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Region of Interest Segmentation Algorithm for Fingerprint

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Abstract

In this research is implemented segmentation algorithm for the region of interest of fingerprint recognition automatically. In auto finger print identification system, It is difficult to notice similarity for fingerprints because the discontinues spots in fingerprint pattern, bifurcations, lakes, independent ridges, dots and islands and crossover. Thus image enhancement techniques are employed prior to minutiae extraction to obtain a more reliable to estimation of minutiae locations. The normalization fingerprint minutiae extraction has been developed using MATLAB programs and this give very good results in terms of enhancement and accuracy

Keywords:

Fingerprint, image enhancement, sobel filter, minutiae extraction, segmentation , ROI, statistic.

1. Introduction

Robust way is quit hard for matching and extraction salient features, especially for poor quality images. In the last years ago the fingerprint recognition is still important pattern recognition problem. The representation of automated fingerprint. Identification system (AFIS) is based on minutiae such as ridge bifurcation and ending, each minutia characterized by its locations and orientation. The minutiae pattern of each finger is quite unique, noise, distortion during the acquisition and errors appears in extraction process results in a number of spurious minutiae, another problem appear for rotation and displacement of the finger placed on the sensor, and a compression might occur if the pressuring is non-uniformly applied. This leads to change the mapping accordingly and leads to nonlinear affine deformation of fingerprint images[1].

There are a lot of minutiae extraction methods found in the literature. Based on image detection domain, there are roughly four kinds of detection algorithms. First kind of methods extracts minutiae directly from the gray-level image [2,3] without using binarization and thinning processes. Second kind of methods extracts minutiae from binary image profile patterns [4]. Third kind of methods extracts minutiae via machine learning methods [4,5]. The fourth kind of methods extract minutiae from binary skeletons [6,7,8]. Most feature extraction algorithms uses thinning for extraction of minutiae from a fingerprint image [5].. Four types of fingerprint images have been tested. some of testing database is downloaded from internet FVC2002[9] and the others got from traditional procedure .

Fingerprints are distinguished some abnormal points on the ridges of finger which called minutia (Figure 1)[10]. 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. Two representation forms for fingerprints separate the two approaches for fingerprint recognition. The first approach, which is minutia-based, represents the fingerprint by its local features, like terminations and bifurcations. The second approach, which uses image-based methods[11], tries to do matching based on the global features of a whole fingerprint image. The first approach is the backbone of the current study.

The results obtained from reading the image until extraction of the minutiae explained in the next sections.

2. Algorithm Building

Recognition system constitutes of fingerprint acquiring device, segmentation and minutia matcher as shown in (Figure 2).

To implement a minutia extractor, a three-stage approach is widely used by researchers. They are preprocessing, minutia extraction and post processing stage (Figure 3).

2.1 Image preprocessing

2.1.1 Finger Print format

Finger print images are available in the forms (gif, jpg, bmp, etc), (Figure 4) shows an example of the original image being loaded by the system developed. In this study has made transformation image into two dimensional array of pixels. Since the finger print image being studied is of height m, and width n, the two dimensional arrays being considered should have m rows , and n columns. Thus, fingerprint image is represented as the compact matrix form:

$$f(x,y) = \begin{bmatrix} f(0,0) & f(0,1)\ldots & f(0,N-1) \\ f(1,0) & f(1,1)\ldots & f(1,N-1) \\ \vdots & \vdots & \vdots \\ f(M-1,0) & f(M-1,1) & f(M-1,N-1) \end{bmatrix}$$

The coordinate vector of the above matrix **V** is defined as **V= [*f(x, y)***], this vector of 1* (m*n) dimension is used in the processing stage.

2.1.2 Calculate Grayscale Statistics

One of the initial steps of the fingerprint feature extraction process is to determine various grayscale statistics at global and local levels. These statistics are used for image normalization, binarization, and segmentation. Local grayscale information is determined using a local 11x11 pixel mask of equal weight. The grayscale mean, standard deviation, mean of the squares and variances are shown in Equations (1),(2), (3), and (4) respectively.

$$M(x,y) = \sum_{i=-5}^{5}\sum_{j=-5}^{5} G(x+i,y+j) \qquad (1)$$

Where: G =grey scale pixel value at x,y

x=horizontal pixel location in image, y=Vertical pixel location in image.

i=pixel offset in horizontal direction. j=pixel offset in vertical direction.

$$S(x,y) = \frac{\sum_{i=-5}^{5}\sum_{j=-5}^{5} \left(G(x+i,y+j) - M(x+i,y+j)\right)\ \hat{}2}{121-1} \qquad (2)$$

$$MS(x,y) = \frac{\sum_{i=-5}^{5}\sum_{j=-5}^{5} G(x+i,y+j)^2}{121} \qquad (3)$$

$$V(x,y) = (MS(x,y) - M(x,y)\ \hat{}2) * (121/(121-1)) \qquad (4)$$

2. 2 Enhancement

Fingerprint Image enhancement is to make the image clearer for easy further operations. Enhancement methods are increasing the contrast between ridges and furrows and for connecting the false broken points of ridges due to insufficient amount of ink, are very useful for keep a higher accuracy to fingerprint recognition. Histogram equalization is adopted in this paper.

2.2.1 Histogram Equalization

Histogram equalization is to expand the pixel value distribution of an image so as to increase the perceptional information. The original histogram of a fingerprint image has the bimodal type, the histogram after the histogram equalization occupies all the range from 0 to 255 and the visualization effect is enhanced (Figure 5).

2.3 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. 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 are confusing with those spurious minutia that are generated when the ridges are out of the sensor.

The image segmentation task is fulfilled by a three-step approach: Block filtering, Segmentation by direction intensity [12] and Region of Interest extraction by Morphological operations. To extract the ROI, a two-step method is used. The first step is block filtering (Sobel) and direction variety check [13], while the second is intrigued from some Morphological methods.

The results of segmentation shown in figure(6).

Block Filtering(Sobel) In order to estimate the block filtering for each block of the fingerprint image with Z*Z in size(Z is 16 pixels). The algorithm is implemented as:

Step 1: Calculate the gradient values along x-direction (d_x) and y-direction (d_y) for each pixel of the block. Two Sobel filters are used to fulfill the task.

Step 2:For each block, use Following formula to get the Least Square approximation of the block filtering.

$$\tan 2\beta = \frac{2\sum\sum\left(d_x d_y\right)}{\sum\sum\left(d^2{}_x - d^2{}_y\right)}$$ for all the pixels in each block. (5)

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 filtering is estimated nearly the same as the way illustrated by the following formula.

$$tan\, 2\,\theta = 2\, sin\,\theta\, cos\,\theta / (cos\,\theta^2 - \, sin\,\theta^2) \qquad (6)$$

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

$$\boldsymbol{K} = \frac{\left[2\sum\sum(d_x * d_y) + \sum\sum\left(d_{x2} - d_{y2}\right)\right]}{Z * Z * \sum\sum\left(d_{x2} + d_{y2}\right)} \qquad (7)$$

For each block, if its certainty level is below a threshold, then the block is regarded as a background block. The direction map is shown in the (figure 7) .

2.3.1Region of Interest

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

2.4 Normalizing

The fingerprint image is normalized to change the range of pixel intensity values to compensate for poor contrast in the image. The normalized image is then processed by a Sobel filter in the next step to determine the image gradients, which ultimately allows the local ridge orientation to be created. Normalizing an image does not require an image mask, and is determined using the formulas listed in Eq.(8).Where *G(x,y)* represents the grayscale image, *M(x,y)* represents the local mean grayscale value, *V(x,y)* represents the local grayscale variance, *mean* represents the global mean grayscale value, and *variance* represents the global grayscale variance. The final normalized image is shown as *N(x,y)* The formulas for global mean and variance are similar to the local mean and variance formulas listed in Eq.(1) and Eq. (4). However, the formulas are applied to the entire image versus a local area.

$$D(x,y) = G(x,y) - M(x,y) \quad (8)$$

$$if\ \left(d(x,y)\right) > 0$$

$$N(x,y) = mean + \sqrt{\left(Variance * D(x,y) * D(x,y)\right) / V(x,y)} \quad (9)$$

Otherwise:

$$N(x,y) = mean - \sqrt{\left(Variance * D(x,y) * D(x,y)\right) / V(x,y)} \quad (10)$$

2.5 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.

2.5.1 Threshold Algorithm

The input image is segmented from the background which ensures the removal of noise. For this, the whole image is divided into blocks of size 16×16 and the variance of each block is computed. The variance is then compared with the threshold value. If the variance of a block is less than the threshold value, then it is deleted from the original figure. This process is carried out for the whole image. The image obtained from the above step is then normalized to get the desired variance of the given image. The normalized image is given by The following steps are taken to calculate the standard deviation:

1- The mean Mg is calculated.

The mean and variance of gray level fingerprint image I, are defined as:

$$Mg(I) = \frac{1}{N*M}\sum_{i=0}^{N-1}\sum_{j=0}^{M-1} I(i,j) \qquad (11)$$

$$\sigma g(I) = \frac{1}{N*M}\sum_{i=0}^{N-1}\sum_{j=0}^{M-1} \left(I(i,j) - Mg(I)\right)^2 \qquad (12)$$

2- The variance σ g Variance is the square of the standard deviation.

2.5.2 The standard deviation

$$\sigma_G^2 = \sqrt{\sigma_G^2}$$

This is used to convert a grayscale vector $\boldsymbol{C_g}$ to a binary vector $\boldsymbol{C_b}$ Each pixel is assigned a new value one or zero according to the standard deviation.

C_b= [b(x, y)], where b(x, y)= 1, otherwise if b(x, y) >= σ g, b(x, y)= 0.

A standard deviation 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 8).

In this Algorithm, grayscale vector C_g is divided into 16 blocks.(Figure 8) shows eight blocks of size m*n/16 each taken from the grayscale. More precisely,$C_g$vector is divided into 16 *vectors* of length m*n/16 each C b$_{\boldsymbol{i}}$, i = 0 to 15.

Normalization vector $\boldsymbol{C_n}$ is defined as a function of standard deviation as follows:

$if\ \ C_g(x_i, y_i) > M_g \qquad then$

$$C_n(x_i, y_i) = Mcb_i + \sigma_{cb_i}^2\left(C_g(x_i, y_i)\right) - M_g/\sigma_{cg}^2 \qquad (13)$$

Else

$$C_n(x_i, y_i) = Mcb_i - \sigma_{cb_i}^2\left(C_g(x_i, y_i)\right) - M_g/\sigma_{cg}^2 \qquad (14)$$

The statistics reading of mean, standard deviation and variance are shown in table(1).

Table (1): Statistics of mean, standard deviation, variance

Mean	Standard deviation	variance	Minimum	Median	Maximum
12.8	0.90	1.80	11	13	15
14.6	.085	.170	12	15	16

3. Algorithm

3.1 Morphological thinning

Ridge Thinning is to eliminate the redundant pixels of ridges till the ridges are just one pixel wide, the result of thinning operation is shown in (figure 9). In this study the Morphological thinning function in MATLAB is used in each scan of the full fingerprint image, the algorithm marks down redundant pixels in each small image window (3x3). And finally removes all those marked pixels after several scans. The thinned ridge map is then filtered by other three morphological operation to remove some false minutiae, isolated points and spikes depends on the inter ridge distance.

3.2 Marking

Marking is marking minutia points, go after the thinning operation. 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 (Figure 10.a). If the central pixel is 1 and has only 1 one-value neighbor, then the central pixel is a ridge ending (figure 10.b). A special case that a genuine branch is triple counted illustrated in (Figure 10.c). Suppose both the uppermost pixel with value 1 and the rightmost pixel with value 1 have another neighbor outside the 3x3 window, so the two pixels will be marked as branches too. But actually only one branch is located in the small region. So a check routine requiring that none of the neighbors of a branch are branches is added.

4. Post-Processing

False Removal

The preprocessing stage does not totally heal the fingerprint image. For example, false ridge breaks due to insufficient amount of ink and ridge cross-connections due to over inking are not totally eliminated. Actually all the earlier stages themselves occasionally introduce some artifacts which later lead to spurious minutia. These false 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. Seven types of false minutia are specified as shown in (figure 11).

M1 is a spike piercing into a valley. In the M2 case a spike falsely connects two ridges. M3 has two near bifurcations located in the same ridge. The two ridge broken points in the M4 case have nearly the same orientation and a short distance. M5 is alike the M4 case with the exception that one part of the broken ridge is so short that another termination is generated. M6 extends the M4 case but with the extra property that a third ridge is found in the middle of the two parts of the broken ridge. M7 has only one short ridge found in the threshold window.

5. Results and discussion

The results which gain from each stage using enhancement algorithm is goal of this application. The matching algorithm of fingerprint image is performed depends critically on the quality of input fingerprint images.

A large numbers of spurious minutiae may be created, and a large errors in minutiae localization (position and orientation) may be generated therefore to ensure that the performance of the minutiae extraction algorithm is robust with respect to the quality of fingerprint images, an enhancement algorithm with standard deviation normalization are used. The method contains three steps: preprocessing (Enhancement, Segmentation and Binarization), extraction of minutia and post-processing to remove the superior minutia.

The procedures in removing false minutia are:

1. If the two minutia of bifurcation and termination are in the same ridge (M1 case) and the distance between one of them is less than D removing them. D is the average inter-ridge width representing the average distance between two parallel neighboring ridges.
2. Removing the two bifurcations (M2, M3 cases) if the distance between two bifurcations in the same ridge is less than D ridge,
3. two terminations will be removed and regarded as false minutia derived from a broken ridge (case M4,M5, M6) if they are a located within a distance D and their directions are coincident with a small angle variation, in case no other termination between them.
4. Removing two terminations (M7), if both of them are located in a short ridge with length less than D.

The proposed procedures in removing false minutia have two benefits. One is that the ridge ID is used to distinguish minutia and the seven types of false minutia are strictly defined comparing with those loosely defined by other methods. The second benefit is that the order of removal procedures is well considered to reduce the computation complexity. It surpasses the way adopted by [8] 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. Two case study are presented. The result of these cases are seen in (figure 12) .

6.Conclusions

In this paper implementation of segmentation algorithm for Regain of Interest of fingerprint recognition by using a standard deviation algorithm which used to estimate the finger profile based on a selection of ridge pixels from a fingerprint image.

All stages of the fingerprint recognition is performed by using MATLAB programming. It is useful to understand the procedures of fingerprint recognition, and demonstrate the key issues of fingerprint recognition.

استخدام خوارزمية التقطيع للمنطقة المختارة لتمييز بصمة الإصبع

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الخلاصة:

تم اعتماد طريقة استخلاص المعلومات للمنطقة المختارة باستخدام خوارزمية التقطيع لتمييز بصمة الإصبع بصورة أوتوماتيكية. ومن الملاحظ انه من الصعب جدا" وجود تشابه في بصمات الأصابع لطبيعة اختلاف الجلد للأصابع والظروف البيئية المحيطة بالإصبع أثناء اخذ البصمة له.وان الدقائق مهمة جدا" حيث انه توجد نقاط منفصلة لبصمة الأصبع كنهايات,خطوط,تشعبات,بحيرات,نهايات مستقاة وغيرها مثل حواف بارزة....تم استخدام الحقيبة البرمجية الماتلاب لتحقيق هذا الأمر في بناء النظام الهيكلي للبحث وتم الحصول على نتائج ممتازة ودقيقة من كافة النواحي بالنسبة للوقت المطلوب والكفاءة.

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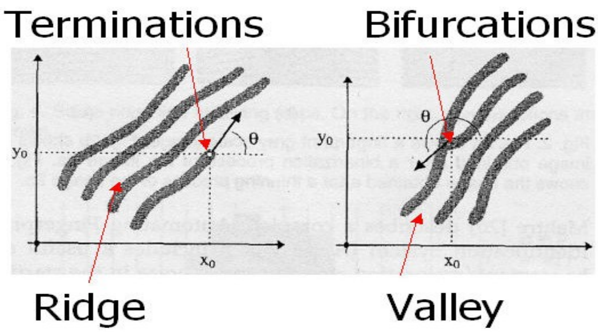
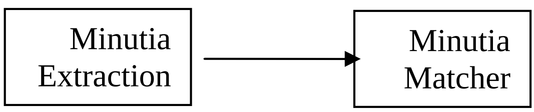


Fig.1 Termination &Bifurcation points



2: Fingerprint identification system

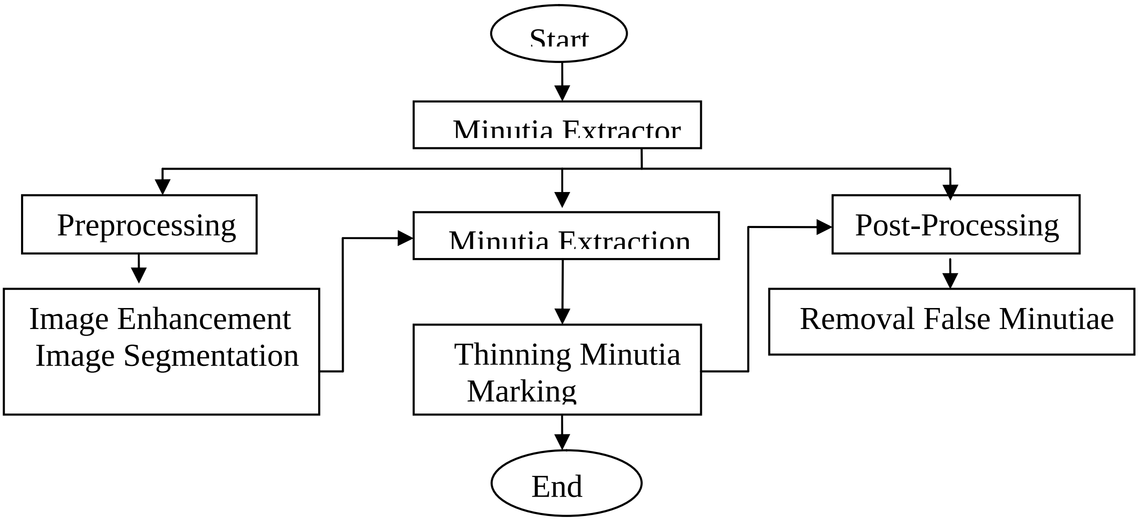


Fig. 3: Analysis Procedure

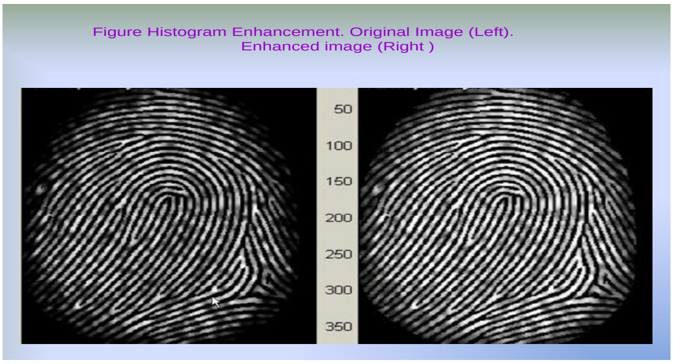
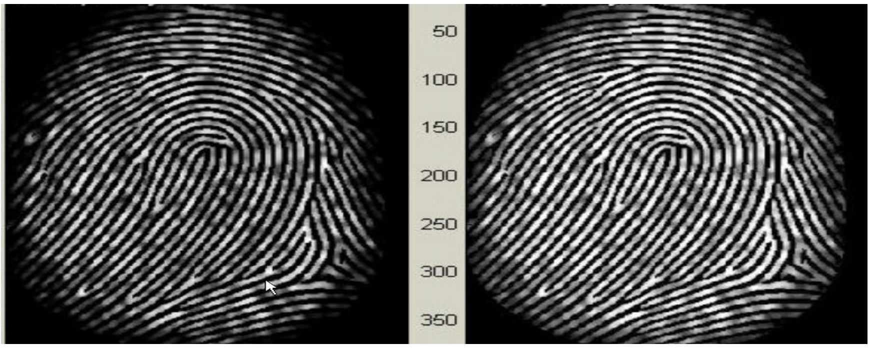


Fig.4:Original Fingerprint Image(case)



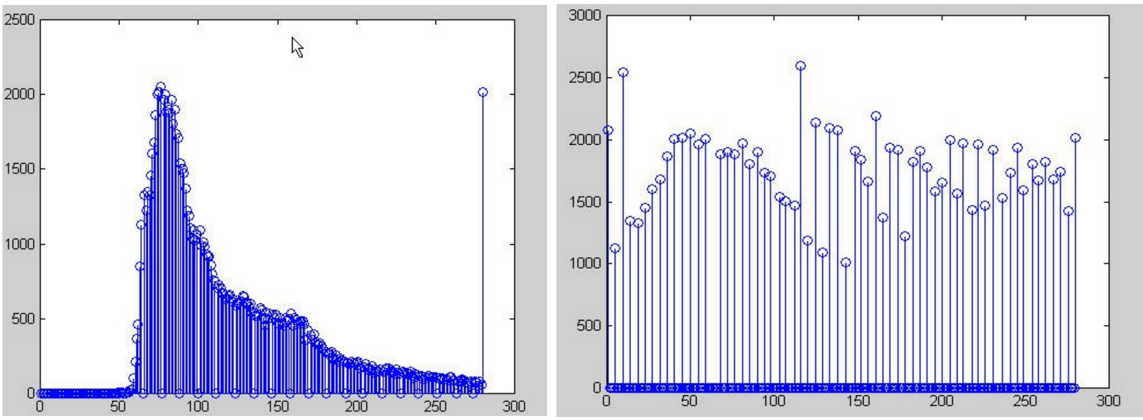


Fig.5: The original histogram and histogram equalization

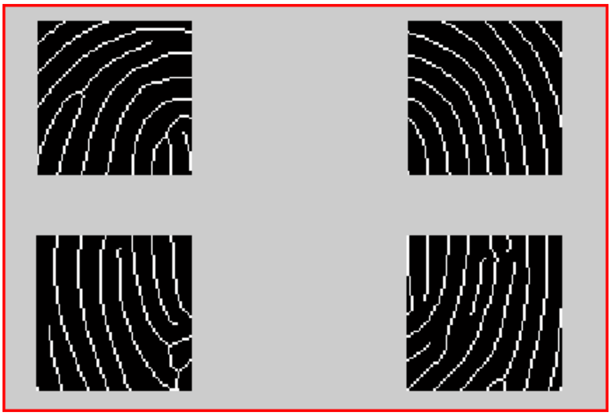


Fig.6: Segmentation process

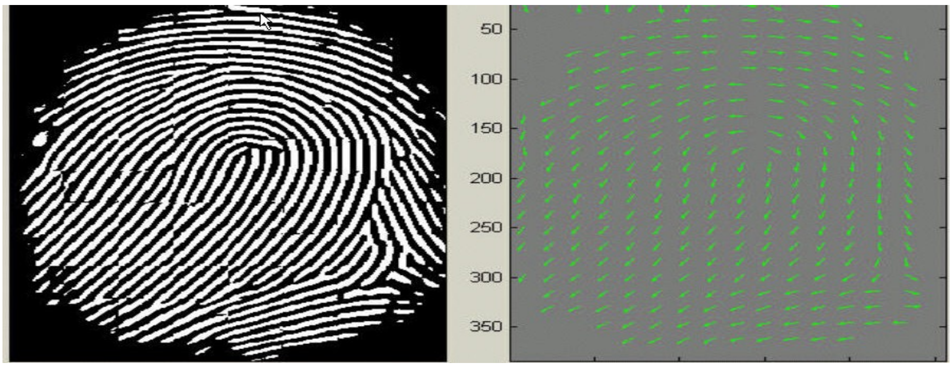


Fig 7: Direction map. Binarized fingerprint (left), Direction map (right)

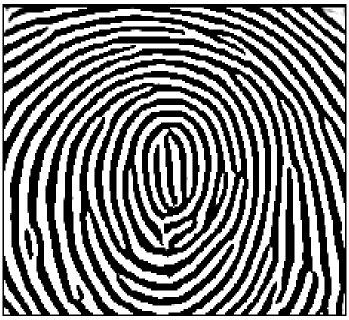
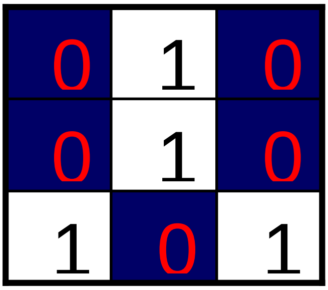
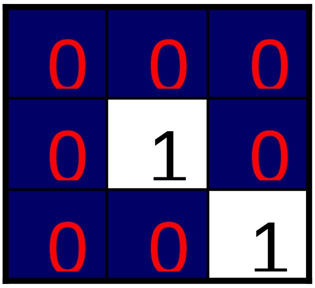


Fig. 8: Fingerprint image after adaptive binarization Binarized image(left), Enhanced gray image(right)

Fig.9: Thinning image





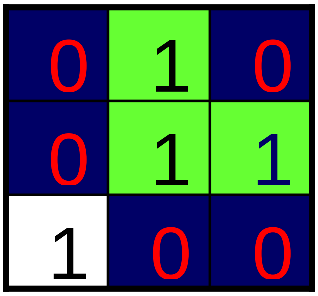


Fig. 10:a. Bifurcation **b. Termination** **c. Triple counting**

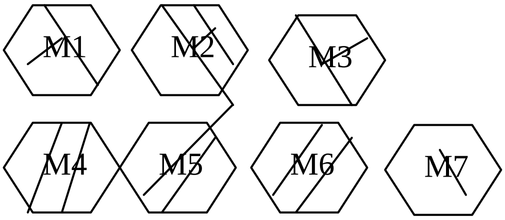


Fig. 11:False Minutiae Structure

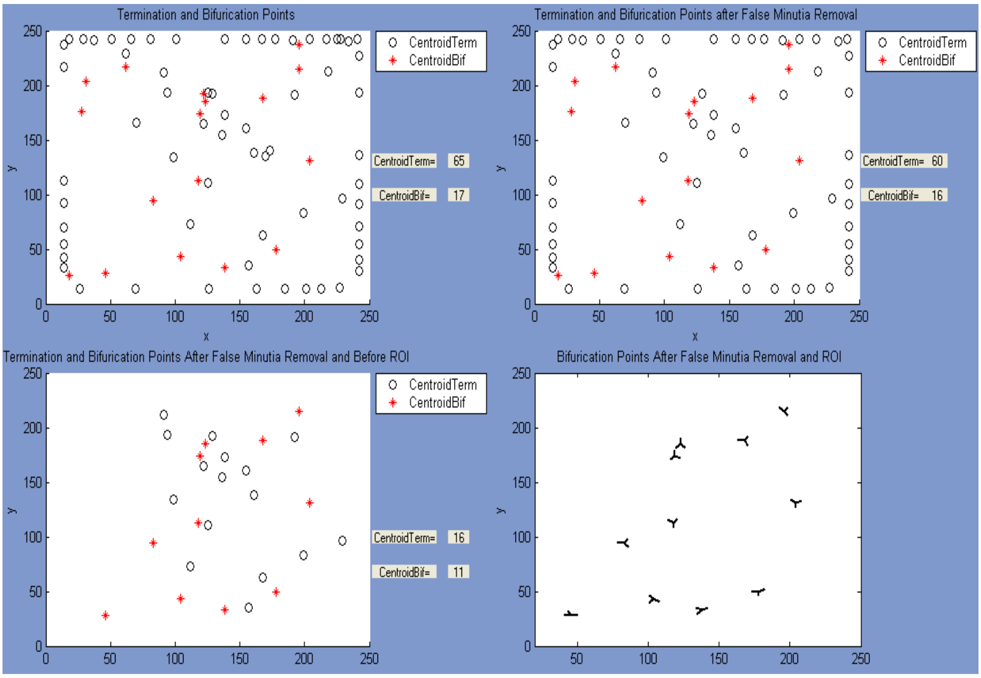


Fig.12: Fingerprint minutia (Termination and Bifurcation)