

Fingerprint Image Segmentation Using Hierarchical Technique

Wan Aezwani Wan Abu Bakar, Ghazali Sulong
Department of Graphics & Multimedia
Faculty of Computer Science & Information System
Universiti Teknologi Malaysia
81310 UTM Skudai
Johor.

aezwani@fsksm.utm.my, ghazali@fsksm.utm.my

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ABSTRACT

Fingerprints are the ridge and furrow patterns on the tip of the finger and its verification is an important biometric technique for personal identification. The quality of the fingerprint image is the most significant factor in a reliable matching process. Thus, any pre-processing algorithm should aim to enhance the quality of the existing features without creating false features [1]. This scenario brings the idea of the research. The research focus on the segmentation approach. The purpose of the study is to identify a segmentation approach of fingerprint image by considering several approaches namely Hierarchical technique and Region growing by pixel aggregation technique. The process is vital when to apply next pre-processing stages i.e. thinning, identifying between true and false minutiae and minutiae extraction process. The research is supported by 50 samples of data that is collected through an available fingerprint device.

1.0 INTRODUCTION

The beginning of the fingerprint is not known. But for certain, there are definite periods in its history. The first period started when human beings become aware of fingerprint that such fingerprint is used as a mean of individual

signature. The second period then started with the development of fingerprint coding and filing system and technique of searching for latent prints [1].

Starting on 1960s, Federal Bureau of Investigation (FBI) and Paris Police Department had made a big investment to support the development of Automated Fingerprint Identification System (AFIS) which is the system to identify the fingerprint matching. Their effort were so successful that a large number of AFIS's are currently installed and in operation at law-enforcement agencies world-wide. These systems have greatly improved the operational productivity of these agencies and reduced the cost of hiring and training human fingerprint experts for manual fingerprint identification. Automatic fingerprint identification rapidly grew beyond law enforcement into civilian application. In fact, fingerprint-based biometric systems are so popular that they have almost become the synonym of biometric systems. Refer to Figure 1.1 to denote a schematic block diagram of an AFIS [4].

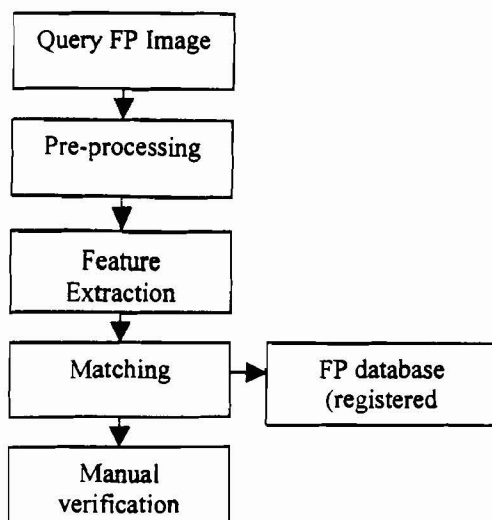


Figure 1.1 : Schematic Block Diagram of an AFIS

Currently, there are nine biometric technology [3] include fingerprint, face, hand geometry, hand vein, retinal pattern, iris, signature, voice print and also facial thermograms. Of the nine technology, nevertheless not many of them are acceptable as indisputable evidence of identity i.e. extensive studies have been conducted on automatic face recognition and number of face recognition system available, yet it has not been proved that face can be used reliably to establish identity. Moreover, although signatures also are legally acceptable biometric, they rank a distant second to fingerprints due to the issues involved with accuracy, forgery and behavioural variability.

1.1 Biometric Overview

Any human physiological or behavioural characteristic can be used to make a personal identification as long as it satisfies following requirements [3] : Universality means that every person should have the characterisation; Uniqueness indicates that no two person should be the same in terms of characteristics; Permanence means that characteristics should be invariant with time; Collectability indicates that the characteristics can be measured quantitatively.

Biometrics is a rapidly evolving technology that has been widely used in forensics such as criminal identification and person security and

has the potential to be widely adopted in a very broad range of civilian applications as in banking security such as electronic fund transfers, ATM security, check cashing, and credit card transaction; Physical access control such as airport access control; Information system security such as access to databases via login privileges; Government benefits distribution such as welfare disbursement programs.

1.2 Statement of the problem

Fingerprint recognition remains as one of the most prominent biometric identification methods. The quality of the fingerprint image is the most significant factor in a reliable matching process. Any pre-processing algorithm should aim to enhance the quality of the existing features without creating false features. The main objectives of this research proposal are :

- To identify techniques involved in segmentation process that is to be applied in fingerprint images.
- To evaluate and analyse the robust segmentation techniques which is to be used in fingerprint recognition methodology.

To propose a technique for fingerprint image segmentation, the author has taken into a great consideration about the field in image processing and pattern recognition area. The theoretical framework of this research is shown in Figure 1.2. The dotted line indicates the focus area of the research.

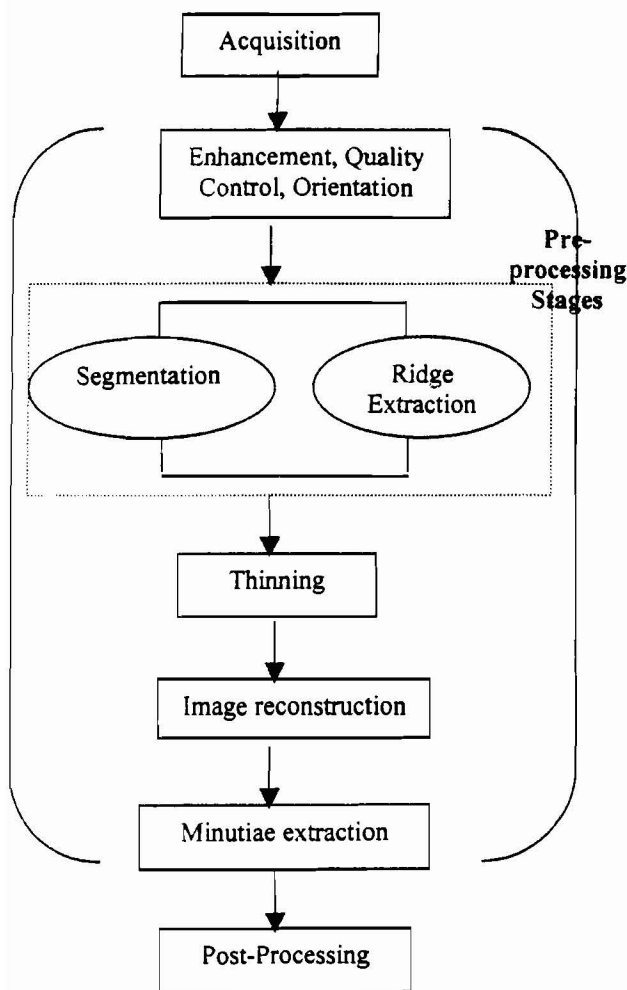


Figure 1.2 : Schematic Block diagram of fingerprint image processing

2.0 LITERATURE REVIEW

2.1 Fingerprint Image Segmentation Methodology

Segmentation is the process to split between the background (set to 0) and the foreground (set to 1) in a binary version. The process is done to indicate a clear features i.e. ridge and valley of a fingerprint image. The goal of segmentation is to pre-process the noisy fingerprint to be enhanced by removing the noise. It extracts the binary version out of the enhanced fingerprint image. There are several possible methods, which have been reviewed by the author during the literature. The methods are given as follows :

2.1.1 Hierarchical Technique

According to [2], using the hierarchical technique is best suited for the image orientation, thus ease of segmentation process. By dividing the two blocks i.e. 8x8 and 16x16, the first block 8x8 is to view the micro-ridges of image whereby the second block 16x16 is to indicate the much clearer to view the macro-ridges of image. The orientation field of a fingerprint image represents the intrinsic nature of the fingerprint image. It plays a very important role in fingerprint image analysis. A new hierarchical algorithm, genuinely proposed by [3], a fairly smooth orientation field estimate can be obtained. After the orientation field of an input fingerprint image is estimated, a segmentation algorithm, which is based on local certainty level of the orientation field, is used to locate the region of interest within the input fingerprint image. The *Certainty Level (CL)* of the orientation field at pixel (i,j) is defined as follows :

$$CL(i, j) = \sqrt{\frac{1}{w \times w} \frac{(V_x(i, j))^2 + V_y(i, j)^2}{V_e(i, j)}}$$

$$\text{where } V_e(i, j) = \sum_{u=i-\frac{w}{2}}^{i+\frac{w}{2}} \sum_{v=j-\frac{w}{2}}^{j+\frac{w}{2}} (G_x^2(u, v) + G_y^2(u, v))$$

where W is the size of a local neighbourhood. For each pixel, if its certainty level of the orientation field is below a certain threshold, T, then the pixel is marked as background pixel.

2.1.2 Region growing by Pixel Aggregation

Let R represent the entire image region. Segmentation is viewed as a process that partitions R into n subregion R_1, R_2, \dots, R_n such that :

- i. $\cup R_i = R_1..R_n$
- ii. R_i is connected region, $i = 1, 2, \dots, n$
- iii. $R_i \cap R_j = \emptyset$ for all i and j, $i \neq j$
- iv. $P(R_i) = \text{TRUE}$ for $i = 1, 2, \dots, n$
- v. $P(R_i \cup R_j) = \text{FALSE}$ for $i \diamond j$

$P(R_i)$ is a logical predicate over the points in set R_i and \emptyset is the null set. Condition (i) indicates that the segmentation must be completed i.e. every pixel must be in region. Condition (ii) requires that points in region must be connected. Condition (iv) indicates that the region must be satisfied by the pixels in a segmented region for e.g. $P(R_i) = \text{TRUE}$ if all pixels in R_i have the same intensity. Finally condition (v) indicates that regions R_i and R_j are different in the sense of predicate P .

According to [1], region growing is a procedure that pixels or subregions are grouping into larger regions. The simplest of these approaches is pixel aggregation, which start with a set of 'seed' points and from these grows regions by appending to each seed point those neighbouring pixels that have similar properties (such as gray-level, texture, colour). To illustrate, let consider in **Figure 2.1 (a)** where the number inside the cells represent gray-level values (0 – 255). Let the points with coordinates (3,2) be used as seeds. Using 2 starting points result in segmentation consist of at most 2 regions :

- R_1 associated with seed (3,2)
- R_2 associated with seed (3,4)

The property P to be used to include a pixel in either region is that the absolute difference between gray-level of that pixel and the gray-level of the seed be less than threshold, T . Any pixel that satisfies this property simultaneously for both seed is arbitrarily assigned to region R_1 . **Figure 2.1 (b)** shows the result obtained using $T=3$. In this case, the segmentation consist of 2 regions where the points in :

- R_1 denotes A's
- R_2 denotes B's

0	0	5	6	7
1	1	5	8	7
0	1	6	7	7
2	0	7	6	6
0	1	5	6	5

Figure 2.1 (a) : original

A	A	B	B	B
A	A	B	B	B
A	A	B	B	B
A	A	B	B	B
A	A	B	B	B

Figure 2.1 (b) : segmentation result using an absolute difference of less than 3 between intensity levels

3.0 RESEARCH DESIGN

The research procedures are subjected to the following methodology. At first fingerprint image is live-scanned through a Biometric Scanner-Veridicom Passprint device and manual scanned through HP Deskscan II. The number of images are restricted to 50 images in TIFF (Tagged Image File Format). Secondly the noise on image is removed through Median Filtering technique 3x3 and image is then enhanced through HighBoost1 and HighPass1 technique. Then the gray-level histogram is plotted and quality control process is done. After that image orientation is estimated. Then the image segmentation process is undertaken. Algorithm is coded using Delphi 3.0 and run the successfully compiled program on the domain images. The result of segmentation techniques is analysed and validated to be ease of use in the forwarding image processing stages.

4.0 RESULT AND DISCUSSION

4.1 Result of Segmentation Process

Segmentation process can be done with or without orientation process. In hierarchical technique, the images have to be processed through noise removal by median filtering, enhancement by HighBoost1 filtering, QC check, orientation regarding to 4 different blocks (i.e. 4x4, 8x8, 16x16, 32x32) before locating the region of interest and segmentation can be done. For example, when segmenting the same image, the effect of segmentation process can be seen at the location of the region of interest (ROI) regarding to the 4 different blocks. 4x4 block showed the most fine-grained ROI at image pixel as compared to the other 3 blocks i.e. 8x8, 16x16 and 32x32 (refer to **Figure 4.1**).

By contrast, based on region growing by pixel aggregation technique, each image has to be processed through noise removal by median filtering 3x3, enhanced by HighPass1 filtering. Next QC check and segmentation processes are done, discarding the orientation process because it shows the wrong effect if the orientation process is undertaken. In this technique, the image is segmented by 3 randomly chosen threshold values i.e. 59, 63, and 71. The effect of segmentation process can be seen when the image is enhanced by HighPass1 filtering versus HighBoost1 filtering.





Block	Location of ROI
4 X 4	
8 X 8	
16 X 16	
32 X 32	

Figure 4.1 : Location of ROI and its segmentation according to 4 different division of blocks (parameter : median 3x3, HB1, threshold value = 93)

4.2 System Analysis

The tested fingerprint images are obtained from 5 individuals with 10 fingers per individual. By using live-scan from Biometric-Scanner Veridicom Passprint, there are restrictions on the position and orientation of fingers imposed. This is because the scanner's screen capture is small and restricted to 300 x 300 dpi per image, thus it is not suitable to capture the individual's thumb print due to the natural size of thumb is bigger than other fingers. Thus, altogether from the 5 individuals, there are 40 (5 X 8) images. The images of the thumbs are rolled manually by ink and scanned through HP Deskscan II. In this way, no restrictions on the position and orientation of fingers were imposed and altogether from the 5 individuals, there are 10 (5 X 2) images of thumbs.

There are drawbacks from both acquisition methods. In the live-scan method, the images often contain extraneous objects like black dots, holes and other artifacts which are common due to dirt on the scanner's screen capture. While in the rolled method, the images often blur (under-inked) or too black (over-inked) and the fingers are not rolled and impressed properly.

4.2.1 Quality Control test

Quality control check depicts the image in a gray-level histogram. Refer to Figure 4.2 (a) and Figure 4.2 (b) for examples of quality check on good and poor images.



Figure 4.2 (a) : Quality control check for good image before enhancement process

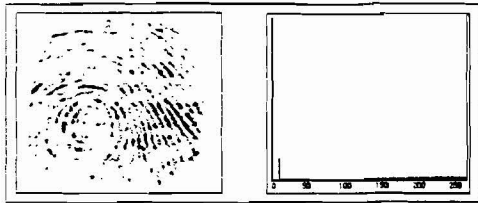


Figure 4.2 (b) : Quality control check for poor image before enhancement process

When the 50 images are passed through quality control check, 84% (42 images) of fingerprint images in the database are of reasonable quality (accepted). These 42 images are accepted mainly because the images are impressed properly which resulted in the average percentage of black and white pixel areas though there's still dirt on the scanner's screen capture. While only 16% (8 images) of them are not of good quality (rejected). This is mainly due to large creases and smudges in ridges, dryness, over-inked or under-inked of the impressed fingers. Refer to Table 4.1 to see the percentage of *False Acceptance Ratio (FAR)* and *False Rejection Ratio (FRR)*.

Table 4.1 : FAR and FRR of images after QC

Sample	Quality Control		FAR (%)	FRR (%)
	Accept	Reject		
50	42	8	84	16

4.2.2 Orientation test

It is proved that only image orientation on block 8 X 8 is suitable for a good image such that the orientation can be displayed in a fine-grained level, while image orientation on block 16 X 16 is suitable for image with bold ridges such that the orientation can be displayed in a coarse-grained level (refer to Figure 4.3)

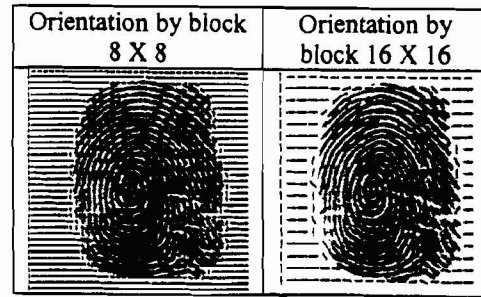






Figure 4.3 : Orientation test result

4.2.3 Segmentation test

Segmentation test is covered regarding to two techniques, which have been discussed earlier. By using hierarchical technique, the region of interest is located differently based on 4 corresponding blocks as shown in Figure 4.1. The result can be measured by concerning the quality versus processing time as shown in Table 4.2. The table shows that the region of interest (ROI) segmented by blocks 4x4 and 8x8 are better in quality but more time is taken with 75 milliseconds for block 4x4 and 37.5 milliseconds for block 8x8. But the ROI for images by blocks 16x16 and 32x32 are lower in quality but better in processing time with 18.75 milliseconds for block 16x16 and 9.375 milliseconds for block 32x32. Thus, the average measure for locating ROI by this technique can be chosen on image with block 16x16 with average in quality and processing time taken.

Table 4.2 : Processing time vs quality by Hierarchical technique

Block	Average Processing time (millisec)	Example of Quality of ROI
4x4	75	
8x8	37.5	

16x16	18.75	
32x32	9.375	

On the other hand, by using region growing by pixel aggregation technique, the result of segmentation differed based on 3 different threshold values i.e. 59, 63 and 71. In this technique, segmentation process is tested based on 2 cases which are RG by HP1 as shown in Table 4.3 (a) and RG by HB1 as shown in Table 4.3 (b). The 4 range checks are considered as follows :

- 0-50 indicates the black pixel area,
- 108-128 indicates the less gray pixel area,
- 140-200 indicates more gray pixel area,
- 210-255 indicates white pixel area.

In the first case (i.e. RG by HP1), Table 4.3 (a) depicts that the percentage of black pixel area is 34% with 65% of white pixel area if the threshold is 59. The percentage of black and white pixel areas are also the same if the threshold value is 63. But for the threshold value of 71, the percentage of black pixel area is 33% with 66% of white pixel area. This means that the segmented images can be accepted because the black and white pixel areas are not very distinct in percentage.

In the second case (i.e. RG by HB1), Table 4.3 (b) depicts that the percentage of black pixel area is 98% with 1% of white pixel area if the threshold is 59. The percentage of black and white pixel areas is also the same if the threshold value is 63 and 71. This means that the segmented images are rejected because the black and white pixel areas are very distinct in percentage.

Table 4.3 (a) : Region growing by HP1

Range check \ Threshold	0-50 Black	108-128 less Gray	140-200 more gray	210-255 white
59	34%	0%	0%	65%
63	34%	0%	0%	65%
71	33%	0%	0%	66%

Table 4.3 (b) : Region growing by HB1

Range check \ Threshold	0-50 Black	108-128 less Gray	140-200 more Gray	210-255 white
59	98%	0%	0%	1%
63	98%	0%	0%	1%
71	98%	0%	0%	1%

To recapitulate, segmentation process can be measured in terms of processing time and quality of the segmented image. In the *hierarchical technique*, a scientific measurement can be obtained from the location of ROI. The location of ROI differed in processing time and quality based on the 4 different blocks (i.e. 4x4, 8x8, 16x16 and 32x32). Among those blocks, the effects in locating ROI are shown as follows :

- If using 4x4 blocks, more processing time is needed but best in quality.
- If using 8x8 blocks, less processing time is needed but lower in quality than (i).
- If using 16x16 blocks, more less processing time is needed but lower in quality than (ii).
- If using 32x32 blocks, the least processing time is needed but the lowest in quality of ROI among all.

The result of ROI by hierarchical regarding to the 4 different blocks is given as follows :

- By using *block 32x32* it is most acceptable in terms of lowest processing time and it is still acceptable in terms of quality by visual representation but not in the machine processing.
- By using *block 4x4*, it is still acceptable in terms of processing time and it is most acceptable in terms of quality by visual representation since it displays

the most discrete ROI. But the problem is the quality if it is by machine processing such that the ROI which it displays maybe is not merely true, it is because the ridges is disjointed.

- By using *block 16x16* it is more acceptable in terms of processing time and it is still acceptable in terms of quality by visual representation as well as machine processing.
- By using *block 8x8*, it is still acceptable in terms of processing time and it is more acceptable in terms of quality by visual representation as well as machine processing.

Thus, as a conclusion for the hierarchical technique, the result of best ROI can be displayed is by using block 16x16 and block 8x8. This is because the block 16x16 gives an average measurement in processing time while block 8x8 gives an average measurement in quality.

Meanwhile, in the *region growing by pixel aggregation technique*, the measurement of segmented image can only be obtained by predicting a threshold value on every image. This means that the threshold values will determine the quality of how good the segmented images are. Thus by predicting the threshold value, the segmented images can still be obtained but not in an efficient way. The processing time for segmentation process by this technique is not significantly different from hierarchical technique. Thus, as a conclusion, the segmentation process by region growing by pixel aggregation is unpredictable since it can be measured in a theoretically but not in scientifically. Based on experimental results, the hierarchical technique by blocks 16x16 and 8x8 is suitable than region growing by pixel aggregation technique for fingerprint image segmentation.

5.0 CONCLUSION

Detecting bad quality images, treating the finger with proper remedies (e.g. application of moisturizer), applying the screen capture with appropriate toner and subsequent recapturing of the fingerprint images are some of the useful strategies to improve the system performance. The result of good image acquisition will

improve the performance in segmentation process.

Regarding segmentation by hierarchical techniques, the image has to be processed through noise removal, enhancement by HBI, orientation and then segmentation is undertaken. During the orientation, image is best be viewed by 8x8 and 16x16 block region because the orientation line is mapped in a fine-grained way. But during the segmentation process, as opposed to the orientation stage, the region of interest of each image is best viewed by block 8x8, if the quality is going to be concerned. While the region of interest of each image is best be viewed by block 16x16 if the processing time is going to be concerned. This segmentation technique can efficiently be applied to the next process i.e. extract minutiae and thinning process of fingerprint images.

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