International Journal of Engineering & Technology, 7 (4) (2018) 2453-2456

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v7i4.16244
Research paper

A Gradient Based Approach for Fingerprint Image Segmentation using Morphological Operators

Reji C. Joy[1*] and S. Hemalatha[2]

[1]*Research Scholar, Department of Computer Science, Karpagam Academy of Higher Education Coimbatore.*
[2]*Assistant Professor, Department of Computer Science, Karpagam Academy of Higher Education Coimbatore.*
[*]*Email: rejigeevar@gmail.com*

Abstract

The advancement of science and technology has made the reliable individual recognition and identification systems to become very popular. From the various biometric characteristics, fingerprint is one of the popular method because of its easiness and not much effort is required to acquire fingerprint. First step for an Automated Fingerprint Identification System (AFIS) is the segmentation of fingerprint from the acquired image. During fingerprint segmentation process the input image is decomposed into foreground and background areas. The foreground area contains information that are needed in the automatic fingerprint recognition systems. However, the background is a noisy region that contributes to the extraction of false features. So in an AFIS, fingerprint image segmentation plays an important role in carefully separating ridge like part (foreground) from noisy background. Gradient based method is commonly used for segmentation process. Since gradient estimation is erroneous in noisy images, the study proposes a combination of gradient mask and morphological operations to segment fingerprint foreground effectively. The results obtained prove that the new method is suited for fingerprint segmentation.

Keywords: *AFIS, fingerprint, gradient mask, morphological operations, segmentation.*

1. Introduction

Along with the technological advancement, the reliable individual recognition and identification system became very important. Many biometric characteristics can be used: iris, face, fingerprint, voice, gait etc. From the various biometric characteristics, fingerprint is one of the popular method as the fingerprint sensors are relatively much more economical than others.

Fingertip contains a pattern of ridges and valleys that are parallel to each other. This pattern is known as fingerprint. A ridge is a curved line and the area between two neighboring ridges is called a valley. A fingerprint verification system consists of four major steps: *image acquisition*, *preprocessing*, *feature extraction* and *matching*. The acquired fingerprint image is made up of two components which are called the foreground and the background (see fig.1). The foreground area is obtained directly by pressing the fingertip against the surface of the scanner. The noisy area at the borders of the image is called the background. Fingerprint matching is carried out by extracting feature points which can be local or global. Most feature extraction algorithms detect a lot of false features when applied to the noisy fingerprint image. So, fingerprint image segmentation plays an inevitable role in the extraction of valid features.

A number of techniques related to fingerprint image segmentation are available in literature. In [1], a segmentation algorithm based on local pixel features like mean, variance and coherence is proposed. Then, the linear combination of these features are taken for segmentation. The limitation of this technique is its low speed. The coherence feature shows whether the ridge orientations are keeping the same direction. The coherence measure will be much higher in the foreground when compared to the background. So, taking into account only the coherence feature will not lead to robust segmentation. In [2], from the acquired fingerprint image Gabor features are extracted. The Gabor response is very high in the foreground area. But, this method is computationally costly. In [3] a feature known as block clusters degree (CluD) is mentioned. CluD tells whether ridge pixels can be clustered. In [4], Harris corner point features are used. It can be seen that Harris point feature is much stronger in foreground when compared to the background area.

Figure 1: A fingerprint image

In this proposal, a novel fingerprint segmentation technique is presented. Each fingerprint can be interpreted as an unique oriented pattern. These patterns consist of ridge-valley structure. An ori-

(a) (b)

Figure 2: (a) A fingerprint image. (b) Gradient image of (a).

entation estimation method used to identify the direction flow of fingerprint ridge contours can be used to identify the foreground. Gradient based technique is used in the paper to compute the intensity gradient vector image. Then, a threshold value is used to extract the ridge like region. But, the gradient based method also have some drawbacks. They are easily affected by noises as gradients are calculated based on pixel. This may lead a true ridge like region to identify as a noisy background area. Morphological operations combined with the gradient mask is used in this paper to resolve this problem and to get the final segmented fingerprint image.
This paper is organized in four sections. Section 2 contains the new proposal for fingerprint image segmentation. Section 3 gives experimental observations and discussion. Finally section 4 gives the conclusion.

2. Proposed Method

The important phases of the proposed method are: (i) *Image Normalization* (ii) *Gradient Mask Estimation* (iii) *Thresholding and Binarization* (iv) *Morphological Operations*.

2.1. Normalization

The acquired fingerprint image may contain varied range of intensity values. Normalization is the process of optimizing the intensities of an image to a range. This process will change the existing range of gray-level values of an image to a desired range of values. It is trivial to include this process because the computation of gradient values may largely affect with the varied intensity values in images. The advantage of the normalization process is that it does not change the structure of fingerprint ridges and thus does not affect overall segmentation process. Let $f_{i,j}$ be the intensity value at a location (i,j), function denoted by $f'_{i,j}$, where $i,j \in 0,1,...,L-1$ and L is the maximum gray-level value, is defined as:

$$f'_{i,j} = \begin{cases} m_0 + \sqrt{\frac{v_0(f_{i,j}-m)^2}{v}} & \text{if } f_{i,j} > m, \\ m_0 - \sqrt{\frac{v_0(f_{i,j}-m)^2}{v}} & \text{otherwise}, \end{cases} \quad (1)$$

where m,v are the existing mean and variance in the image and m_0,v_0 are the required mean and variance after normalization. Normalization can be done globally or locally in an image. When applied locally the m,v are the block mean and variance of the existing image and m_0,v_0 is the mean and variance after normalization. In this paper, $m_0 = 50$ and $v_0 = 50$ is used.

2.2. Gradient Mask Estimation

Gradient mask of a fingerprint image is computed using a gradient vector image which is usually used for fingerprint orientation estimation. This computation is largely affected by the noises present in the fingerprint image. To alleviate the noise sensitivity, rather than finding gradient for every pixel, a gradient mask for a block of image pixels is computed. It is crucial to accurately determine the block size because, a small block size will capture the details of an image but largely affected by the noise; while a large block attenuates noises well, but it blurs the details and may break fingerprint ridge orientation[11].
The intensity gradient vector image estimation method proposed by [5] is used in this work to compute the gradient mask. This method make use of a block level estimation of gradient image so as to alleviate noises. The method computes the orientation of a pixel (i,j) by the following steps:

1. Consider the given image into a several neighborhood size of W with respect to a chosen center pixel (i,j). Usually the block size W is taken as $(2x+1) \times (2x+1)$ for the orientation estimation. The size of W should be chosen such that it should not large to contain different ridges and not too short to miss the ridges. In [5], It is suggested to choose the neighborhood as half of the average width of the ridges and valleys .
2. For each pixel (i,j) in the input image $f(i,j)$, compute the gradient image $G(i,j)$ as

$$G(i,j) = G_i(i,j)e^{j\theta_i(i,j)} \quad (2)$$

where $G_i(i,j)$ is the gradient amplitude which is denoted as

$$G_i(i,j) = \sqrt{{G_x}^2 + {G_y}^2} \quad (3)$$

where G_x, G_y are gradients of horizontal, vertical directions respectively and θ is the orientation which are represented by

$$G_x(i,j) = \frac{\partial f(i,j)}{\partial i}; \quad G_y(i,j) = \frac{\partial f(i,j)}{\partial j} \\ \theta(i,j) = tan^{-1}\frac{G_y}{G_x} \quad (4)$$

Here $\partial_x(i,j)$ and $\partial_y(i,j)$ are gradient magnitudes along x(horizontal) and y(vertical) directions. This can be measured by using two sobel filters.
3. Store each block gradient image as Gradient mask.

Fig.2(a) shows the original image and Fig.2(b) shows the gradient magnitude image.

2.3. Thresholding and Binarization

The value of gradient mask will be low along the fingerprint regions where the intensity values are smooth and high in the region where the intensity values changes very abruptly. It indicates that low value will be along the background and highest along the ridge borders. To segment the foreground region from its background, it is used a threshold to the fingerprint image by applying the gradient mask. The gradient mask can be applied by a convolution operation with the fingerprint image. The steps of thresholding can be summarized as follows:

Step 1: Scan the image from top to bottom and left to right.
Step 2: A convoluted image $C(i,j)$ can be obtained by the discrete convolution of $G(i.j)$ computed by Eq.(4), the gradient mask and $I(i,j)$, the fingerprint image and this can be expressed as:

$$C(i,j) = G(i,j) * I(i,j) \\ = \frac{1}{MN}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1}(G(m,n)I(i-m,j-n)) \quad (5)$$

Step 3: Segmentation of the foreground area from its background will be obtained by applying a threshold operation defined by:

$$S(i,j) = \begin{cases} 1 & \text{if } C(i,j) > T \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

where T is the desired threshold value for separating the foreground from the background.

Step 4: Store $S(i,j)$ as a binary image where pixels labeled 1 correspond to objects, whereas pixels labeled 0 correspond to the background.

2.4. Morphological Operations

The separation of foreground and background is not accurate especially in low quality fingerprint images (see fig. 3(a)). In such cases, many small segmented clusters are formed apart from single large compact cluster. Sometimes, one small spurious cluster may be formed inside a much larger segmented region. However, in [7], it is suggested to use neighboring pixel information to get a more meaningful segmented region. Therefore, gradient mask based method is itself not enough to segment the fingerprint foreground area effectively. This can also be substantiated from Table 1 where 16.1% is miss-segmented when gradient mask based method used. There are number of methods are proposed in the literature, say boundary based or region based method like region growing, to consider neighborhood pixels in the different regions and to form more meaningful cluster that are possible group [6]. However, we have taken morphological operators to group different regions from the thresholded image $S(i,j)$ to form cluster. Morphological operators make use of structural elements, morphological operations like dilation and erosion to see whether the neighboring pixels fall under same region. Morphological operations as a post-processing step is one of the widely accepted methods in fingerprint segmentation [1, 9, 8]. The morphological operations [10] used in our paper is described as follows:

Step 1: Perform a binary dilation by a structuring element on the thresholded image $S(i,j)$ obtained using Eq.6 to combine several small clusters of fingerprint ridge regions. Binary dilation is given by:

$$\begin{aligned} S_d &= (S \oplus B) \\ &= \{z : z = s + b \text{ for some } s \in S \text{ and } b \in B\} \\ &= \bigcup_{b \in B} (S)_b \end{aligned} \quad (7)$$

where B is the structuring element and S_d is the dilated image.

Step 2: Regions that are spuriously formed as background after the dilation operation is removed by filling holes in the binary image. This is done by a flood-fill operation.

Step 3: Perform a binary erosion using the same structuring element B to make it meaningful large clusters. Binary erosion is given by

$$\begin{aligned} S_e &= (S_d \ominus B) \\ &= \{z : B + z \subseteq S_d\} \\ &= \bigcap_{b \in B} (S)_{-b} \end{aligned} \quad (8)$$

where S_e is the eroded image.

Step 4: Finally remove the clusters which are having an area (A) less than a threshold value to segment the fingerprint foreground region. Here area A is defined as:

$$A = \sum_{(r,c) \in C} 1 \quad (9)$$

where C is a cluster.

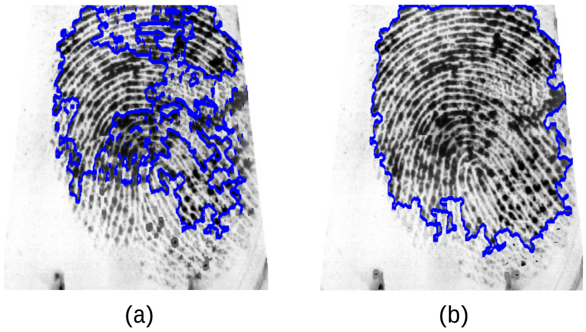

Figure 3: (a) Before Morphology (b) After Morphology.

Fig. 3(b) shows the fingerprint image where the foreground regions are marked that are segmented from its background using the morphological operations.

3. Experimental Results and Discussions

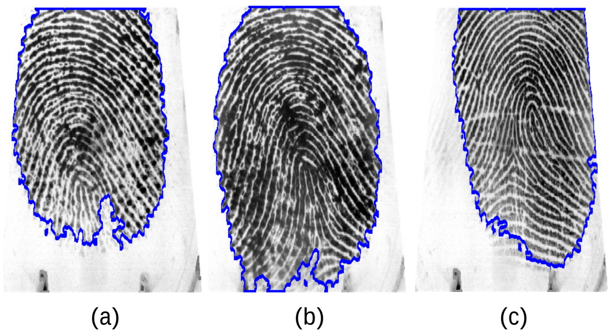

Figure 4: Segmentation results of some fingerprints images

The proposed fingerprint segmentation method has been tested with a standard Verifinger_Sample_DB dataset taken form Neurotechnologija web site [12]. Data set comprises a total of 520 fingerprint images (8 different fingers of 65 persons). A comparison of results obtained using the above two different fingerprint segmentation methods have been listed in the Table 1. The first method uses gradient mask and the second uses a combination of gradient mask and morphological operations. The test results clearly shows that the performance of the second method is more superior from the earlier. Fig. 4 shows some segmented images.

Table 1: Comparison of different fingerprint segmentation methods

Method	Number of Correctly Segmented	Segmentation Accuracy (%)	Miss-Segmentation (%)
Gradient Based Method	439	83.9	16.1
Gradient Based + Morphological	464	88.9	11.1

For an automatic fingerprint segmentation system, it is important to make sure that the feature information is not lost after the segmentation since these information are crucial for the subsequent processing.

Therefor, the overall accuracy of fingerprint segmentation algorithm depends on how well the feature areas are included in the segmented image. This can be estimated by computing the ratio by which the false background regions has been treated as true foreground region and the ratio by which the true foreground region has been treated as false background region. In the above two cases, the later one is more important. This can be analyzed by finding the ratio by which the true singular point of the fingerprint images are discarded by the segmentation algorithm. The study has chosen the successful inclusion of singular points as a performance measure for estimating the segmentation accuracy since this feature information is important for fingerprint classification.

To conduct this analysis, 26 images out of 520 have been excluded. Table 2 shows the test result of this analysis. It can be shown that even when the segmentation of fingerprint image is moderate, the algorithm is able to include the singular point region in the foreground area for 98.7% of images. Fig. 5(a-c) shows some true cases and Fig. 5(d-f) shows some failed cases.

Table 2: Performance measure of the proposed method in the Verifinger_Sample_DB dataset [12]

Fingerprint images in the dataset	520
Fingerprint images taken for testing	494
Segmented images with successful inclusion of singular points	488
Segmentation Accuracy	98.7

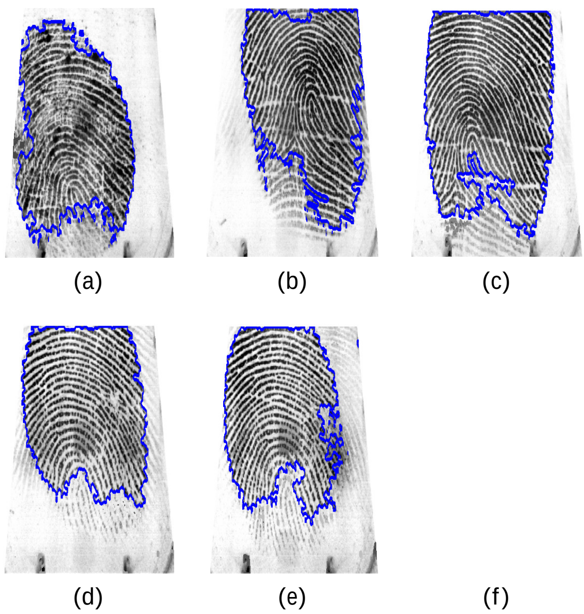

Figure 5: Segmentation results:(a-c) True cases: Segmentation result is moderate, but the singular point region is included. (d-f) Failed cases: Both segmentation result is moderate and missing singular point region.

4. Conclusion

Every automatic fingerprint identification system precedes a fingerprint segmentation step in its pre-processing phase. The objective of fingerprint segmentation is to separate the fingerprint ridge like area from its background. Accuracy of an automatic segmentation also depends on how well it includes the feature points of an image. In this paper, an automatic fingerprint segmentation method is presented. The method uses a combination of gradient mask and morphological operators to segment the fingerprint images effectively. Experimental results shows that, even for images, segmentation accuracy is moderate and the proposed method included the important feature areas of fingerprint in the segmented region thus it can be used for the effective fingerprint segmentation.

References

[1] A. M. Bazen and S. H. Gerez, "Segmentation of fingerprint images", *ProRISC 2001 Workshop on Circuits, Systems and Signal Processing, Veldhoven*, The Netherlands, (2001).

[2] 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)*, (2005), pp.239–244.

[3] X. Chen, J. Tian, J. Cheng, X. Yang, "Segmentation of fingerprint images using linear classifier", *EURASIP Journal on Applied Signal Processing*, Vol.2004, No.4, (2004), pp.480–494.

[4] C. Wu, S. Tulyakov, V. Govindaraju, "Robust Point-Based Feature Fingerprint Segmentation Algorithm", *Proceedings of Lee, S.-W., Li, S.Z. (eds.) ICB 2007*, LNCS, Vol.4642, Springer, Heidelberg (2007), pp.1095–1103.

[5] D.Luo, Q.Tao, J.Long, and X.Wu, "Orientaion consistency based feature extraction for fingerprint identification", *Proceedings of TENCON'02 IEEE*, Vol.1, (2002), pp.494-497.

[6] R. C. Gonzalez, and P. Wintz, "Digital Image Processing.2nd Edition", *Addison-Wesley*, (1987).

[7] Jinhai Zhang, "The research of fingerprint image segmentation method", *Consumer Electronics, Communications and Networks (CECNet)*, (2012), pp.701-704.

[8] R. Shekhar, and M. Pradeep, "Correlation based Fingerprint Image Segmentation", *International Journal of Computer Applications*, Vol.68, No.7, (2013).

[9] M. U. Akram, A. Ayaz, and J. Imtiaz, "Morphological and gradient based fingerprint image segmentation", *Information and Communication Technologies (ICICT)*, (2011), pp.1-4.

[10] Rein van den Boomgaard, Richard van Balen, "Methods for fast morphological image transforms using bitmapped binary images", *Proceedings of CVGIP: Graphical Models and Image Processing*, Vol. 54, No.3, (1992), pp.252-258.

[11] Zacharias, G. C., and P. S. Lal, "Singularity detection in fingerprint image using orientation consistency", *Proceedings of International Mutli-Conference on Automation Computing Communication Control and Compressed Sensing (iMac4s)*, (2013).

[12] http://www.neurotechnologija.com/download.html