# IMPROVED FINGERPRINT IMAGE SEGMENTATION USING NEW MODIFIED GRADIENT BASED TECHNIQUE

*M. Usman Akram, Sarwat Nasir, Anam Tariq, Irfan Zafar, Wasim Siddique Khan*

Department of Computer Engineering
College of Electrical and Mechanical Engineering
National University of Sciences & Technology, Rawalpindi, Pakistan.
Email: usmakram@gmail.com, sarwatnasir83@gmail.com ,anamtariq12@yahoo.co.uk,
cheemanustian@gmail.com wasimsiddique@gmail.com

## ABSTRACT

An important step in fingerprint recognition is the segmentation of the region of interest (ROI). The objective of fingerprint segmentation is to extract the region of interest (ROI) which contains the desired fingerprint impression. Fingerprint image segmentation highly influences the performances of Automatic Fingerprint Identification System (AFIS). We present in this paper, a Modified Gradient Based Method to extract ROI. The distinct feature of our technique is that it gives high accurate segmentation percentage for fingerprint images even in case of low quality fingerprint images. The proposed algorithm is applied on FVC2004 database. Experimental results demonstrate the improved performance of the proposed scheme.

***Index Terms—*** Segmentation, Region of Interest, Mean, Coherence, Gradient

## 1. INTRODUCTION

The unchangebility of fingerprints during the human life span and the uniqueness of each individual's fingerprints are the basis for using fingerprints for identification purposes [1]. Fingerprint based recognition is most popular among the biometric-based security systems due to the uniqueness and invariability of fingerprint feature and the feasibility of fingerprint verification system [1]. As the first step of fingerprint recognition, segmentation that aims to extract precisely fingerprint foreground from background not only convenient to the further processing but also reduces computational cost since all the subsequent processing will only be focused on foreground of fingerprint image. A fingerprint is a pattern of parallel ridges and valleys on the surface of fingertip [2]. Most Automatic Fingerprint Identification systems (AFIS) are based on local ridge features; ridge ending and ridge bifurcation, known as minutiae [3]. Segmentation of fingerprint image is the most important part of AFIS. Feature extraction algorithms extract a lot of false features (minutiae) 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 minutiae.

There are two types of fingerprint segmentation algorithms: unsupervised and supervised. In Unsupervised algorithms, block wise features such as local histogram of ridge orientation [4],[5], gray-level variance, magnitude of the gradient in each image block [6], Gabor feature [7],[8] are extracted. Supervised method first extracts several features like coherence, average gray level, variance and Gabor response [8],[9], and then a simple linear classifier is chosen for classification.

The method described in [10] is based on the local certainty level of the orientation field, which is computed using the intensity gradient of the image. Those 16x16 pixel blocks in which the certainty level is higher than a given threshold are considered as foreground blocks. In [11] the average gradient on each block is computed which is expected to be high in the foreground and low in the background. In [12] gradient coherence, gray intensity mean and variance are also used in segmentation. The segmentation technique presented in [13] is based on Gabor filters.

In this paper, we present the Modified Gradient based method for segmentation and compare our technique with Mean and Variance based technique and Direction based technique.

This paper is organized in five sections. Section 2 presents the traditional segmentation techniques. Section 3 contains the proposed method for fingerprint segmentation. Experimental results of our technique compared with other techniques are discussed in section 4 followed by conclusion in section 5.

## 2. SEGMENTATION TECHNIQUES

Fingerprint images have various resolution and normally 500 dpi fingerprint images are used [18]. Generally scanned image includes noisy background and distortion which may cause problem in further steps of AFIS. So, some preprocessing is

CCECE/CCGEI May 5-7 2008 Niagara Falls. Canada
978-1-4244-1643-1/08/$25.00 

required to mitigate the effect of such unwanted region [16].

### 2.1. Mean and Variance based Method

Mean and variance based method can significantly reduce the number of basic image entities, and due to the good discontinuity preserving filtering characteristic, the salient features of the overall image are retained [1].

Steps for mean and variance based method [1] are summarized as follows:

1. Divide the input image $I(i,j)$ into non-overlapping blocks with size w x w.

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 empirically a threshold value working on different images . If the $std(I)$ is greater than threshold value, the block is considered as foreground otherwise it belongs to background.
   Figure 1 shows the segmented images based on mean and variance method.

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

### 2.2. Direction Based Method

This method is mainly based on the coherence of direction. A fingerprint consists of parallel line structures. The coherence will be considerably higher in the foreground than in the background [14].

The steps for Direction Based Method [14][17] are summarized as follows:

1. Divide the input image $I(i,j)$ into non-overlapping blocks with size w x w.

2. Use 3x3 sobel vertical and horizontal masks defined in equations 3 and 4 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.

$$sobelVertical = \begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix} \tag{3}$$

$$sobelHorizontal = \begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix} \tag{4}$$

3. Estimate the local orientation using equations 5, 6 and 7 [11].

$$V_x(i,j) = \sum_{u=i-w/2}^{i+w/2} \sum_{v=j-w/2}^{j+w/2} (\partial_x(u,v))(\partial_y(u,v)) \tag{5}$$

$$V_y(i,j) = \sum_{u=i-w/2}^{i+w/2} \sum_{v=j-w/2}^{j+w/2} \partial_x^2(u,v) - \partial_y^2(u,v) \tag{6}$$

$$V_z(i,j) = \sum_{u=i-w/2}^{i+w/2} \sum_{v=j-w/2}^{j+w/2} (\partial_x(u,v) + \partial_y(u,v))^2 \tag{7}$$

4. Calculate background certainty and orientation field using equation 8.

$$coh = \sqrt{\frac{(V_x^2(i,j) + V_y^2(i,j))}{w^2 * V_z}} \tag{8}$$

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

   Figure 2 shows the segmented images for direction based method.

Above mentioned methods can correctly segment the fingerprint images whose boundary is distinct and background is uniform (Fig. 1 and Fig. 2). But Mean and Variance based method does not work well on too wet or too dry fingerprint images, while direction-based method can not slice off the false trace caused by sweat [17].

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

## 3. MODIFIED GRADIENT BASED METHOD

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. In this section, we present a new Modified Gradient Based Method for fingerprint segmentation. In this method, we compute the local gradient values for fingerprint images which detect sharp change in the gray level value of background. This technique segments the fingerprint images accurately especially very dry and wet fingerprint images are segmented in an accurate manner.

Steps for our proposed method are summarized as follows:

1. Divide the input image $I(i, j)$ into non-overlapping blocks with size w×w. In our case w = 8.

2. Use histogram equalization to enhance the contrast between background and foreground.

3. Use a 3×3 median filter to reduce the noise in background of the image [15].

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 9 and 10 respectively

$$M_x = \frac{1}{w^2} \sum_{i=-w/2}^{w/2} \sum_{j=-w/2}^{w/2} \partial_x(i, j) \tag{9}$$

$$M_y = \frac{1}{w^2} \sum_{i=-w/2}^{w/2} \sum_{j=-w/2}^{w/2} \partial_y(i, j) \tag{10}$$

6. Compute standard deviation for both $M_x$ and $M_y$ using equations 11 and 12.

$$std_x = \sqrt{\frac{1}{w^2} \sum_{i=-w/2}^{w/2} \sum_{j=-w/2}^{w/2} (\partial_x(i, j) - M_x(I))^2} \tag{11}$$

$$std_y = \sqrt{\frac{1}{w^2} \sum_{i=-w/2}^{w/2} \sum_{j=-w/2}^{w/2} (\partial_y(i, j) - M_y(I))^2} \tag{12}$$

7. Compute the gradient deviation using equation 13.

$$grddev = std_x + std_y \tag{13}$$

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

   Figure 3 shows the segmented images based on Boundary Values and Modified Gradient Based method.

**Fig. 3**. 1st Row:Fingerprint Images from FVC2004 database, 2nd Row: Modified Gradient Based method Segmented Images

## 4. EXPERIMENTAL RESULTS

The performance of our proposed technique is tested on FVC2004 [18] database. The database contains 40 different fingers and 8 impressions of each finger (40x8=320 fingerprints).The images in DB1, DB2, DB3 and DB4 are 640x480, 328x364, 300x480 and 288x384 respectively and each having a resolution of 500 dpi. Segmentation results of our enhanced segmentation method compared with Mean and Variance based method and Direction based method are shown in Table 1.

**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 |
| Direction Based | 227 | 71.0 | 93 | 29.0 |
| Proposed Segmentation | 294 | 91.8 | 26 | 8.2 |

**Table 2**. Results and Comparison-II

| Quality of image | Mean and Variance Based (%) | Direction Based (%) | Proposed Segmentation (%) |
|---|---|---|---|
| White Background | 97 | 95 | 89 |
| Grayish Background | 87 | 91 | 91 |
| Dark Background | 6 | 12 | 92 |
| Noisy Background | 42 | 57 | 91 |

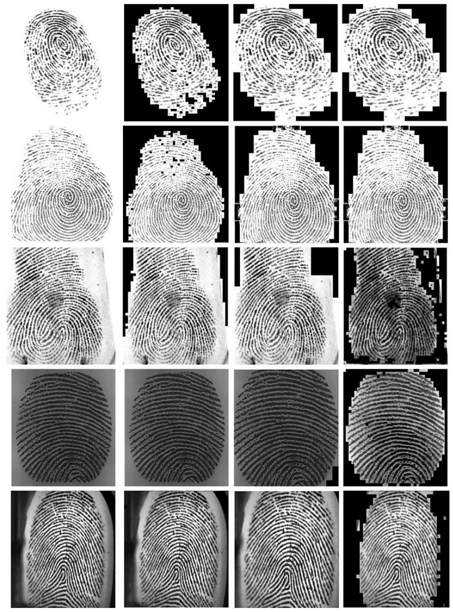

**Fig. 4**. Pictorial comparison of proposed algorithm with traditional techniques. Ist column shows fingerprint images from FVC2004. 2nd and 3rd columns show the ROI detected with Mean and variance based and Direction based techniques respectively. 4th column shows the ROI detected with Proposed Technique

The results of the image segmentation with Mean and Variance Based scheme, Direction Based scheme and Proposed scheme are summarized in Table 2. For above mentioned techniques, a comparative analysis of the computation time, with AMD Athlon 64bit processor 3000+, 801 MHz, and 1 GB RAM, is performed and is summarized in Table 3. Figure 4 demonstrate that proposed technique detects ROI more accurately than other techniques even for very dry and oily images.

## 5. CONCLUSION

In this paper a new Modified Gradient based scheme for fingerprint segmentation is proposed. Our segmentation technique detects ROI by computing the local gradient values followed by the application of Modified Gradient Based method to extract it. In the proposed scheme, mean and standard deviation of gradient of the image is computed. The segmentation results show that our proposed algorithm performs better than the Mean and Variance based method and Direction based segmentation technique. The proposed technique gives better results even in case of dry and low quality images. Furthermore, a reduction in computational time is also achieved with this scheme.

**Table 3**. Evaluation of Computational Time

| Techniques | Processing Time Seconds |
|---|---|
| Mean and Variance | 0.27 |
| Direction based Method | 0.22 |
| Proposed Segmentation | 0.15 |

## 6. REFERENCES


[1] D. Maltoni, D. Maio, A. K. Jain, and S. Prabhakar, ”Handbook of Fingerprint Recognition”, *Springer-Verlag*, June 2003.

[2] Jie Zhou and Jinwei Gu, ”A Model-Based Method for the Computation of Fingerprints’ Orientation Field”,*IEEE Trans. on Image Processing*, VOL. 13, No. 6, pp.821-835, JUNE 2004.

[3] A.K Jain, H. Lin and R. Boole, ”On-Line Fingerprint Verification”, *IEEE Trans. PAMI*, Vol.19,No.4, pp.302-314,1997.

[4] Mehtre and Chatterjee, ”Segmentation of fingerprint images - a composite method”, *Pattern Recognition*, Vol.22, No 4, pp.381-385, 1989.

[5] Mehtre, B.M., Murthy, N.N., Kapoor, S., Chatterjee, ”Segmentation of fingerprint images using the directional

image",*Pattern Recognition*, Vol 20, No.4, pp.429-435, 1987.

[6] N.K.Ratha, S.Chen and A.K.Jain, "Adaptive flow orientation-based feature extraction in fingerprint images",*Pattern Recognition*, Vol.28, No.11, pp.1657-1672, 1995.

[7] F.Alonso-Fernandez, J.Fierrez-Aguilar, J.Ortega-Garcia, "An enhanced gabor filter-based segmentation algorithm for fingerprint recognition systems", *Proceedings of the 4th International Symposium on Image and Signal Processing and Analysis(ISPA 2005)*. pp. 239-244, 2005.

[8] A.Bazen and S.Gerez, "Segmentation of fingerprint images",*Proc. Workshop on Circuits Systems and Signal Processing (ProRISC 2001)*, pp. 276-280, 2001.

[9] E.Zhu,Yin, J.Hu andC.Zhang, "A systematic method for fingerprint ridge orientation estimation and image segmentation", *Pattern Recognition*,Vol.39, No.8, pp.1452-1472, 2006.

[10] A. K. Jain, L. Hong, S. Pankanti, and R. Bolle, "An identity authentication system using fingerprints," *Proc. IEEE*, vol. 85, pp. 1365-1388, Sept. 1997.

[11] Dario Maio and Davide Maltoni, "Direct gray-scale minutiae detection in fingerprints", *IEEE Trans. on Pattern Analysis and Machine Inteligence*, vol. 19, pp. 27-40, Jan. 1997.

[12] A. Bazen and S. Gerez, "Segmentation of fingerprint images," *Workshop on Circuits Systems and Signal Processing, ProRISC*, pp. 276-280, 2001.

[13] LinLin Shen, Alex Kot, and WaiMun Koo, "Quality measures of fingerprint images", emph3rd Audio and Video-Based Person Authentication, AVBPA,pp. 266-271,2001.

[14] A.M. Bazen and S.H. Gerez. "Directional Field Computation for Fingerprints Based on the Principal Component Analysis of Local Gradients", *ProRISC 2000 Workshop on Circuits, Systems and Signal Processing, Veldhoven, The Netherlands*, Nov. 2000.

[15] Lim and S.Jae, "Two-Dimensional Signal and Image Processing" , *Englewood Cliffs, NJ, Prentice Hall*, pp. 469-476, 1990.

[16] L. Hong, Y. Wan, and A. Jain, "Fingerprint Enhancements: Algorithm and Evaluation", *Proc. IEEE Trans. on Pattern Analysis and Machine Intelligence*, vol.20, no. 8, pp. 777-789, 1998.

[17] Zhongchao Shi, Yangsheng Wang, Jin Qi, Ke Xu, "A New Segmentation Algorithm for Low Quality Fingerprint Image", *IEEE Proceedings of the Third International Conference on Image and Graphics (ICIG04)*, 2004.

[18] Finger print Verification Contest 2004; FVC2004: Available at (http://bias.csr.unibo.it/fvc2004.html)

Intentional Blank Page