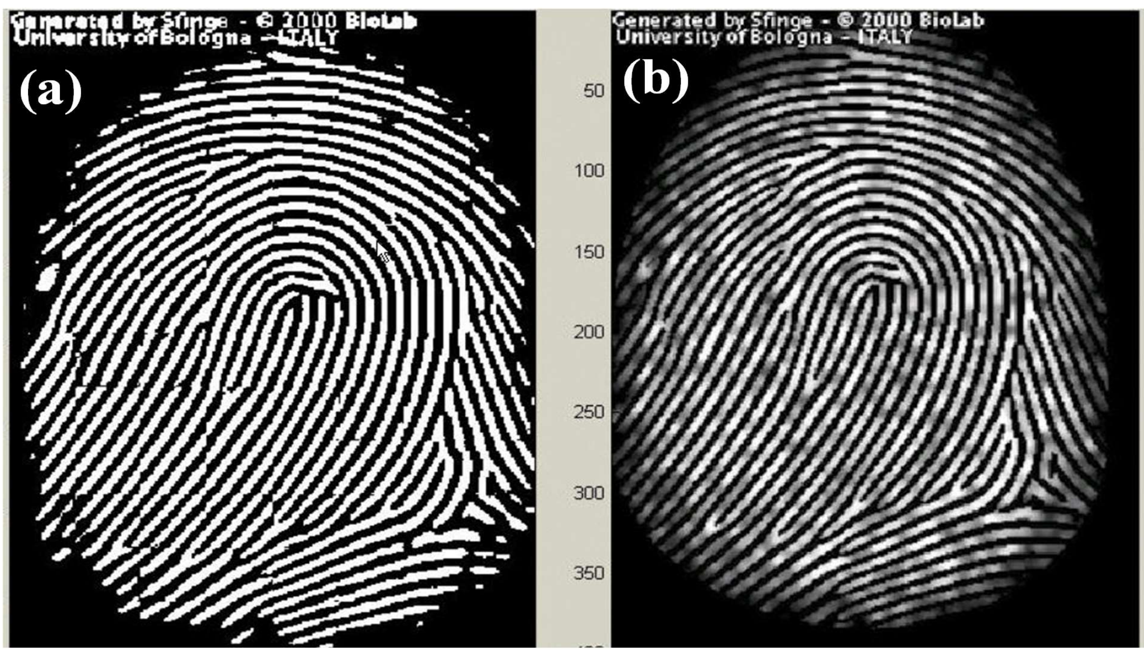


Figure 8 Fingerprint Enhancement by (a) enhanced image and (b) original image

Figure 3.2.1 the Fingerprint image after adaptive binarization Binarized image (left), Enhanced gray image (right)

3.3 Fingerprint Image Segmentation

In general, only a Region of Interest (ROI) is useful to be recognized for each fingerprint image. The image area without effective ridges and furrows is first discarded since it only holds

background information. Then the bound of the remaining effective area is sketched out since the minutiae in the bound region are confusing with those spurious minutiae that are generated when the ridges are out of the sensor.
To extract the ROI, a two-step method is used. The first step is block direction estimation and direction variety check, while the second is intrigued from some Morphological methods.

1. Block direction estimation

1.1) Estimate the block direction for each block of the fingerprint image with WxW in size (W is 16 pixels by default). The algorithm is:

- Calculate the gradient values along x-direction (g_x) and y-direction (g_y) for each pixel of the block. Two Sobel filters are used to fulfill the task.
- For each block, use following formula to get the Least Square approximation of the block direction.

  $tg2ß = 2 \sum \sum (g_x*g_y)/\sum \sum (g_x^2-g_y^2)$ for all the pixels in each block.

  The formula is easy to understand by regarding gradient values along x-direction and y-direction as cosine value and sine value. So the tangent value of the block direction is estimated nearly the same as the way illustrated by the following formula.

  $tg2\theta = 2\sin\theta \cos\theta / (\cos^2\theta - \sin^2\theta)$

1.2) After finished with the estimation of each block direction, those blocks without significant information on ridges and furrows are discarded based on the following formulas:

$$E = \{2 \sum \sum (g_x*g_y) + \sum \sum (g_x^2-g_y^2)\}/ W*W*\sum \sum (g_x^2+g_y^2)$$

For each block, if its certainty level E is below a threshold, then the block is regarded as a background block.
The direction map is shown in the following diagram. We assume there is only one fingerprint in each image.

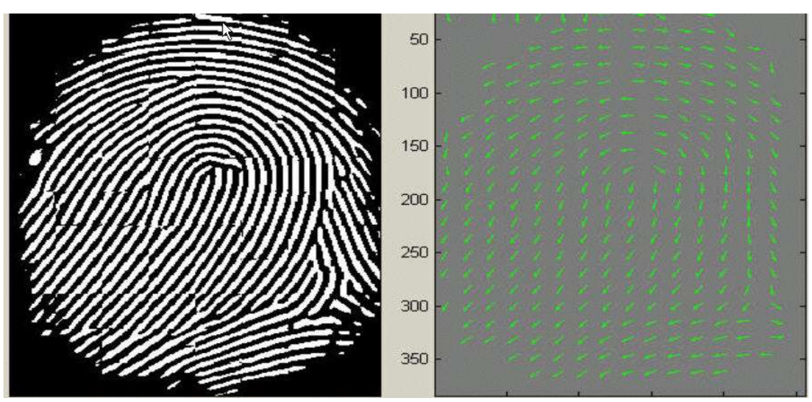
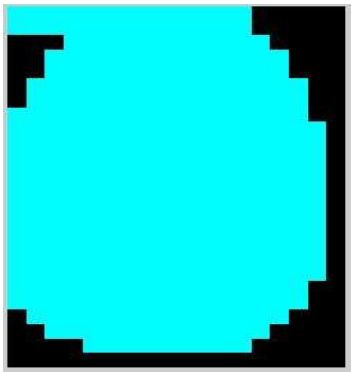


Figure 3.3.1.1 Direction map. Binarized fingerprint (left), Direction map (right)

2. ROI extraction by Morphological operations

Two Morphological operations called 'OPEN' and 'CLOSE' are adopted. The 'OPEN' operation can expand images and remove peaks introduced by background noise [Figure 3.3.2.2]. The 'CLOSE' operation can shrink images and eliminate small cavities [Figure 3.3.2.3].



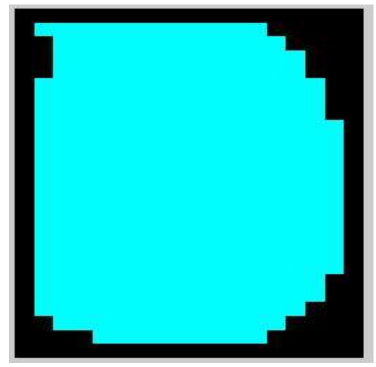
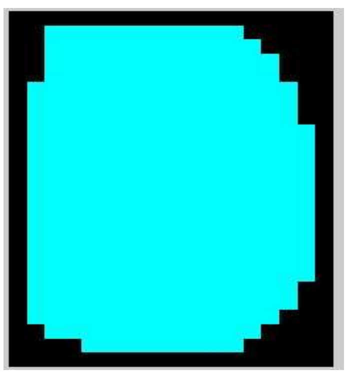
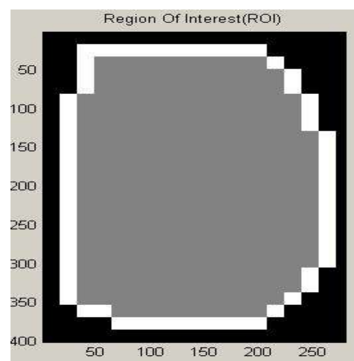


Figure 3.3.2.1 Original Image Area Figure 3.3.2.2 After CLOSE operation





3.2.3 After OPEN operation Figure 3.3.2.4 ROI + Bound

Figure 3.3.2.4 shows the interest fingerprint image area and its bound. The bound is the subtraction of the closed area from the opened area. Then the algorithm throws away those leftmost, rightmost, uppermost and bottommost blocks out of the bound so as to get the tightly bounded region just containing the bound and inner area.

4. EXPERIMENTATION RESULTS

[a] Testing Grayscale image with fft factor=0.45

Figure 4.1

Figure 4.2

Now testing same image with fft factor=0.7

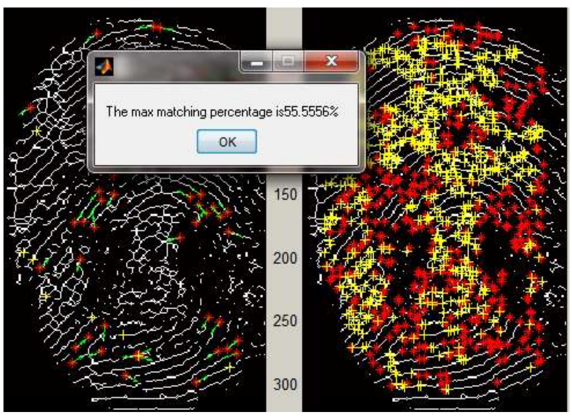


Figure 4.3

So it was observed that on increasing the fft factor, the maximum matching percentage increased from 16% to 55.556%.

[b] Testing a grayscale scale image with non uniform background (fft factor 0.45).

Figure E.4

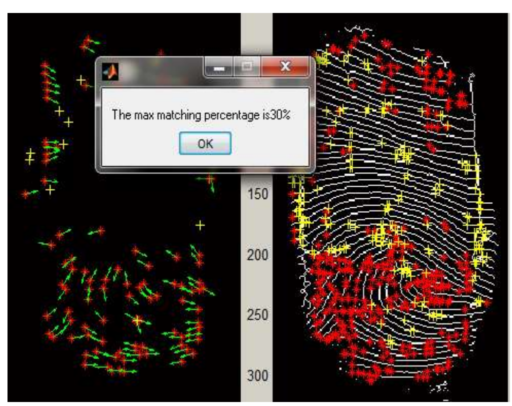


Figure 4.5

Now testing same image with improved background (fft factor 0.45)

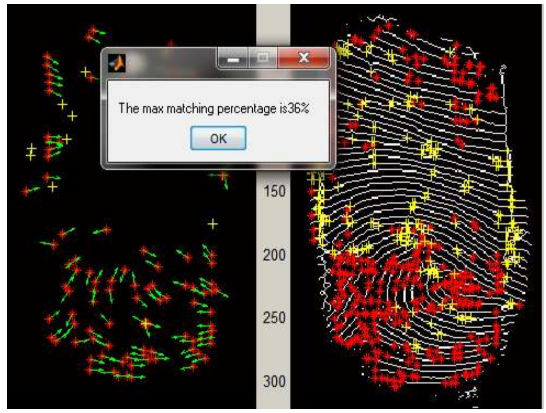


Figure 4.6 Figure 4.7

Testing further with fft factor =0.7

Figure 4.8

So from above trails it was observed that on improving background of the image the match percentage increased from 30% to 36% and further increasing fft factor increased percentage from 36% to 40%.

5. CONCLUSION

Our project has combined many methods to build a minutia extractor and a minutia matcher. The combination of multiple methods comes from a wide investigation into research paper. Also some novel changes like segmentation using Morphological operations, 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 our project, which are not reported in other literatures we referred to.

Also a program coding with MATLAB going through all the stages of the fingerprint recognition is built. It is helpful to understand the procedures of fingerprint recognition and demonstrate the key issues of fingerprint recognition.

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