Touch-Less Finger-Print Recognition

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Abstract - Our research is to overcome drawbacks in the current techniques for touch-less fingerprint recognition. We focus mainly image preprocessing, feature extraction and feature match. Each task analyzed by classical and up-to-date methods. Depending on the analysis, an integrated solution for demonstration of fingerprint recognition is developed. Our demonstration program is coded by MATLAB. To improve the performance of system optimization at coding level and algorithm level are proposed. The enhancements of performance can be judged by conducting experiments upon a variety of fingerprint images. The touch-less fingerprint recognition system can be divided into three main modules: preprocessing, feature extraction and matching. We put more emphasis on them so that drawbacks in current techniques can be overcame.

Keywords – *Feature Extraction, Binarization, Fourier Transform, Orientation, Ridge Thinning, Gabor Filtering.*

1. Introduction

Range of techniques is available for identity verification using biometrics. Such as Iris, Face, Voice and Finger-Print. Of which finger-print recognition plays an important role in verification. Fingerprint is the feature pattern of one Finger. Each person has his own fingerprints with the sub-task, some classical and up-to-date methods in permanent uniqueness. A fingerprint is composed of many ridges and furrows. Fingerprints are not distinguished

by their ridges and furrows, but by Minutia, which are some abnormal points on the ridges.

1.1 Biometrics

- Biometric templates are unique to an individual.
- Unlike password, pin number, or smart card, they cannot be forgotten, misplaced lost or stolen.
- The person trying to access is identified by his real id (represented by his unique biometric).

1.2 A Fingerprint

A fingerprint is the feature pattern of one finger. It is believed with strong evidences that each fingerprint is unique. Each person has his own fingerprints with the permanent uniqueness. So fingerprints have being used for identification and forensic investigation for a long time.

Fig.1 Fingerprint

A fingerprint is composed of many ridges and furrows. These ridges and furrows present good similarities in each small local window, like parallelism and average width. However, shown by intensive research on fingerprint recognition, fingerprints are not distinguished by their ridges and furrows, but by Minutia, which are some abnormal points on the ridges. Among the variety of minutia types reported in literatures, two are mostly significant and in heavy usage: one is called termination, which is the immediate ending of a ridge; the other is called bifurcation, which is the point on the ridge from which two branches derive.

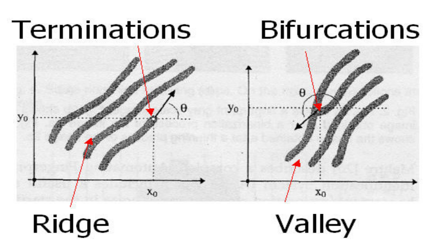


Figure : Minutia.

Fig.2 Minutia

1.3 Fingerprint Recognition

The fingerprint recognition problem can be grouped into two sub-domains: one is fingerprint verification and the other is fingerprint identification. In addition, different from the manual approach for fingerprint recognition by experts, the fingerprint recognition here is referred as AFRS (Automatic Fingerprint Recognition System), which is program-based.

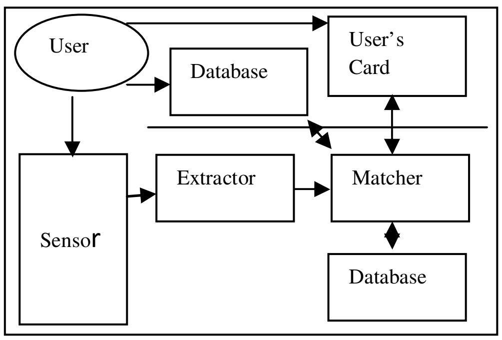


Fig.3 Fingerprint Recognition

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).

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). However, all fingerprint recognition problems, either verification or identification, are ultimately based on a well-defined representation of a fingerprint. As long as the representation of fingerprints remains the uniqueness and keeps simple, the fingerprint matching, either for the 1-to-1 verification case or 1-to-m identification case, is straightforward and easy.

2. Related Work

The first Automated Fingerprint Identification System (AFIS) was developed by [3] Palm System. The iris biometric was officially released as a commercial authentication tool by Defense Nuclear Agency. Multispectral Fingerprint Imaging (MSI) has been introduced by Lumidigm, Inc. (Rowe et al.,). Unlike conventional optical fingerprint sensors, MSI devices scan the subsurface of the skin by using different wavelengths of light (e.g., 470 nm (blue), 574 nm (green), and 636 nm (red)). The fundamental idea is that different features of skin cause different absorbing and scattering actions depending on the wavelength of light. Fingerprint images acquired using the MSI technology appear to be of significantly better quality compared to conventional optical sensors for dry and wet fingers. Multispectral fingerprint images have also been shown to be useful for spoof detection.

Sherlock et al. [4] proposed a fingerprint enhancement method in the Fourier domain. In this approach, a fingerprint image is convolved with precomputed filters, which result in a set of filtered images. The enhanced fingerprint image is constructed by selecting each pixel from the filtered image whose orientation is the closest to that of the original pixel. The next stage in fingerprint automation occurred at the end of 1994 with the Integrated Automated Fingerprint Identification System (IAFIS) competition. The competition identified and investigated three major challenges:

(1) Digital fingerprint acquisition

(2) Local ridge characteristic extraction and

(3) Ridge characteristic pattern matching (David et al.).

Teddy and Martin [6], described the latent fingerprint image enhancement using spectral analysis technique. The latent fingerprints are often blurred, incomplete, degraded and their spatial definition is not clear. This work has presented techniques from frequency (spectral) analysis that can be used for the enhancement and restoration of degraded, noisy and sometimes incomplete fingerprint by using high-pass Butterworth filter and/or band-pass Butterworth filter. Rolled or flat fingerprint captured using ink or live scan usually need only the spatial filtering techniques, such as brightness, contrast, gamma and/or color map adjustment to examine the minutiae information. However for latent fingerprint, besides the spatial image enhancement filtering, one needs to use frequency (spectral) analysis techniques or a combination of both spatial and frequency enhancement techniques to isolate and enhance the degraded and often very weak, fingerprint information from a variety of background patterns.

Naji et al.[7] proposed a segmentation algorithm based on histogram equalizer and automated the method of choosing the threshold value during segmentation. Segmentation algorithms can generally be unsupervised, where a threshold is set on detected features to segment the image, or supervised where a simple linear classifier is used to classify features as part of region of interest or the background. Examples of supervised methods include the work of Alonso-Fernandez et al , where Gabor filters were used for segmentation. Apart from supervised and unsupervised methods, neural networks are also used. E-Kyung and Bae [12][13] proposed an adaptive filter according to oily/dry/neutral images, instead of uniform filtering. To identify oily/dry/neutral, five features such as Mean, Variance, Block directional difference, Ridgevalley thickness ratio and Orientation change are used for clustering by Ward's clustering algorithm. After clustering, if the image is dry, then the ridges are enhanced by extracting their centerlines and removing white pixels, that is, ridge enhancement. For oily images, valleys are enhanced by dilating thin and disconnected ones, that is, 0valley enhancement. For neutral image, there is no need for filtration.

Recently, Chengpu et al. [23] proposed the enhancement technique by using the combination of Gabor filter and Diffusion filter methods. The authors have combined the advantages of Gabor filtering and Diffusion filtering methods and proposed an enhancement method using the two filters: the lowpass filter (1D Gaussian filter) and the band-pass filter (1D Gabor filter).

Jainam Shah*, Ujash Poshiya [28] Proposed touch-less fingerprint recognition systems that use digital camera. We present some challenging problems that occur while developing the touch-less system. These problems are low contrast between the ridge and the valley pattern on fingerprint image, non-uniform lighting, motion blurriness and defocus, due to less depth of field of digital camera. The touch-less fingerprint recognition system can be divided into three main modules: preprocessing, feature extraction and matching. Preprocessing is an important step prior to fingerprint feature extraction and matching. In this paper we put our more emphasis on preprocessing so that the drawbacks stated earlier can be removed.

European Commission Joint Research Centre [31] The objective of this study is to carry out a thorough and integrated in-depth assessment of the technical feasibility of different age limits for fingerprint recognition - in particular of children aged between 6 and 12 years - in the context of large-scale databases. The study should give therefore an answer as to whether the change of size of fingerprints of this age group - related to the growth process of fingerprints has a crucial impact on accuracy for verification.

3. Proposed Methodology

A fingerprint recognition system constitutes of fingerprint acquiring device, minutia extractor and minutia matcher.

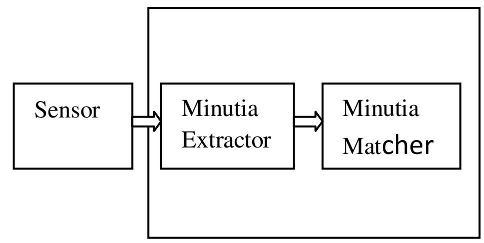


Fig.4 Proposed Methodology

For fingerprint acquisition, optical or semi- conduct sensors are widely used. They have high efficiency and acceptable accuracy except for some cases that the user's finger is too dirty or dry. To implement a minutia extractor, a three stage approach is widely used. preprocessing, minutia extraction and postprocessing . For preprocessing stage, Fourier Transform used to do image enhancement.

Binarization is carried using locally adaptive threshold method. Segmentation is done by orientation flow and Region of Interest extraction by Morphological operations. Minutia extraction done by thinning algorithms and minutia marking.

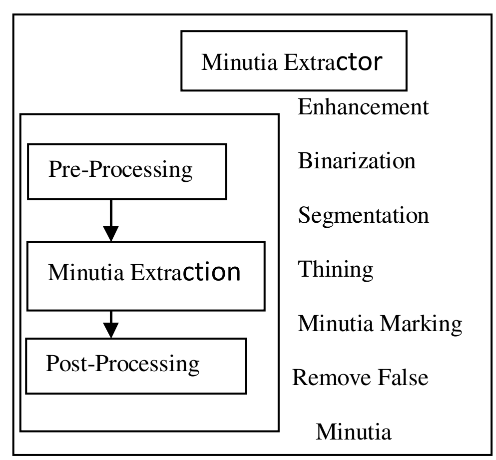


Figure.5

In postprocessing stage, Removal of false minutia with Gabor filtering is done to unify terminations and bifurcations.

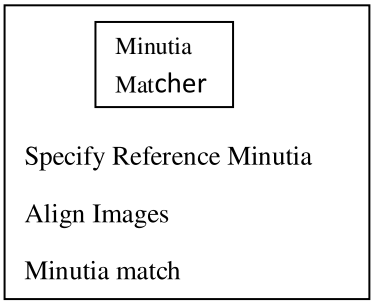


Figure. 6

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

4. Performance Analysis and Result

Enhancement is done to make the image clearer for easy further operations. As the acquired fingerprint images may not be of perfect quality. Enhancement methods, helps for increasing contrast between ridges and furrows and for connecting false broken points of ridges. Method adopted in our system is Fourier Transform. Here image is divided into small processing blocks (32 by 32 pixels) and perform Fourier transform according to:

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

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 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

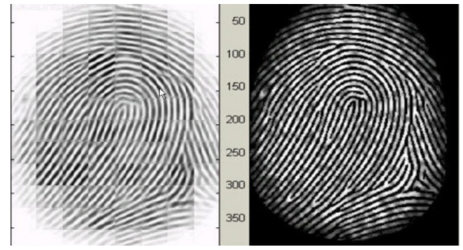
$$g(x,y) = F^{-1}\{F(u,v) \times / F(u,v) /^{k}\}$$

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

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

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

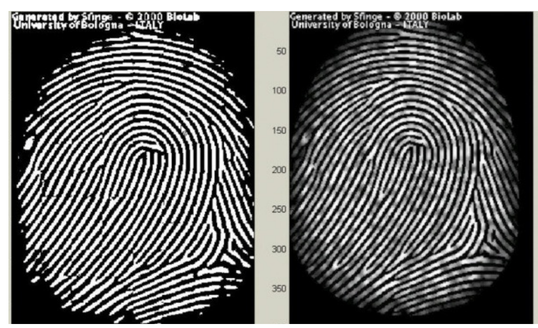
Figure presents the image after FFT enhancement.



Enhanced image Original image

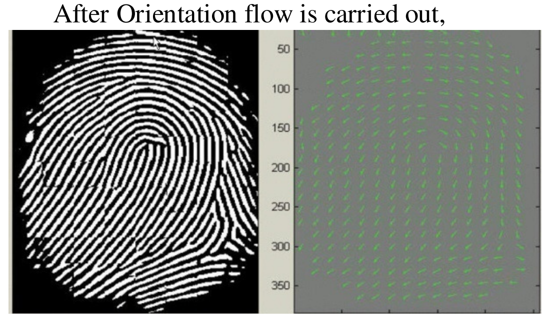
Figure.7

The enhanced image after FFT has the improvements to connect some falsely broken points on ridges and to remove some spurious connections between ridges. 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 operation, ridges in fingerprint highlighted with black color while furrows are white. A locally adaptive binarization method is performed to binarize the fingerprint image.



Binarized image Enhanced gray image

After Orientation flow is carried out,

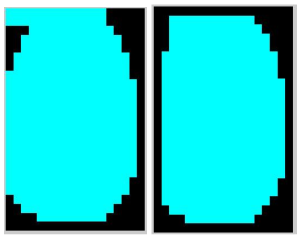


Binarized fingerprint orientation map

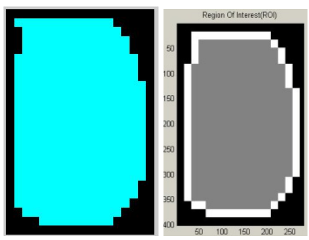
Figure. 8

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 minutia in the bound region are confusing with those spurious minutia that are generated when the ridges are out of the sensor. Two Morphological operations called 'OPEN' and 'CLOSE' are adopted. The 'OPEN' operation can expand images and remove peaks introduced by background noise The 'CLOSE' operation can shrink images and eliminate small cavities



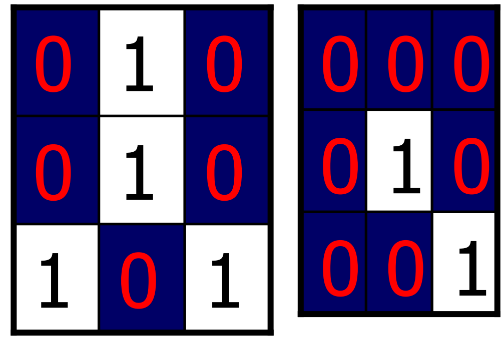
Original Area OPEN operation



CLOSE operation ROI + Bound

Figure. 9

Last Figure shows interested fingerprint image area and its bound. Bound is subtraction of closed area from opened area. Then algorithm removes area other than ROI from bound so as to get tightly bounded region just containing the bound and inner area. Ridge Thinning is to eliminate the redundant pixels of ridges till the ridges are just one pixel wide uses parallel thinning algorithm. In one-in-all method to extract thinned ridges from gray-level fingerprint images directly. This method traces along the ridges having maximum gray intensity value. However, binarization is implicitly enforced since only pixels with maximum gray intensity value are remained. Also in Our method advancement of each trace step still has large computation complexity although it does not require the movement of pixel by pixel as in other thinning algorithms. Thus the third method is bid out which uses the built-in Morphological thinning function in MATLAB. The thinned ridge map is then filtered by Morphological operations to remove some H breaks, isolated points and spikes. After the fingerprint ridge thinning, marking minutia points is relatively easy. In general, for each 3x3 window, if the central pixel is 1 and has exactly 3 one-value neighbors, then the central pixel is a ridge branch. If the central pixel is 1and has only 1 one-value neighbor, then the central pixel is a ridge ending

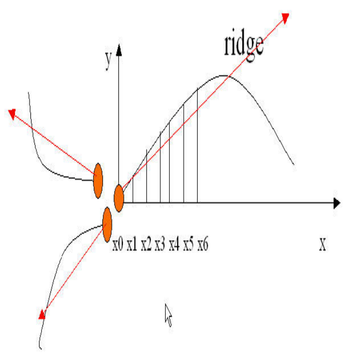


Bifurcation Termination

Figure.10

The average inter-ridge Width D, average distance between two neighboring ridges. Scan a row of thinned ridge image and sum up all pixels in row whose value is one. Then divide the row length with the above summation to get an inter-ridge width. For more accuracy, such kind of row scan is performed upon several other rows and column scans are also conducted, finally all the inter-ridge widths are averaged to get the D. Together with the minutia marking, all thinned ridges in the fingerprint image are labeled with a unique ID for further operation.The preprocessing stage does not totally heal fingerprint image. All the earlier stages themselves occasionally introduce some artifacts which later lead to spurious minutia. These false minutia will significantly affect the accuracy of matching if they are simply regarded as genuine minutia. So some mechanisms of removing false minutia are essential to keep the fingerprint verification system effective procedures in removing false minutia are:If the distance between one bifurcation and one termination is less than D and the two minutia are in the same ridge(m1 case) . Remove both of them. Where D is the average inter-ridge width representing the average distance between two parallel neighboring ridges. If the distance between two bifurcations is less than D and they are in the same ridge, remove the two bifurcations. (m2, m3 cases).If two terminations are within a distance D and their directions are coincident with a small angle variation. And they suffice the condition that no any other termination is located between the two terminations. Then the two terminations are regarded as false minutia derived from a broken ridge and are removed. (case m4,m5, m6).If two terminations are located in a short ridge with length less than D, remove the two terminations (m7). Our procedures in removing false minutia have two advantages. One is that the ridge ID is used to distinguish minutia and the seven types of false minutia are strictly defined.

The second advantage is that the order of removal procedures is well considered to reduce the computation complexity. It surpasses the way adopted by that does not utilize the relations among the false minutia types. For example, the procedure3 solves the m4, m5 and m6 cases in a single check routine. And after procedure 3, the number of false minutia satisfying the m7 case is significantly reduced. Various data acquisition conditions such as impression pressure can change type of minutia , so the unification of both termination and bifurcation is necessary. So each minutia is characterized by x-coordinate, y-coordinate, and orientation. The orientation calculation for a bifurcation needs to be specially considered. All three ridges deriving from the bifurcation point have their own direction, represents the bifurcation orientation. Simply chooses the minimum angle among three anticlockwise orientations starting from the x-axis. Both methods cast the other two directions away, so some information loses. We proposed to break a bifurcation into three terminations. These new terminations are three neighbor pixels of bifurcation and each of three ridges connected to the bifurcation before is now associated with a termination resp.



0	0	1
1	1	0
0	0	1

Figure.11

Given two set of minutia of two fingerprint images, the minutia match algorithm determines whether the two minutia sets are from the same finger or not. An alignment-based match algorithm includes two consecutive stages:

Alignment stage. Given two fingerprint images to be matched, choose any one minutia from each image, calculate the similarity of the two ridges associated with the two referenced minutia points. If the similarity is larger than a threshold, transform each set of minutia to a new coordination system whose origin is at the referenced point and whose x-axis is coincident with the direction of the referenced point.

Match stage: After we get two set of transformed minutia points, we use the elastic match algorithm to count the matched minutia pairs by assuming two minutia having nearly the same position and direction are identical.

The ridge associated with each minutia is represented as a series of x-coordinates $(x_1, x_2 \ldots x_n)$ of the points on ridge. A point is sampled per ridge length L starting from the minutia point, where L is average inter-ridge length. And n is set to 10 unless total ridge length is less than 10*L.

So two ridges is derived from:

$$S = \sum^{m}_{i=0} x_i X_i / [\sum^{m}_{i=0} x_i^2 X_i^2]\text{^}0.5,$$

where $(x_{i\sim}x_n)$ and $(X_{i\sim}X_N)$ are set of minutia for each fingerprint image respectively. And m is minimal one of n and N value. If similarity score is larger than 0.8, then go to step 2, otherwise continue to match the next pair of ridges. For each fingerprint, translate and rotate all other minutia with respect to the reference minutia according to the following formula:

$$\begin{pmatrix} xi\_new \\ yi\_new \\ \theta i\_new \end{pmatrix} = TM * \begin{bmatrix} (xi - x) \\ (yi - y) \\ (\theta i - \theta) \end{bmatrix}$$

where (x,y,θ) is the parameters of the reference minutia, and TM is

$$TM = \begin{pmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

The following diagram illustrate the effect of translation and rotation:

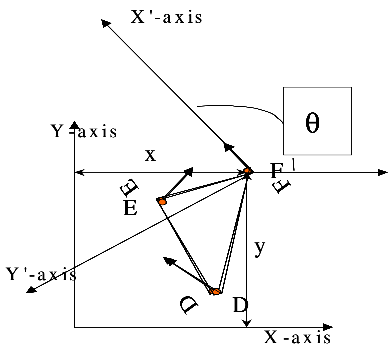


Figure: 12

The new coordinate system is originated at minutia F and the new x-axis is coincident with the direction of minutia F. No scaling effect is taken into account by assuming two fingerprints from the same finger have nearly the same size.

The matching algorithm for aligned minutia patterns needs to be elastic since strict match requiring that all parameters (x, y, θ) are same for two identical minutia is impossible due to the slight deformations and inexact quantization of minutia. Our approach to elastically match minutia achieved by placing a bounding box around each template minutia. If the minutia to be matched is within rectangle box and the direction discrepancy between them is very small, then the two minutia are regarded as a matched minutia pair. Each minutia in the template image either has no matched minutia or has only one corresponding minutia. The final match ratio for two fingerprints is the number of total matched pair over number of minutia of the template fingerprint. The score is 100*ratio and ranges from 0 to 100. If the score is larger than a pre-specified threshold, the two fingerprints are from the same finger. However, the elastic match algorithm has large computation complexity and is vulnerable to spurious minutia.

Table: 1

Method	Total Samples	True Positive	Time
Gabor + Minutiae	100	98	2.8sec
Minutiae	100	76	1.98sec
Gabor	100	85	1.35sec
PCA	100	83	1.45sec

40% : Training 60% : Testing

Above table shows the comparison of results of recognition when used different algorithms. It shows the time and accuracy by using minutia algorithm , Gabor algorithm, and PCA (principle component analysis) method. It can be clearly Seen from table that our algorithm with combine use of Gabor and minutia gives more accuracy as compare to others. The results are taken at the stages where out of 100 images 40 are used for training and 60 are used for testing. Moreover if change is made for training and testing images our algorithm gives 98% accuracy when 10 images used for training and 90 images used for testing.

5. Conclusion and Future Work

Our research paper 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 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 research paper . 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. Further study is needed to minimize the mathematical calculations and complication at some stages so that large data can be handled by system with increased accuracy.

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