

“Biometric Fingerprint”

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ABSTRACT: Fingerprint-based identification is one of the most important biometric technologies which have drawn a Substantial amount of attention. Humans have used fingerprints for personal identification for centuries and the validity of fingerprint identification has been well established. In fact, fingerprint technology is so common in personal identification that it has almost become the synonym of biometrics. Fingerprints are believed to be unique across individuals and across fingers of same individual. Even identical twins having similar DNA, are believed to have different fingerprints. These observations have led to the increased use of automatic finger print based identification in both civilian and law-enforcement applications.

I. INTRODUCTION:

A fingerprint is the pattern of ridges and furrows on the surface of a fingertip. Ridges and valleys are often run in parallel and sometimes they bifurcate and sometimes they terminate. When fingerprint image is analyzed at global level, the fingerprint pattern exhibits one or more regions where ridge lines assume distinctive shapes. These shapes are characterized by high curvature, terminations, bifurcations, cross-over etc. These regions are called singular regions or singularities. These singularities may be classified into three topologies; loop, delta and whorl. At local level, there are other important features known as minutiae can be found in the fingerprint patterns. Minutiae mean small details and this refers to the various ways that the ridges can be discontinuous. A ridge can suddenly come to an end which is called termination or it can divide into two ridges which is called bifurcation.

Fingerprint matching techniques can be broadly classified as minutiae based and correlation based. Minutiae based technique first locates the minutiae points in a given fingerprint image and matches their relative placements in a stored template fingerprint. A good quality fingerprint contains between 60 and 80 minutiae, but different fingerprints have different number of minutiae. The performance of minutiae-based techniques rely on the accurate detection of minutiae points and the use of sophisticated matching techniques to compare two minutiae fields which undergo non-rigid transformations. Correlation based techniques compare the global pattern of ridges and valleys to see if the ridges in the two fingerprints align

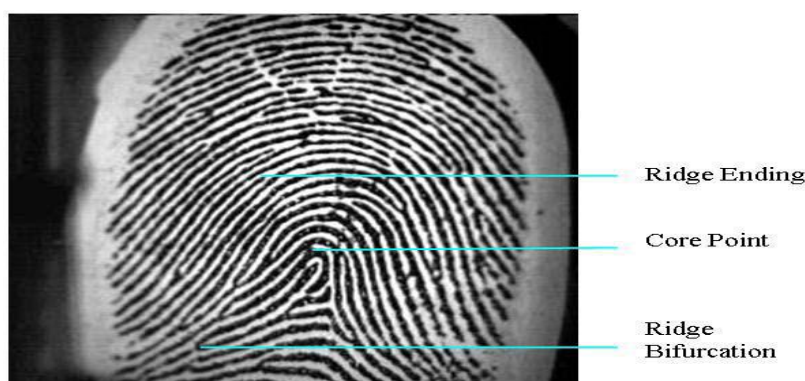


Figure1: Finger rint Pattern

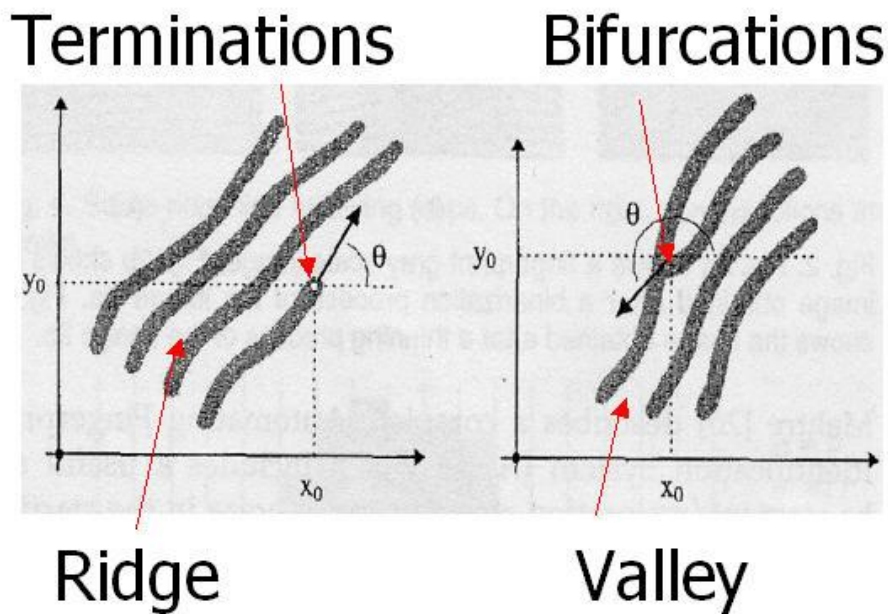
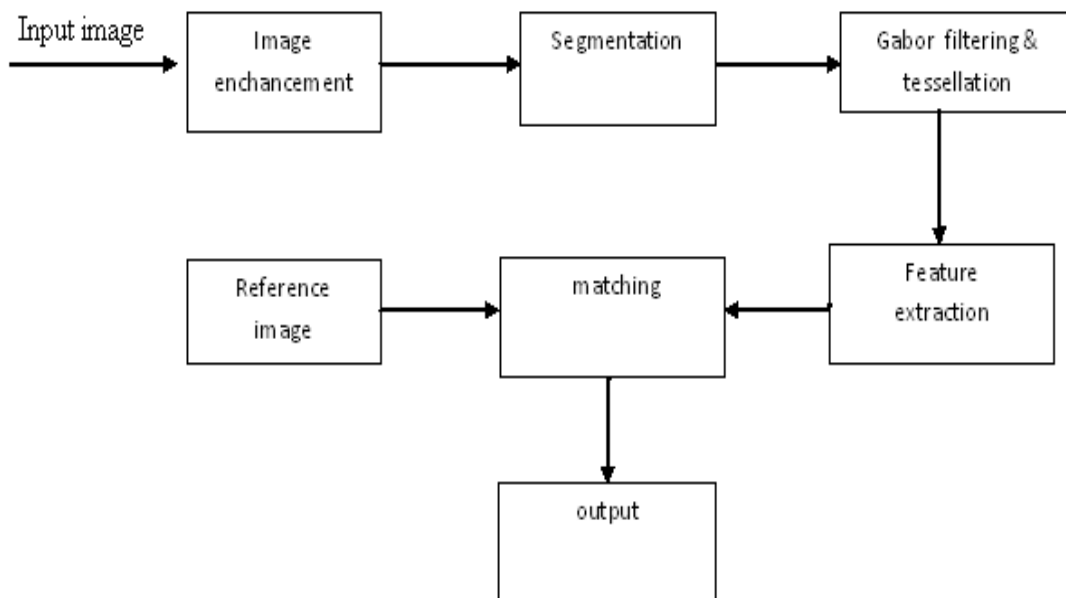


Figure1.1: Minutia (Valley is also referred as Furrow, Termination is also called Ending, and Bifurcation is also called Branch).

Flow diagram of fingerprint recognition algorithm.



The fingerprint recognition problem can be grouped into two sub-domains: one is fingerprint verification and the other is fingerprint identification (Figure 1.2.). 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.

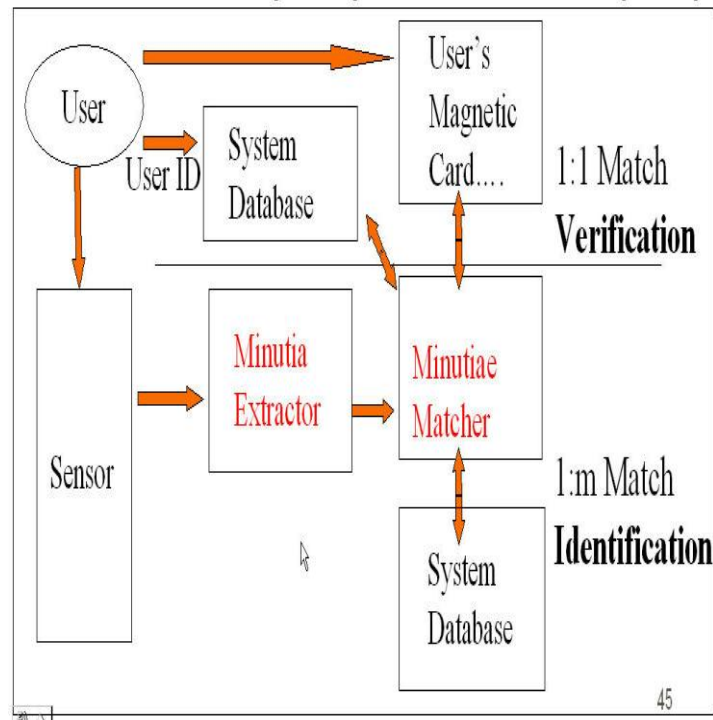


Figure 1.2: Verification vs. Identification

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).

II. IMAGE ENHANCEMENT

When an image is scanned from a finger print scanner the center of image and its support are quite clear and easy to study. There is another part of image that is much darker and its size and other feature are not easily discernable. In this the problem to enhance dark areas while leaving the other area as unchanged as possible since it does not require enhancement. The objective of enhancement is to improve the interpretability of the information present in images for human viewers.



Figure3: Input Fringer Print



Figure4: Enhance Fingerprint

$J = \text{imadjust}(I, [\text{low_in}; \text{high_in}], [\text{low_out}; \text{high_out}])$ maps the values in intensity image I to new values in J such that values between low_in and high_in map to values between low_out and high_out . Values below low_in and above high_in are clipped; that is, values below low_in map to low_out , and those above high_in map to high_out .

Fingerprint Image Enhancement algorithm are employed to emphasize ,sharpen Or smoothen image features for display & analysis. Image enhancement can be Classified in two broad categories as

- 1- Spatial domain method.
- 2- Transform domain method.

Spatial domain method operates directly on pixels. In our project we are using this method . In it we are using histogram based operation because they are simple, fast & with them acceptable results for some applications can be achieved.

2.1.Histogram :- The histogram of an image is a plot of the number of occurrences Of gray levels in the image against the gray-level values. The histogram provides a convenient summary of the intensities in an image ,but it is unable to convey any information regarding spatial relationships between pixels.

2.2.Histogram Equalization: Histogram equalization is to expand the pixel value distribution of an image so as to increase the perceptual information. Equalization is a process that attempts to spread out the gray levels in an image so that they are evenly distributed across their range. It assigns the brightness values of pixels based on the mage histogram.It is a technique where the histogram of resultant image should be as flat as possible.

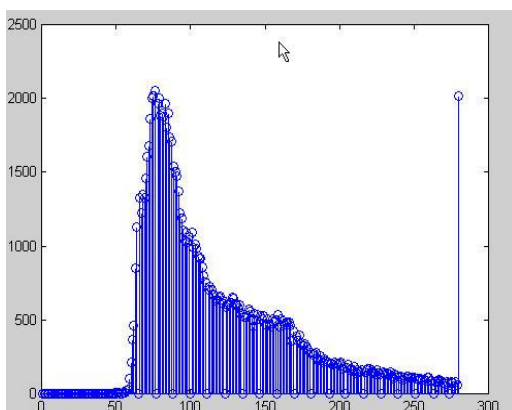


Figure3.1.1 the Original histogram of a fingerprint image

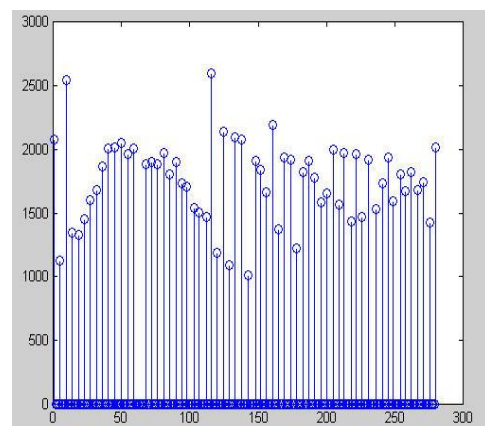


Figure3.1.2 Histogram after the Histogram Equalization

The right side of the following figure [**Figure 3.1.1.3**] is the output after the histogram equalization.

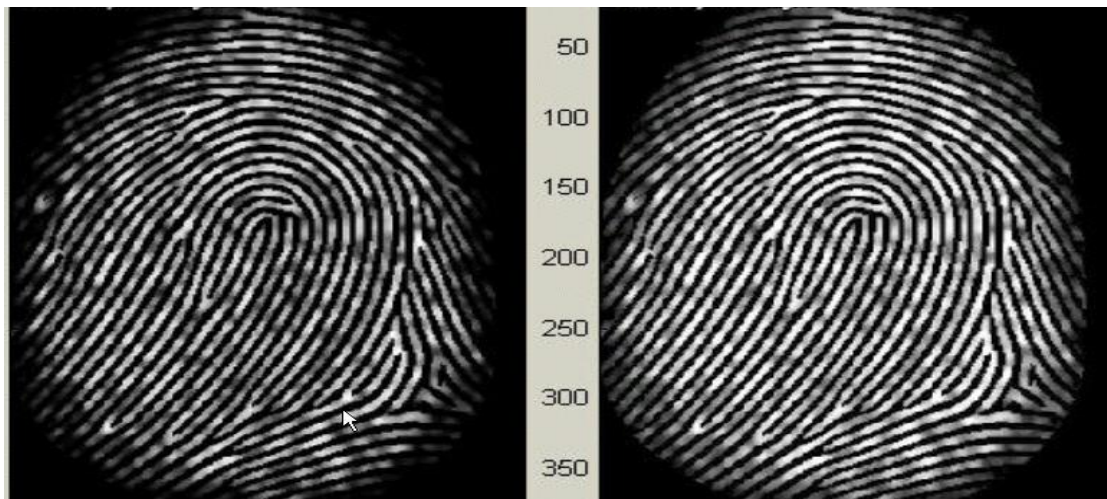


Figure3.1.3 Histogram Enhancement. Original Image (Left). Enhanced image (Right)

2.3.Fingerprint Image Binarization

Fingerprint Image Binarization is to transform the 8-bit Gray fingerprint image to a 1-bit image with 0-value for ridges and 1-value for furrows. After the 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 [Figure 3.2.1].

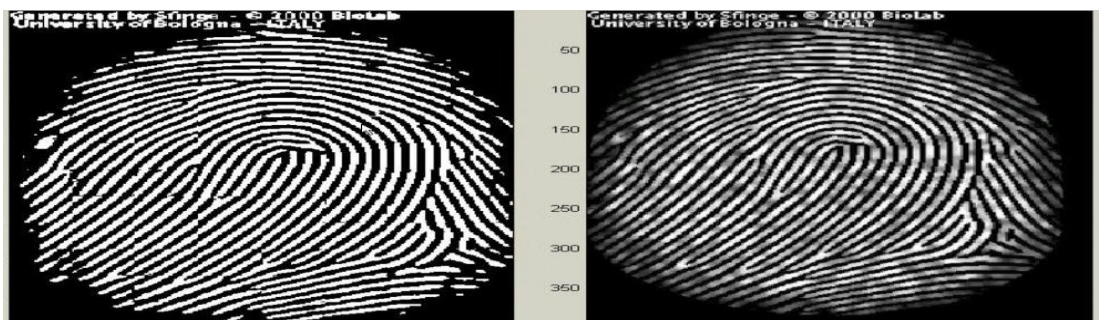


Figure3.2.1 the Fingerprint image after adaptive binarization Binarized image (left), Enhanced gray image (right)

2.4.Segmentation

The first step of the fingerprint enhancement algorithm is image segmentation. Segmentation is the process of separating the foreground regions in the image from the background regions. The foreground regions correspond to the clear fingerprint area containing the ridges and valleys, which is the area of interest. The background corresponds to the regions outside the borders of the fingerprint area, which do not contain any valid fingerprint information. When minutiae extraction algorithms are applied to the background regions of an image, it results in the extraction of noisy and false minutiae. Thus, segmentations employed to discard these background regions, which facilitate the reliable extraction of minutiae. 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 minutia in the bound region is confusing with that spurious minutia 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 [1], while the second is intrigued from some Morphological methods.

2.4. Block direction estimation

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

- [1] 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.
- [2] For each block, use Following formula to get the Least Square approximation of the block direction.
- [3] $tg2\theta = 2 \sum \sum (g_x * g_y) / \sum \sum (g_x^2 - g_y^2)$ for all the pixels in each block.
- [4] 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.
- [5] $tg2\theta = 2 \sin\theta \cos\theta / (\cos^2\theta - \sin^2\theta)$
- [6] 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.

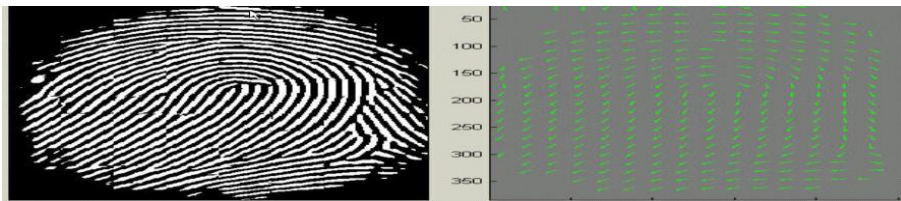


Figure 3.3.1.1 Direction map Binarized fingerprint (left), Direction map (right)

2.5. 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].

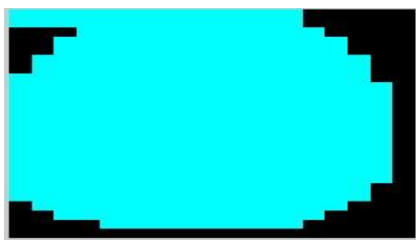


Figure 3.3.2.1 Original Image Area

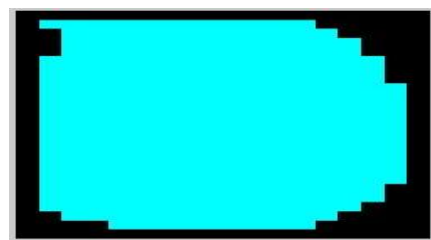


Figure 3.3.2.2 After CLOSE operation

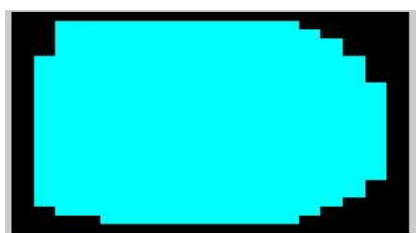


Figure 3.3.2.3 After OPEN operation

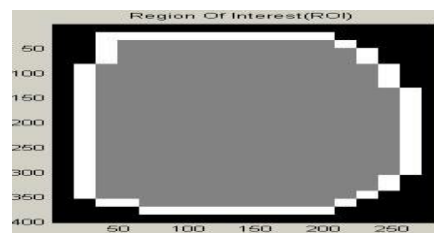


Figure 3.3.2.4 ROI + Bound

Figure 3.3.2.4 show 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.

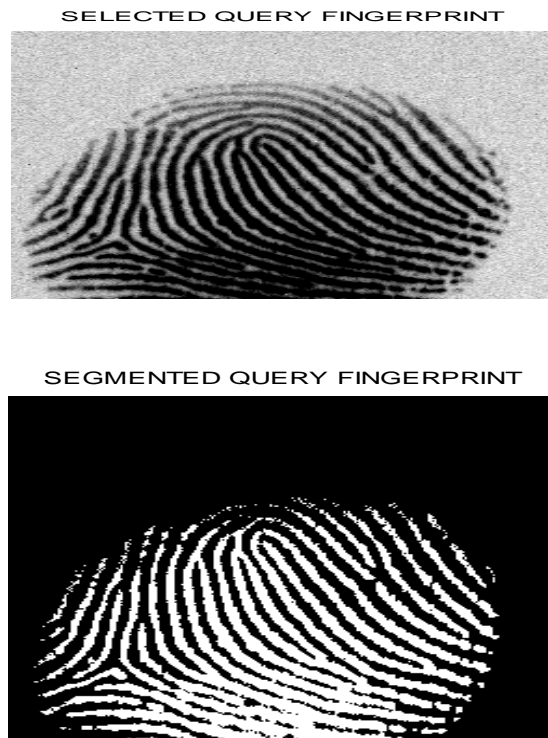


Figure5: Selected and Segmented Query Finger Print

2.6.Gabor Filter

Gabor filter method is assumed that the parallel ridges and valleys exhibit some ideal sinusoidal-shaped plane waves associated with some noises. In other words, the 1-Dsignal orthogonal to the local orientation is approximately a digital sinusoidal wave.

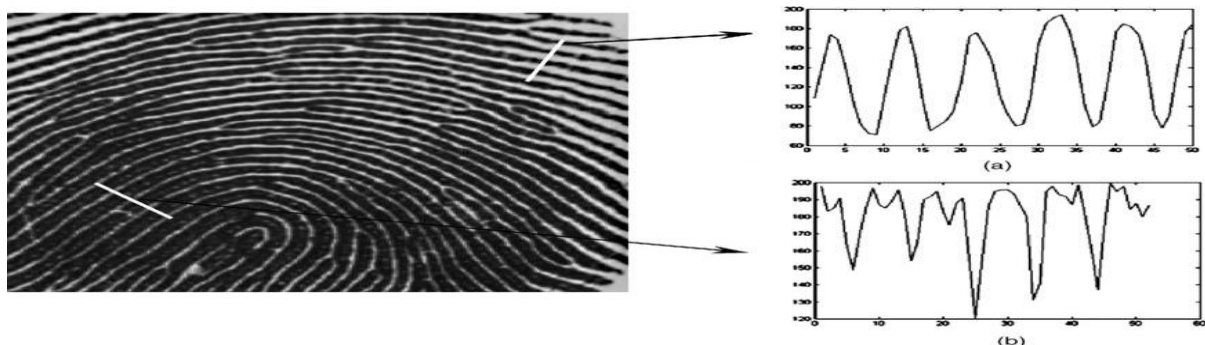


Figure6: Ridges and Valleys Pattern

Fingerprint images present a strong orientation tendency and have a well-defined spatial frequency in each local neighborhood that does not contain singular point(s) Gabor filters are band-pass filters which have both orientation-selective and frequency-selective properties and have optimal joint resolution in both spatial and frequency domains. By applying properly tuned Gabor filters to a fingerprint image, the true ridge and furrow structures can be greatly accentuated. These accentuated ridges and furrow structures constitute an

efficient representation of a fingerprint image. An even symmetric Gabor filter has the following general form in the spatial domain:

$$G(x, y; f, \theta) = \exp\left\{\frac{-1}{2}\left[\frac{x'^2}{\delta_x^2} + \frac{y'^2}{\delta_y^2}\right]\right\} \cos(2\pi fx'),$$

$$x' = x\sin\theta + y\cos\theta,$$

$$y' = x\cos\theta - y\sin\theta,$$

where f is the frequency of the sinusoidal plane wave along the direction q from the x -axis, and δ_x and δ_y specify the Gaussian envelope along x and y axes, respectively, which determine the bandwidth of the Gabor filter. In our algorithm, the filter frequency f is set to the average ridge frequency ($1/K$), where K is the inter ridge distance. The average inter ridge image. If f is too large, spurious ridges may be created in the filtered image, whereas if f is too small, nearby ridges may be merged into one. The bandwidth of the Gabor filters is determined by δ_x and δ_y . The selection of the values of δ_x and δ_y is based on the following trade-off. If they are too large, the filter is more robust to noise, but is more likely to smooth the image to the extent that the ridge and furrow details in the fingerprint are lost. On the other hand, if they are too small, the filter is not effective in removing noise. In our algorithm, the values of δ_x and δ_y were empirically determined and both were set to 4.0. If we decompose formula into two orthogonal parts, one parallel and the other perpendicular to the orientation ϕ , the following formula can be

$$g(x, y, T, \phi) = h_x(x; T, \phi) \cdot h_y(y; \phi)$$

$$= \left\{ \exp\left(-\frac{x_\phi^2}{2\sigma_x^2}\right) \cos\left(\frac{2\pi x_\phi}{T}\right) \right\}$$

$$\cdot \left\{ \exp\left(-\frac{y_\phi^2}{2\sigma_y^2}\right) \right\}$$

The first part h_x behaves as a 1-D Gabor function which is a band pass filter, and the second one h_y represents a Gaussian function which is a low pass filter. Therefore, a 2-D even-symmetric Gabor filter (TGF) performs a low pass filtering along the orientation ϕ and a band pass filtering orthogonal to its orientation ϕ . The band pass and low pass properties along the two orthogonal orientations are very beneficial to enhancing fingerprint images, since these images usually show a periodic alternation between ridges and valleys orthogonal to the local orientation and parallel exhibit an approximate continuity along the local orientation. It should be pointed out that h_x in formula could be treated as a non-admissible mother wavelet (indicated by its Fourier representation). Its band pass property is related with the σ_x . If σ_x is too small, the band pass filter degenerates into a low pass function. On the other hand, if σ_x is appropriately large, h_x can be approximately regarded as an admissible mother wavelet with good band pass property. The filter frequency f is set to the average ridge frequency ($1/K$), where K is the inter ridge distance. The average inter ridge distance is approximately 10 pixels in a 500 dpi fingerprint image. If f is too large, spurious ridges may be created in the filtered image, whereas if f is too small, nearby ridges may be merged into one. The σ_x is the standard deviation of the 2-D Gaussian function along the x -axis and σ_y along the y -axis. σ_x and σ_y control the spatial-frequency bandwidth of the response. The larger they are, the wider bandwidth is expected. However, too wide bandwidth can unexpectedly enlarge the noises, and too narrow bandwidth tends to suppress some useful signals. The value of σ_y determines the smoothing degree along the local orientation. Too large σ_y can blur the minutiae. In our algorithms, σ_y is empirically set as 4.0.

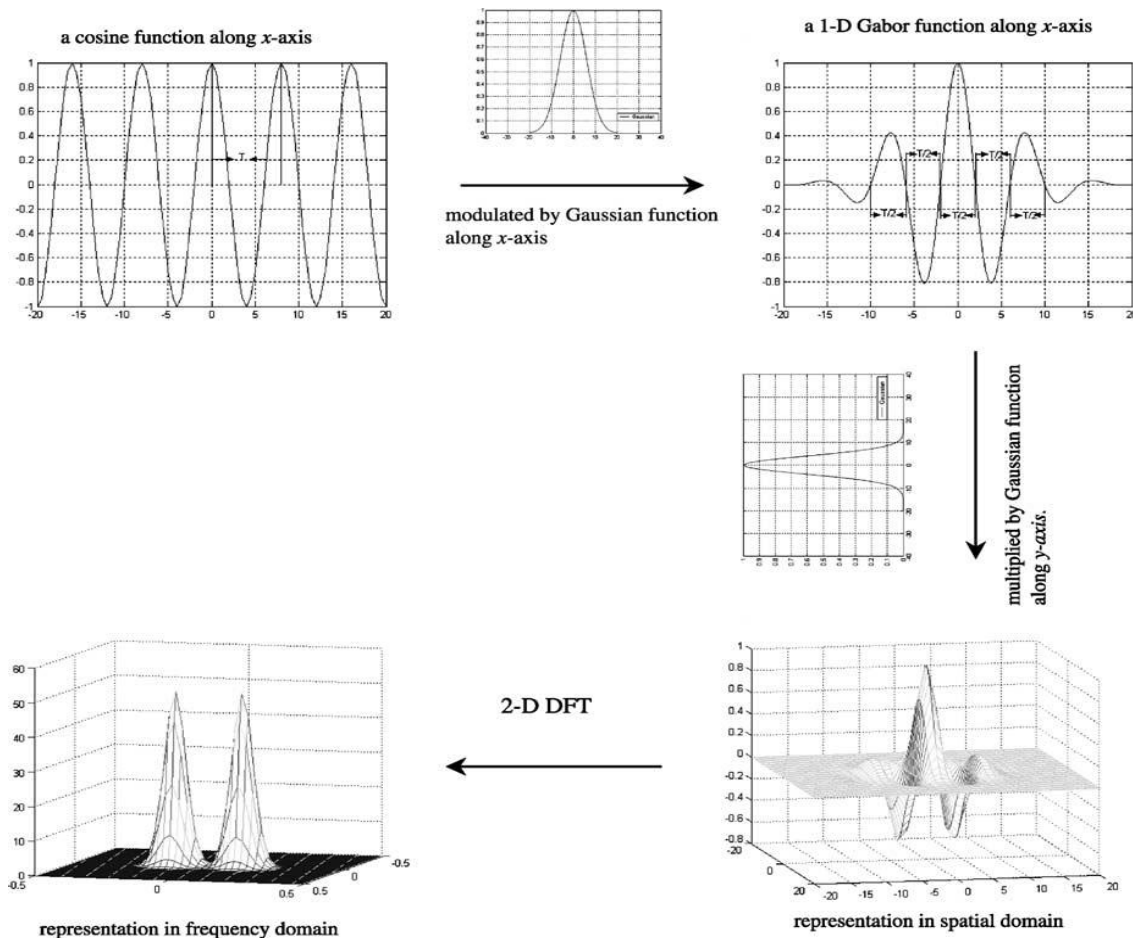


Figure7: Gabor Filter Function

A fingerprint image is decomposed into four component images corresponding to four different values of q (0° , 45° , 90° , and 135°) with respect to the x -axis. A fingerprint image is convolved with each of the four Gabor filters to produce the four component images. Convolution with a 0° -oriented filter accentuates ridges parallel to the x -axis, and it smoothes ridges which are not parallel to the x -axis. Filters tuned to other directions work in a similar way. The four component images capture most of the ridge directionality information present in a fingerprint image by reconstructing a fingerprint image by adding together all the four filtered images. The reconstructed image is similar to the original image but the ridge has been enhanced before decomposing the fingerprint image, we normalize the region of interest in each sector separately to a constant mean and variance. Normalization is done to remove the effects of sensor noise and finger pressure differences. Let $I(x, y)$ denote the gray value at pixel (x, y) , M_i and V_i , the estimated mean and variance of sector S_i , respectively, and $N_i(x, y)$, the normalized gray-level value at pixel (x, y) . For all the pixels in sector S_i , the normalized image is defined as:

$$N_i(x, y) = \begin{cases} M_0 + \sqrt{\frac{(V_0) \times (I(x, y) - M_i)^2}{V_i}}, & \text{if } I(x, y) > M_i \\ M_0 - \sqrt{\frac{(V_0) \times (I(x, y) - M_i)^2}{V_i}}, & \text{otherwise,} \end{cases}$$

Where M_0 and V_0 are the desired mean and variance values, respectively. Normalization is a pixel-wise operation which does not change the clarity of the ridge and furrow structures.

If normalization is done on the entire image, then it cannot compensate for the intensity variations in the different parts of the finger due to finger pressure differences. Normalization of each sector separately alleviates this problem. Ridges have been enhanced ridge and valley structures.

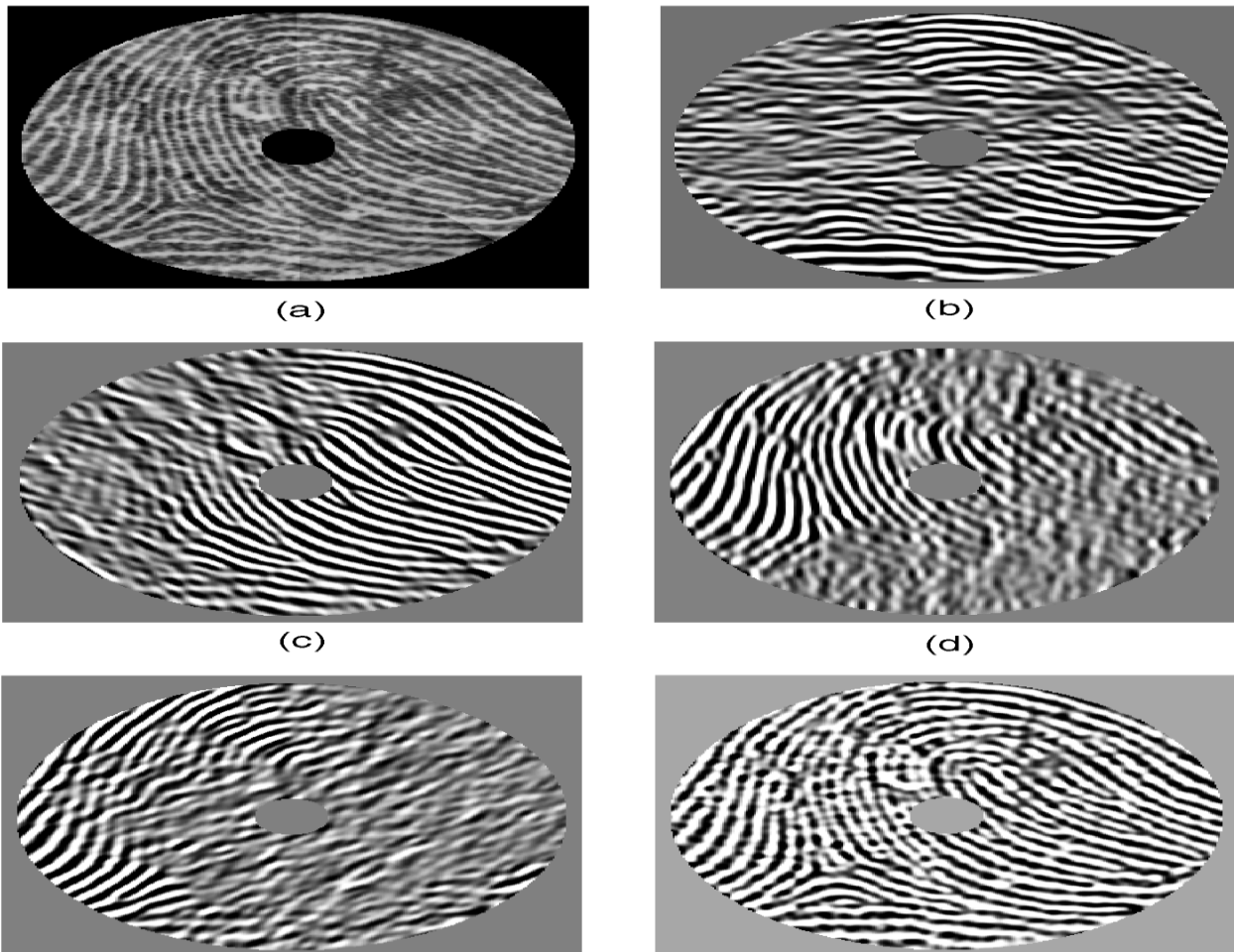


Figure8: Gabor Filter Output

III. TESSELLATION

A fingerprint consists of a series of ridges that mainly flow parallel to the locally dominant direction and occasionally make local singularities, like a core or delta point. Since fingerprint patterns have strong directionality, directional information can be exploited as fingerprint features. In this sense, a DFB is suitable for extracting the features of fingerprints containing many linear and directional components because it can effectively and accurately decompose an image into several directional sub band outputs. For feature extraction, the original fingerprint image is decomposed into directional sub band outputs using the DFB, and the directional energy of each block can be obtained from the decomposed sub band outputs.

Let denote the coefficient at position of sub band corresponding to an image block. The energy of the image block associated with sub band is defined as

$$E_{B\theta} = \sum_{x,y \in B} f_{B\theta}(x,y)$$

Where $\theta \in \{0, 1, 2, \dots, 7\}$ Each energy value is calculated from the sub band corresponding to the image block. The directional energy distributions of the sample fingerprint image blocks. We can see that by this directional filtering operation the ridges and valleys became more distinct and noisy components were suppressed at the same time.

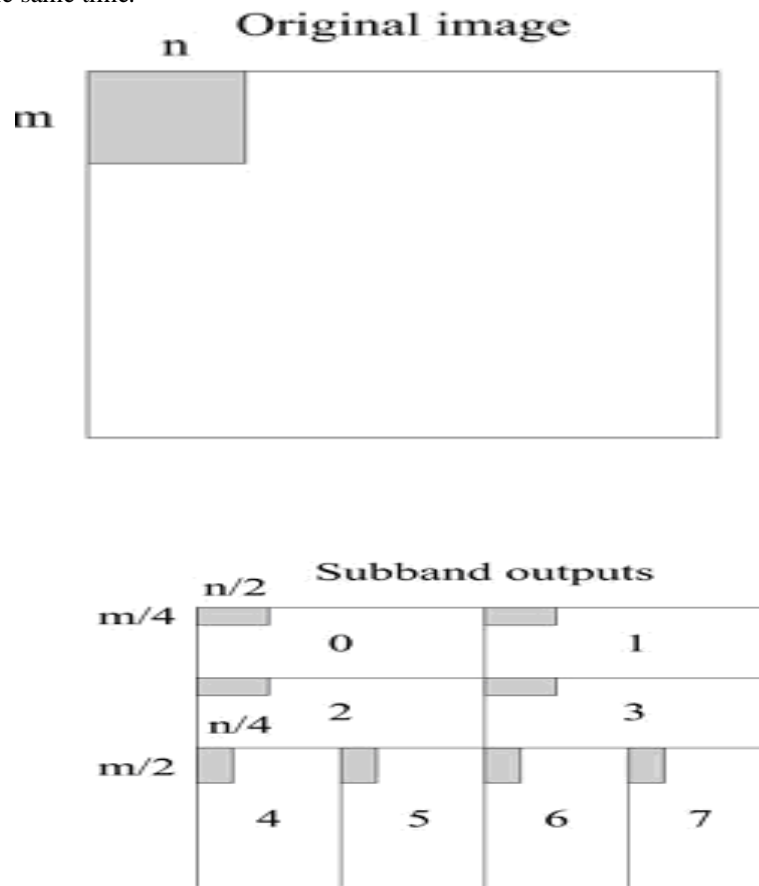


Figure9: Tessellation

IV. FEATURE Extraction

In each component image, a local neighborhood with ridges and furrows that are parallel to the corresponding filter direction exhibits a higher variation, whereas a local neighborhood with ridges and furrows that are not parallel to the corresponding filter tends to be diminished by the filter which results in a lower variation. The spatial distribution of the variations in local neighborhoods of the Component images thus constitute a characterization of the global ridge structures and are well captured by the standard deviation of grayscale values. The standard deviation within the sectors defines the feature vector.

Let $C_i^\theta(x, y)$ be the component image corresponding to θ for sector S_i

For $\forall i, i = 0, 1, \dots, 47$ and $\theta \in [0^\circ, 45^\circ, 90^\circ, 135^\circ]$, Feature is the standard deviation $F_{i\theta}$ defined as

$$F_{i\theta} = \sqrt{\sum_{K_i} (C_{i\theta}(x, y) - M_{i\theta})^2}$$

Where K_i is the number of pixels in S_i and $M_{i\theta}$ is the mean of the pixel values in $C_{i\theta}(x, y)$. The dimensional feature vectors, also called Finger Codes

V. FINGERPRINT ALIGNMENT AND MATCHING

Before the input print and template print are compared with each other, they should be translation ally and rotationally aligned with each other. In the proposed method, the translational alignment is accomplished by the reference point detection procedure for the ROI extraction processes. Rotational alignment is achieved by generating cyclical input feature vectors and matching input feature vectors with template feature vectors. Since the proposed feature extraction process is performed on a block-by-block basis and the directions of ridges change smoothly, the proposed method is robust to small angular deviations, even without rotation compensation. However if the input image is significantly rotated, the performance Degrades compensation for rotation is partially achieved by cyclically rotating the feature values in the feature vector and finding the minimum distance between the input and template feature vector. This only provides robustness for a small perturbation with in, that is , half the angle of a sector. However, for this method to be invariant to smaller perturbations , the extent of the rotation needs to be the same as the multiple of the angle of a sector, e.g., 22.5, 45 or many feature vectors for a variously rotated image must be enrolled in the database. To compensate effectively for various kinds of rotation, the proposed method converts the ROI from Cartesian to polar coordinates. In Cartesian coordinates, the rotation of an image changes the entire directional sub bands to totally different ones, whereas in polar coordinates rotation corresponds to a horizontal shift in each directional sub band output. Thus the coordinate system conversion facilitates the procedure of compensating for rotation. Instead of using a single feature vector as the input, the proposed method performs matching using several feature vectors in which various rotations are considered. After an input fingerprint image is decomposed into eight directional sub band outputs, the input feature vectors are obtained by cyclically shifting the sub band images

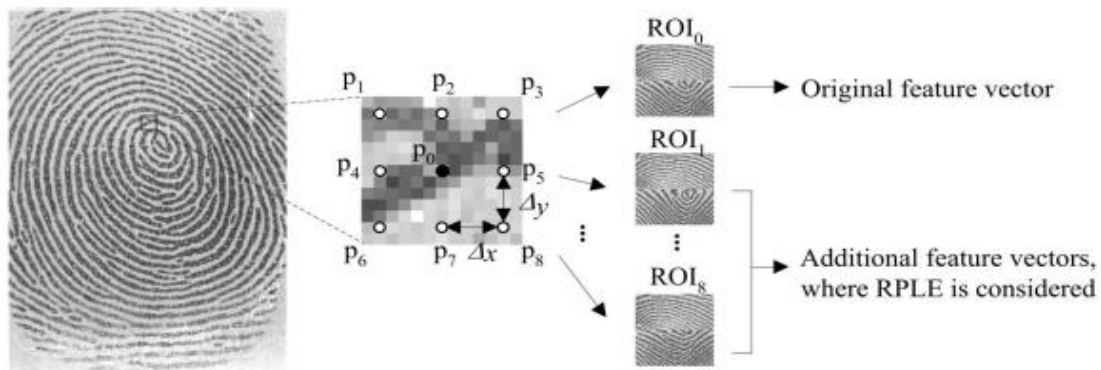


Figure10: Feature vector

Fingerprint matching is performed based on finding the normalized Euclidean distance between the input feature vectors and the template feature vector enrolled in the database. Let denote the θ -direction feature value for the k th block of the ROI for an input fingerprint image, in which degree rotation is considered and let denote the θ -direction feature value for the k th block of the ROI for the template fingerprint. Then the normalized Euclidean distance between input and template image

$$\hat{d} = \min_R \sqrt{\frac{1}{l} \sum_k \sum_{\theta} d_{k\theta}^R}$$

where

$$d_{k\theta}^R = \begin{cases} (v_{k\theta}^R - t_{k\theta})^2, & \text{if } v_{k\theta}^R \neq 0 \text{ and } t_{k\theta} \neq 0 \\ 0, & \text{otherwise.} \end{cases}$$

$$R \in \{-10, -9, \dots, -1, 0, 1, \dots, 9, 10\}, \theta \in \{0, 1, 2, \dots, 7\},$$

and l is the number of the feature vector elements where $d_{k\theta}^R$ is not zero. Rotational and translational alignment between the input and template fingerprints is achieved by finding the minimum normalized Euclidean distance between the input and template feature vectors.

VI. SIMULATION RESULT

SELECTED QUERY FINGERPRINT

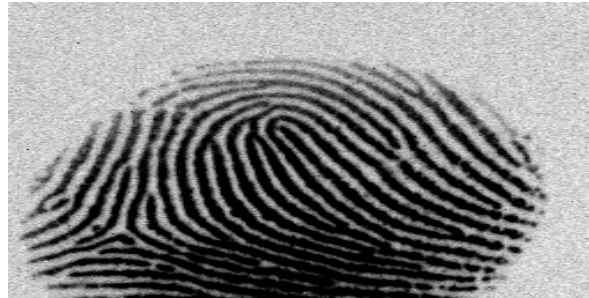


Figure11: Input Image

SEGMENTED QUERY FINGERPRINT



Figure12: Segmented query fingerprint

ENHANCED QUERY FINGERPRINT



Figure13: Enhanced Image

0 degree GABOR FILTER OUTPUT [QUERY].

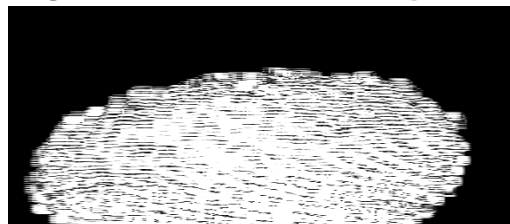


Figure14: 0 degree gabor filter output

45 degree GABOR FILTER OUTPUT [QUERY].

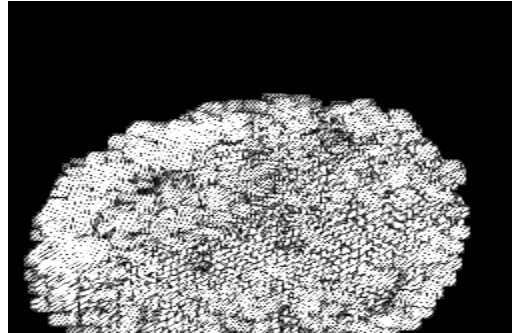


Figure15: 45degree gabor filter output

90 degree GABOR FILTER OUTPUT [QUERY].

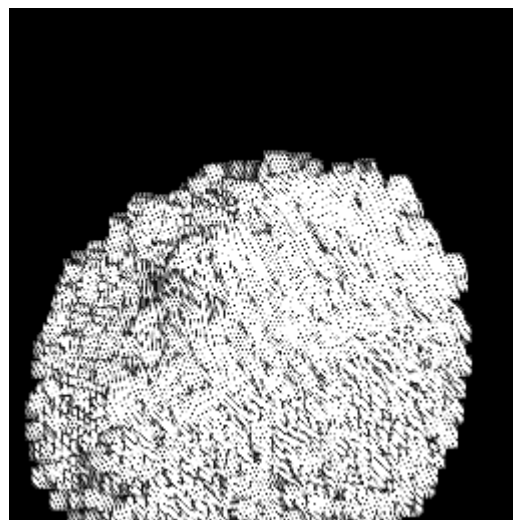


Figure16: 90 degree gabor filter output

135 degree GABOR FILTER OUTPUT [QUERY].

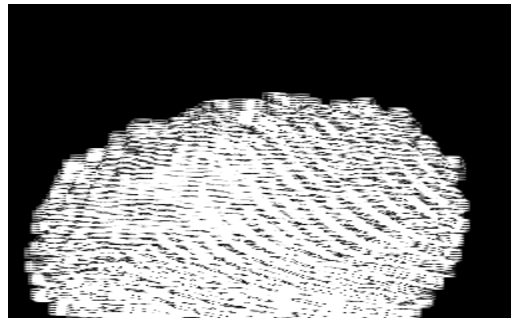
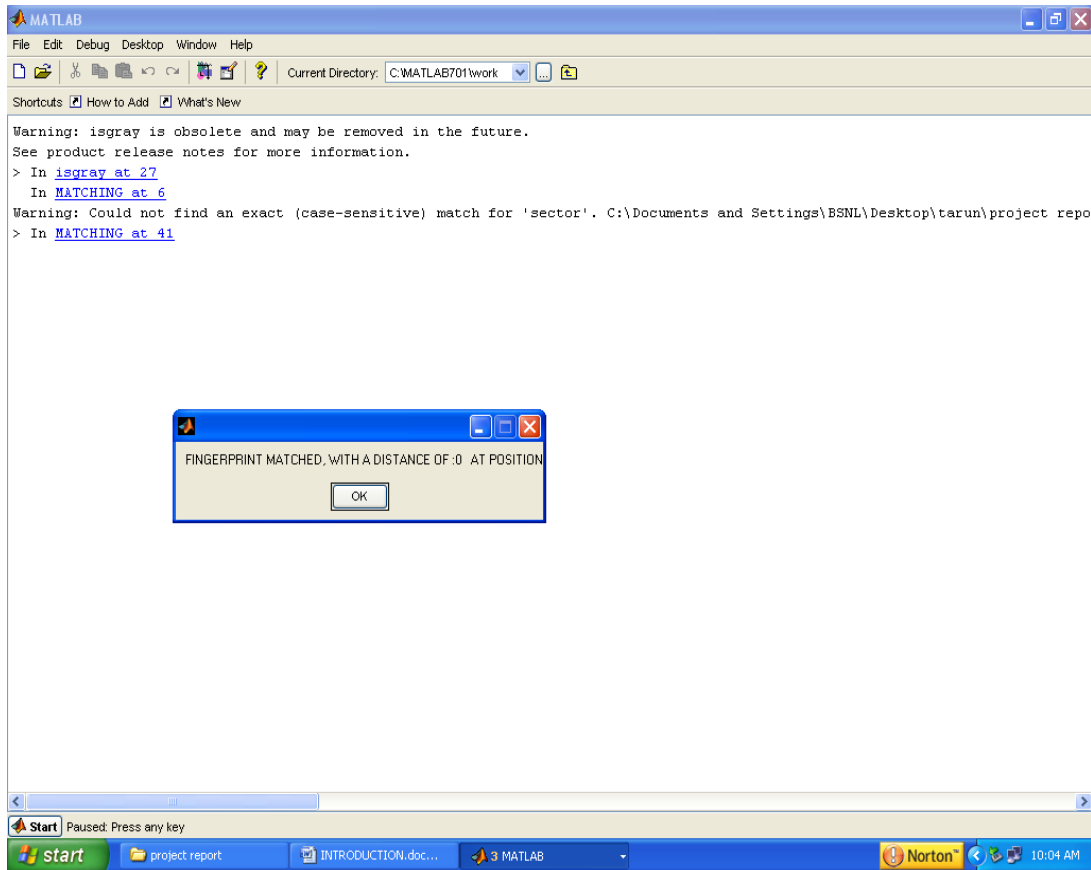


Figure17: 130 degree gabor filter output



User Manual

1. Type command `start_gui_single_mode` in MATLAB 6.0

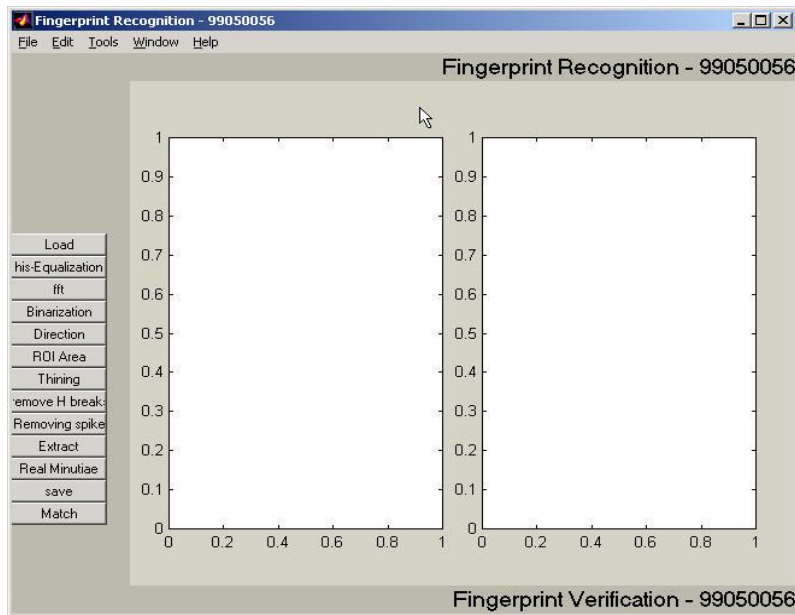


Figure M.1 the User Interface of the Fingerprint Recognition System. The series of buttons on the left side will be invoked sequentially in the consequent demonstration. The two blank areas are used to show the fingerprint image before and after a transaction respectively.

2. Click Load Button

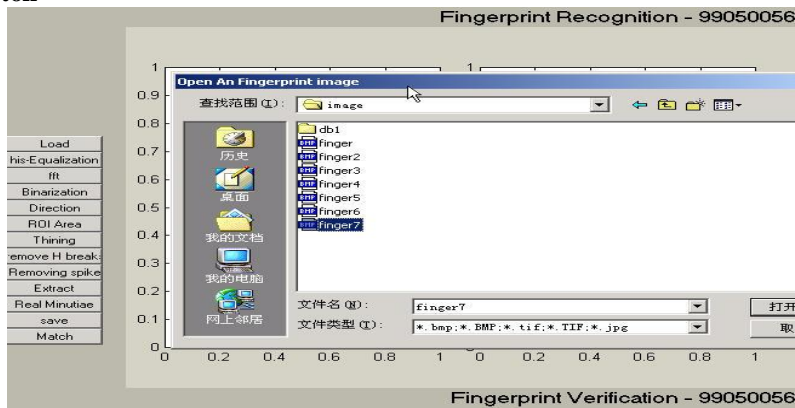


Figure M.2 Load a gray level fingerprint image from a drive specified by Users. Multiple formats are supported and the image size is not limited. But the fingerprint ridges should have large gray intensity comparing with the background and valleys.

3. Click his-Equalization Button

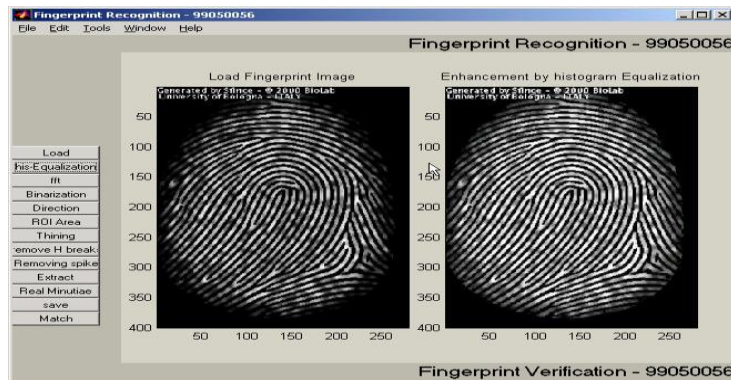


Figure M.3 After Histogram Equalization. The image on the left side is the original fingerprint. The enhanced image after the Histogram Equalization is shown on the right side.

4. Click fft Button

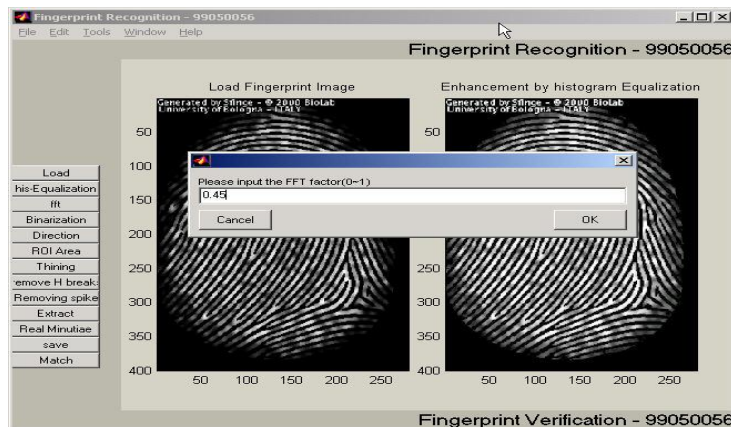


Figure M.4 Captured window after click 'FFT' button. The pop-up dialog accepts the parameter k (please refer the formula 2). The experimental optimal k value is 0.45. Users can fill any other constant in the dialog to get a better performance. The enhanced image will be shown in the left screen box, which however is not shown here. Its replaced by gabour

5. Click Binarization Button

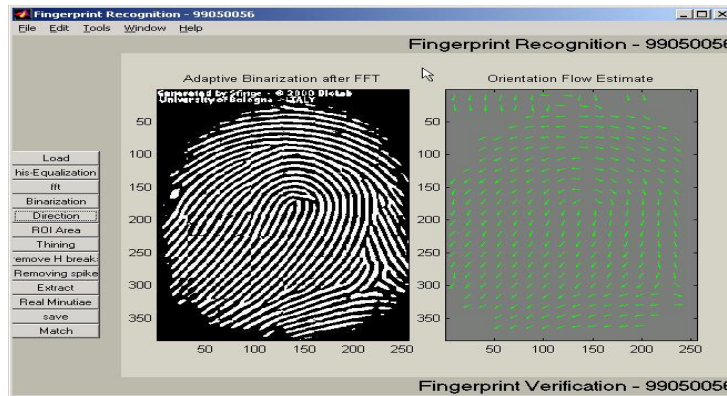


Figure M.5.6 Screen capture after binarization (left) and block direction estimation (right).

7. Click ROI Area Button

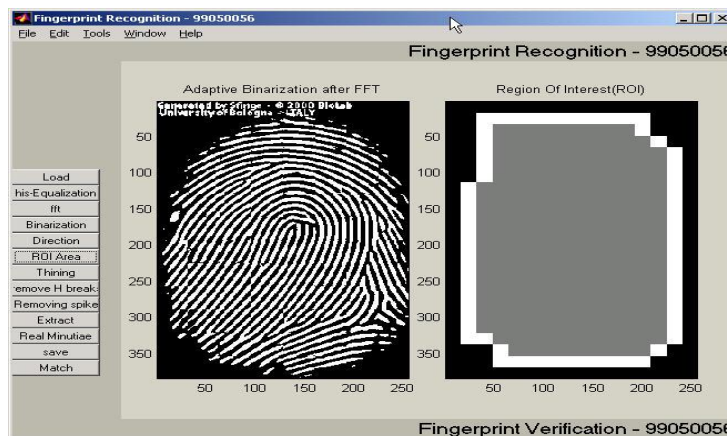


Figure M.7 ROI extraction(right). The intermediate steps for all the morphological operations such as close and open are not shown. The right screen box shows the final region of interest of the fingerprint image. The subsequent operations will only operate on the region of interest.

8. Click **Thinning** Button

9. Click **Remove H breaks** Button

10. Click **Remove spikes** Button

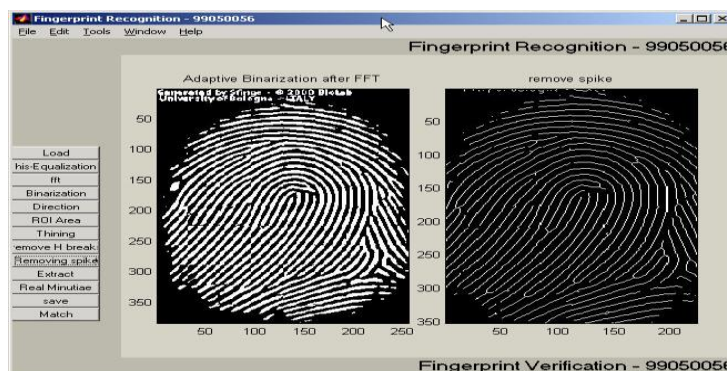


Figure M.10 the Fingerprint image after thinning, H breaks removal, isolated peaks removal and spike removal.(right).

11. Click Extract Button
Click Real Minutia Button

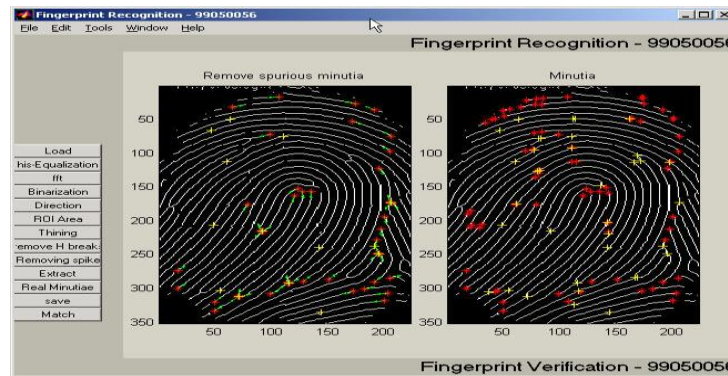


Figure M.12 Minutia marking (right) and False Minutia Removal (Left). Bifurcations are located with yellow crosses and terminations are denoted with red stars. And the genuine minutia (left) is labeled with orientations with green arrows.

12. Click Save Button

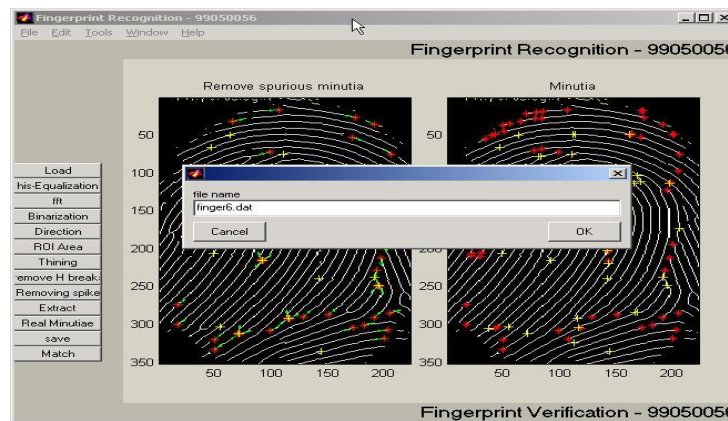


Figure M.13 Save minutia to a text file. The saved text file stores the information on all genuine minutia. The exact format of the files are explained in the source code.

13. Click Match Button

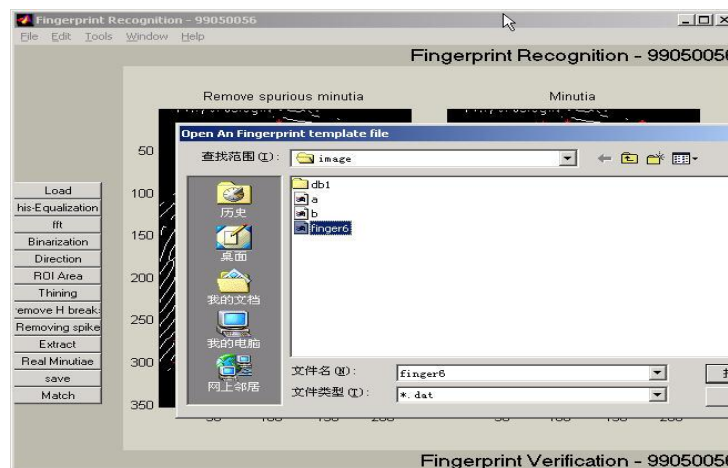


Figure M.14 Load two minutia files and do matching. Users can open two minutia data files from the dialog invoked by clicking the 'Match' button. The match algorithm will return a prompt of the match score. But be

noted that matching in the GUI mode is not encouraged since the match algorithm relies on heavy computation. Unpredicted states will happen after a long irresponsive running time. Batch testing is prepared for testing match. Please refer the source files for batch testing.

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