FINGERPRINT IMAGE SEGMENTATION BASED ON BOUNDARY VALUES

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Abstract: A critical step in automatic fingerprint identification system(AFIS) is the accurate segmentation of fingerprint images. The objective of fingerprint segmentation is to extract the region of interest(ROI). We present a method for fingerprint segmentation based on boundary area gray-level values. We also present a modified traditional gradient based segmentation technique. The enhanced segmentation technique is tested on FVC2004 database and results show that our modified method gives better results in all cases.

1 INTRODUCTION

Fingerprint recognition is regarded as the most popular biometric technique for person identification. A fingerprint is a pattern of parallel ridges and valleys on the surface of fingertip (Zhou and Gu, 2004). Most Automatic Fingerprint Identification systems(AFIS) are based on local ridge features; ridge ending and ridge bifurcation, known as *minutiae*(A.K Jain and Boole, 1997). Segmentation of fingerprint image is the most important part of AFIS. Feature extraction algorithms extract a lot of false features when applied to the noisy background area. The purpose of segmentation is to remove the noisy area at the borders of fingerprint image. It is especially important for the reliable extraction of fingerprint features. Figure 1 shows fingerprint segmentation. There are two

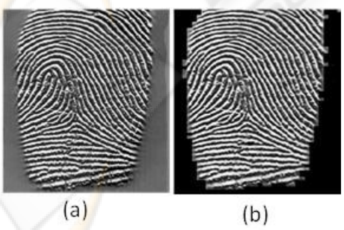

Figure 1: (a) Original Image (b) Segmented image.

types of fingerprint segmentation algorithms: unsupervised and supervised. In Unsupervised algorithms, block wise features such as local histogram of ridge orientation (Mehtre and Chatterjee, 1989),(Mehtre, 1987), gray-level variance, magnitude of the gradient in each image block (N.K.Ratha and A.K.Jain, 1995), Gabor feature (F.Alonso-Fernandez, 2005),(A.Bazen and S.Gerez, 2001) are extracted. Supervised method first extracts several features like coherence, average gray level, variance and Gabor response (E.Zhu, 2006), then a simple linear classifier is chosen for classification. Figure 2 shows the sample fingerprint images from set B of FVC2004 database(FVC, 2004).

Figure 2: Fingerprint images from FVC2004 database.

There are by far many algorithms focusing on the segmentation of fingerprint image. A method based on local certainty level of the orientation field was described in (A. K. Jain and Bolle, 1997). In (Maio and Maltoni, 1997) the average gradient on each block is computed which is expected to be high in the foreground and low in the background. In (A.Bazen and S.Gerez, 2001) gradient coherence, gray intensity mean and variance are also used in segmentation. The segmentation technique presented in (Lin-Lin Shen and Koo, 2001) is based on Gabor filters. All previous methods have some problems in different cases especially when it is difficult to distinguish between foreground and background. In this paper we have proposed a method which uses traditional tech-

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niques based on mean, variance, gradient and ridge orientation. This method takes decision on the basis of boundary area gray-level values.

This paper is organized in five sections. Section 2 presents the traditional segmentation techniques and shows where they are good and where they fail to segment the image accurately. It also contains our modified gradient based method. Section 3 contains the proposed method for fingerprint segmentation. Experiment results of our technique compared with other techniques are discussed in section 4 followed by conclusion in section 5.

2 SEGMENTATION TECHNIQUES

In AFIS, the processing of the surrounding background in fingerprint image is not necessary and consumes more processing time in all stages. Cutting or cropping out the region that contains the fingerprint feature(ROI) minimizes the number of operations on the fingerprint image.

2.1 Mean and Variance based Method

Steps for this method are summarized as follows:

1. Divide the input image I(i,j) into non-overlapping blocks with size w x w. in our case w = 8.
2. Compute the mean value M(I) for each block using equation (1)

$$M(I) = \frac{1}{w^2} \sum_{i=-w/2}^{w/2} \sum_{j=-w/2}^{w/2} I(i,j) \tag{1}$$

3. Use the mean value computed in step 2 to compute the standard deviation value std(I) from equation (2)

$$std(I) = \sqrt{\frac{1}{w^2} \sum_{i=-w/2}^{w/2} \sum_{j=-w/2}^{w/2} (I(i,j) - M(I))^2} \tag{2}$$

4. Select a threshold value. If the std(I) is greater than threshold value, the block is considered as foreground otherwise it belongs to background.

   Figure 3 shows the segmented images based on mean and variance method. Images in 2nd row show that this method is good only for light backgrounds.

Figure 3: 1st Row: Fingerprint Images from FVC2004 database, 2nd Row: Mean and Variance Based Segmented Images.

2.2 Modified Gradient based Method

We have modified the traditional gradient based method and steps for our method are summerized as follows:

1. Divide the input image I(i,j) into non-overlapping blocks with size w x w. In our case w = 8.
2. Use histogram equalization to enhance the contrast between background and foreground.
3. Use a 3x3 median filter to reduce the noise in background of the image(Lim and S.Jae, 1990).
4. Compute the gradients $\partial_x(i,j)$ and $\partial_y(i,j)$ at each pixel (i,j)which is the center of the block.
5. Compute the mean values M_x and M_y for x and y component of the gradient using equations (3) and (4) respectively

$$M_x = \frac{1}{w^2} \sum_{i=-w/2}^{w/2} \sum_{j=-w/2}^{w/2} \partial_x(i,j) \tag{3}$$

$$M_y = \frac{1}{w^2} \sum_{i=-w/2}^{w/2} \sum_{j=-w/2}^{w/2} \partial_y(i,j) \tag{4}$$

6. Compute standard deviation for both M_x and M_y using equations (5) and (6)

$$std_x = \sqrt{\frac{1}{w^2} \sum_{i=-w/2}^{w/2} \sum_{j=-w/2}^{w/2} (\partial_x(i,j) - M_x(I))^2} \tag{5}$$

$$std_y = \sqrt{\frac{1}{w^2} \sum_{i=-w/2}^{w/2} \sum_{j=-w/2}^{w/2} (\partial_y(i,j) - M_y(I))^2} \tag{6}$$

7. Compute the gradient deviation using equation(7)

$$grddev = std_x + std_y \tag{7}$$

8. Select a threshold value. If grddev is greater than threshold value, the block is considered as foreground otherwise it belongs to background.

   Figure 4 shows the segmented images based on gradient based method. Images in 2nd row of figure 4 show that this method is good for dark background.

Figure 4: 1st Row: Fingerprint Images from FVC2004 database, 2nd Row: Gradient Based Segmented Images.

2.3 Direction based Method

A fingerprint consists of parallel line structures. The coherence will be considerably higher in the foreground than in the background. The steps for calculating the coherence(Bazen and Gerez., 2000) are summarized as follows

1. Divide the input image I(i,j) into non-overlapping blocks with size w x w. In our case w = 8.
2. Use 3x3 sobel vertical and horizontal masks defined in equations (8) and (9) respectively to compute the gradients$\partial_x(i,j)$ and $\partial_y(i,j)$ and at each pixel (i , j)which is the center of the block.

$$sobelHorizontal = \begin{pmatrix} -1 & 0 & 1 \\ 2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix} \quad (8)$$

$$sobelVertical = \begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix} \quad (9)$$

3. Estimate the local orientation using equations (10), (11) and (12).

$$V_x(i,j) = \sum_{u=i-w/2}^{i+w/2} \sum_{v=j-w/2}^{j+w/2} (\partial_x(u,v))(\partial_y(u,v)) \quad (10)$$

$$V_y(i,j) = \sum_{u=i-w/2}^{i+w/2} \sum_{v=j-w/2}^{j+w/2} \partial_x^2(u,v) - \partial_y^2(u,v) \quad (11)$$

$$V_z(i,j) = \sum_{u=i-w/2}^{i+w/2} \sum_{v=j-w/2}^{j+w/2} (\partial_x(u,v) + \partial_y(u,v))^2 \quad (12)$$

4. Calculate background certainty and orientation field using equation (13)

$$coh = \sqrt{\frac{(V_x^2(i,j) + V_y^2(i,j))}{w^2 * V_z}} \quad (13)$$

5. Select a threshold value empirically. If the coh is greater than threshold value, the block is considered as foreground otherwise it belongs to background.

   Figure 5 shows the segmented images based on direction based method. Images in 2nd row show that this method is good for light background and it gives almost same results as mean and variance based technique.

Figure 5: 1st Row: Fingerprint Images from FVC2004 database, 2nd Row: Direction Based Segmented Images.

3 ENHANCED SEGMENTATION METHOD

In section 2, three methods are discussed and their results are also shown in figures 3, 4 and 5. In this section, we present a method which is summarized as follows

1. Divide the input image I(i,j) into non-overlapping blocks with size w x w. In our case w = 8.
2. Locate the blocks that contains the boundary of the fingerprint image.
3. Compute the gray-level values for those blocks.
4. Set a threshold T almost near to 240(whitish gray color). if block pixels have gray value greater than the threshold, use mean and variance based method or direction based method. Otherwise use gradient based method which is modified in this paper and is discussed in section 2.

Figure 6: 1st Row: Fingerprint Images from FVC2004 database, 2nd Row: Enhanced Method Based Segmented Images.

Table 1: Results and Comparison-I.

Approaches	Accurately Segmented (Numbers)	Accurately Segmented (%)	Poorly Segmented (Numbers)	Poorly Segmented (%)
Mean and Variance	213	66.5	107	33.5
Gradient Based	294	91.8	26	8.2
Direction Based	227	71.0	93	29.0
Enhanced Segmentation	303	94.6	17	5.4

Figure 6 shows the segmented images based on enhanced segmentation method. Images in 2nd row show that this method is good for all quality images.

4 EXPERIMENTAL RESULTS

Our modification is verified on FVC2004(FVC, 2004) database(DB1-B, DB2-B, DB3-B and DB4-B). It contains 320 images of different sizes, scanned with 500 dpi resolution. The technique is also tested on low quality, dry and high pressure fingerprint images. The results are compared with other techniques and they are summarized in table 1 and table 2.The decision for accurate segmentation and poor segmentation is based on human eye observation. Figure 7 shows the comparison of all techniques and the proposed method uses the best result from the results of methods discussed in section 2.

5 CONCLUSIONS

In this paper a new modified method for fingerprint segmentation is proposed. Firstly three old methods are discussed and also their results are analyzed for different quality fingerprint images. Then a new method is presented for accurate fingerprint segmentation. Finally experimental results are compared with that obtained by traditional methods and our fingerprint segmentation technique gives better results for all kind of fingerprint images.

Table 2: Results and Comparison-I.I.

Quality of image	Mean and Variance (%)	Gradient Based (%)	Direction Based (%)	Enhanced Segmenteion (%)
White Background	97	87	95	97
Grayish Background	87	89.3	91	91
Dark Background	6	92	12	92
Noisy Background	42	91.0	57	91

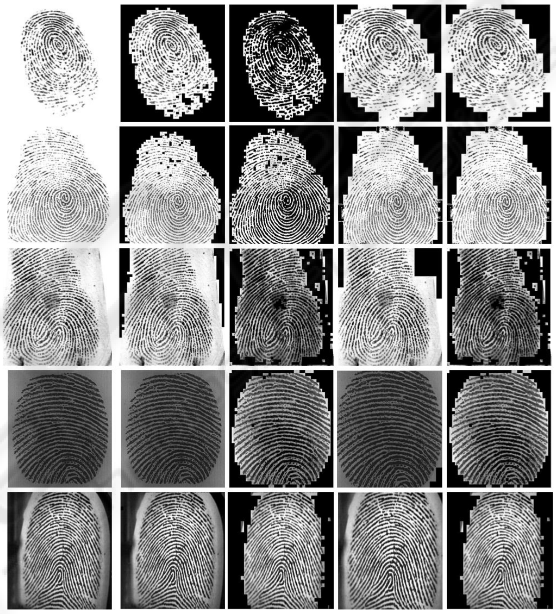

Figure 7: 1st Column: Fingerprint Images from FVC2004 database, 2nd column: Mean and Variance Based Segmented Images, 3rd column: Gradient Based Segmented Images, 4th column: Direction Based Segmented Images, 5th column: Enhanced Segmentation Based Segmented Images.

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