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Algorithm Based on Point Feature for Fingerprint Image Segmentation

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Abstract: The segmentation of fingerprint images is very important to automatic fingerprint recognition system. To decide which part of the image belongs to the foreground and which part to the background, different methods have been proposed. Some of the traditional methods are introduced and implemented in this paper and a novel pixel based fingerprint segmentation algorithm is proposed. Two kinds pixel features, being the coherence of direction and the variance of gray level are used in the segmentation and fuzzy c-means clustering algorithm is used to select threshold. Morphology technology is applied as post processing to obtain a smooth contour line. The experimental results demonstrate the effectiveness of the proposed method, especially in low quality images, in terms of including less background and excluding less foreground. In addition, this robust segmentation algorithm is capable of filtering efficiently spurious boundary.

Key words: Fingerprint . segmentation . FCM . contour

INTRODUCTION

Fingerprint recognition is a biometric technology. The technology has been used for personal identification for a very long time. With the development of computer technology; the automatic fingerprint identification system has become popular.

The fingerprint image is divided into two parts: foreground region and background region. Foreground is the region which contains ridge and background refers to the region which has no ridge and some very vague area [1]. Regardless of the quality of the fingerprint image, the background is one-third or one-half of the total area of the entire image. In order to implement the following steps, we need to remove background region while retaining the foreground region. If background areas are included into segmented fingerprint, false features are possibly introduced into detected feature set. If some parts of foreground region are excluded, useful feature points may be missed [2]. We should design an accurate segmentation method in the background region while ensuring the foreground to be retained.

This paper is organized as follows: section second discusses the traditional algorithms and points out their shortcomings. Then, section third presents our algorithm which can segment the fingerprint images with a smooth contour. Finally, section fourth gives some experimental results and the conclusion.

TRADITIONAL ALGORITHMS

Threshold is very important for image segmentation. The output of the threshold algorithm is a binary image. White pixel indicates the foreground region and black pixel indicates the background region. In this paper, we choose the threshold through fuzzy C-means algorithm.

Fuzzy C-means is attempting to define C clusters of the data, through an iterative procedure [2, 3]. The algorithm assumes that a data point can belong to more than one cluster centers. The level of belonging depends on the distance of a data point from the C cluster centers. In the fuzzy C-means iterative procedure, we firstly initialize the value of C which is the number of clusters and the cluster centers. Then FCM algorithm calculates the new cluster centers as well as the memberships of every data point to each one of these cluster centers. The new cluster centers and the new membership values of each data point are calculated according to the distances of a data point from the cluster centers. This iterative procedure is stopped when the difference in value between the memberships of a data point from the cluster centers of two iterative is smaller than a threshold ε [4, 5].

The FCM algorithm minimizes the objective function $J_q(U,V)$.

$$J_q(U,V)=\sum_{k=1}^{n}\sum_{i=1}^{c}(u_{ik})^q d^2(x_k,v_i) \qquad (1)$$

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$X = \{x_1, x_2, ..., x_n\} \subseteq R^p$. n is the number of data point. c is the number of clusters $(2 \le c \prec n)$. u_{ik} is the membership of x_k to the i^{th} cluster. q is a weighting exponent on each fuzzy membership. v_i is the centre of cluster i. $d^2(x_k, v_i)$ is a distance measure between object x_k and cluster centre v_i. The iterative process is described as follows:

1. Initializing the values of c, q and ε.
2. Initializing the fuzzy partition matrix U.
3. b = 0, b is the loop counter.
4. Calculating the c cluster centers $\{v_i^{(b)}\}$:

$$v_i^{(b)} = \frac{\sum_{k=1}^{n} (u_{ik}^{(b)})^q x_k}{\sum_{k=1}^{n} (u_{ik}^{(b)})^q} \quad (2)$$

5. Calculate the membership $U^{(b+1)}$ For k = 1 to n:

$$u_{ik}^{(b+1)} = \frac{1}{\sum_{j=1}^{c} (\frac{d_{ik}}{d_{jk}})^{\frac{2}{q-1}}} \quad (3)$$

6. If $\left|U^{(b)} - U^{(b+1)}\right| \prec \varepsilon$, stop; otherwise, set b = b+1 and go to step 4.

A subset of FVC2002 (10 fingerprints, each fingerprint has 8 images, so there are 80 fingerprint images) is used to get the cluster centers. The fingerprint image size is 300 * 300 and the block size is set as 15 * 15. So,we get a total of 32,000 samples. when selecting two cluster centers, the fingerprint images can be divided into two types of blocks:the foreground of fingerprinting and the background blocks. When four cluster centers are selected, the fingerprints can be divided into four kinds region which are clear region, affected by noise but does not affect feature extraction region, seriously affected by noise that can not be restored region and non-fingerprint region.

Feature selection is the first step to design fingerprint segmentation algorithm. There are two general kinds of feature used for fingerprint segmentation: block features and point features. Point features include local mean, local variance and direction coherence. Block mean, block standard deviation are most common block features for fingerprint segmentation.

In order to test the performance of fingerprint segmentation algorithms, we select two fingerprint images which are difficult to be segmented. They are shown in Fig. 1.

Fig. 1: The fingerprint images used to be segmented

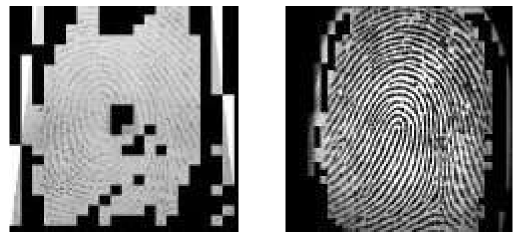


Fig. 2: The fingerprint images segmented by variance

Segment the fingerprint images by gray scale variance: For a fingerprint image F, F (i, j) is the gray scale of pixel (i, j). The image is divided into M×N blocks of size w×w (may or may not overlap). So for each small block (I,J) 0<I≤M, 0<J≤N, we can calculate the two features: block mean M and block variance S [6].

The segmentation algorithm based on gray scale is described as follows:

1. Dividing the fingerprint image into blocks.
2. Calculating the mean of gray scale of each block, by the following formula:

$$M(I,J) = \frac{1}{w*w} \sum_{i=I*w-w/2}^{I*w+w/2} \sum_{j=J*w-w/2}^{J*w+w/2} F(i,j) \quad (4)$$

3. Calculating the variance of gray scale for each block

$$S(I,J) = \frac{1}{w*w} \sum_{i=I*w-w/2}^{I*w+w/2} \sum_{j=J*w-w/2}^{J*w+w/2} [F(i,j) - S(I,J)]^2 \quad (5)$$

4. Determining the threshold for image segmentation.

When the fingerprint image blocks are divided into four kinds according to the variance,the cluster centers are 0.69407, 0.12377, 0.5061 and 0.32487. Or they can be divided into two kinds when the cluster center are 0.57091and 0.19832.

Whether the blocks should be removed or not is decided by its membership to the cluster centers. The blocks of fingerprint images in Fig. 2 are divided into four categories. The noise block that can not be restored by enhance algorithm and non-fingerprint area are removed.

Segment the fingerprint images by direction coherence: Fingerprint image is a texture images. In the foreground region, perpendicular to the direction of ridge to compute projection, pixel gray level changes as sinusoidal mode obviously and along the ridge direction to compute projection, pixel gray level is a flat line relatively. In the background region, as no apparent ridge direction, regardless of the projection direction, the fluctuations of pixel gray level are not obvious [7]. Take advantage of this feature, the direction of the fingerprint image can be used to segment the fingerprint image.

We calculate the horizontal and vertical gradient matrix component G_x and G_y. The direction coherence can be calculated by them.

Since a fingerprint image mainly consists of parallel line structures, the coherence will be considerably higher in the foreground than in the background.

1. We define the coherence in the direction of fingerprint as C_σ and it can be calculated by formula (6), (7), (8) and (9).

$$V_x(i,j) = G_x^2(i,j) - G_y^2(i,j) \quad (6)$$

$$V_y(i,j) = 2G_x(i,j)\,G_y(i,j) \quad (7)$$

$$V_e(i,j) = G_x^2(i,j) + G_y^2(i,j) \quad (8)$$

$$C_o(i,j) = \frac{\sqrt{V_x^2(i,j) + V_y^2(i,j)}}{V_e} \quad (9)$$

2. Calculating the block direction coherence.

C_o (i, j) is divided into w×w small blocks We calculate these block direction coherence BLCOKC respectively

$$BLCOKC = \frac{1}{w*w}\sum_{i=1}^{w}\sum_{j=1}^{w} C_o(i,j) \quad (10)$$

According to the direction coherence of the fingerprint blocks, when the cluster centers are 0.77493, 0.51927, 0.32905 and 0.13686,the image blocks are divided into four kinds. On the other hand they can be divided into two kinds when the cluster centers are 0.61365 and 0.21677. Figure 3 shows the result.

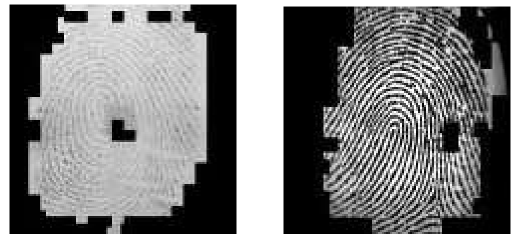


Fig. 3: Segmented by direction coherence

From above, we can see that the traditional fingerprint segmentation algorithms are block-wise [8]. Block-wise segmentation algorithms have two shortcomings: 1) The segmented fingerprint image has serrated edge and is very difference with the actual fingerprint shape. 2) How to determine the threshold isn't easy.

OUR ALGORITHM

We propose a new fingerprint image segmentation algorithm, which produce smooth contour. The segmented fingerprint image looks like very natural. For some fingerprint images which are very difficult to be segmented by traditional segmentation algorithms, our algorithm will still be able to segment them accurately. Our algorithm is described as follows:

1 Calculating the gradient of fingerprint images [6];

$$G = \sqrt{G_x^2 + G_y^2} \quad (11)$$

2. Constructing a 7×7 Gaussian filter operator:

$$filtg = \begin{bmatrix} 0.0000 & 0.0002 & 0.0011 & 0.0018 & 0.0011 & 0.0002 & 0.0000 \\ 0.0002 & 0.0029 & 0.0131 & 0.0216 & 0.0131 & 0.0029 & 0.0002 \\ 0.0011 & 0.0131 & 0.0586 & 0.0966 & 0.0586 & 0.0131 & 0.0011 \\ 0.0018 & 0.0216 & 0.0966 & 0.1592 & 0.0966 & 0.0216 & 0.0018 \\ 0.0011 & 0.0131 & 0.0586 & 0.0966 & 0.0586 & 0.0131 & 0.0011 \\ 0.0002 & 0.0029 & 0.0131 & 0.0216 & 0.0131 & 0.0029 & 0.0002 \\ 0.0000 & 0.0002 & 0.0011 & 0.0018 & 0.0011 & 0.0002 & 0.0000 \end{bmatrix}$$

3 Filtering the gradient matrix:

$$G = filtg \otimes G \quad (12)$$

4. Calculating the mean of the gradient matrix which used as threshold:

Fig. 4: The region which is larger than threshold

Fig. 5: The region after close operator

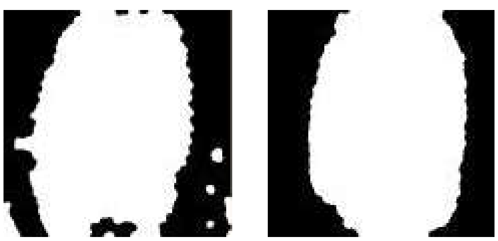


Fig. 6: The region after open operator

$$T = \frac{1}{P*Q}\sum_{i=1}^{P}\sum_{j=1}^{Q} G(i, j) \tag{13}$$

$$G(i, j) = \begin{cases} 1 & \text{if G(i,j)>T} \\ 0 & \text{otherwise} \end{cases} \tag{14}$$

5. Constructing the structure elements:

$$SE = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

6. Processing each pixel by the structure elements of the mathematical morphological close operation. We get a template region.

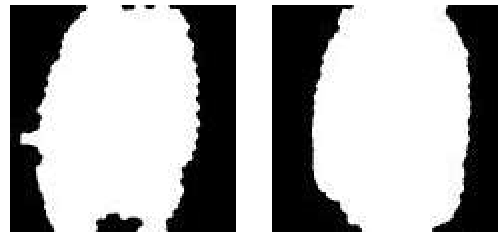


Fig. 7: The region of the fingerprint image

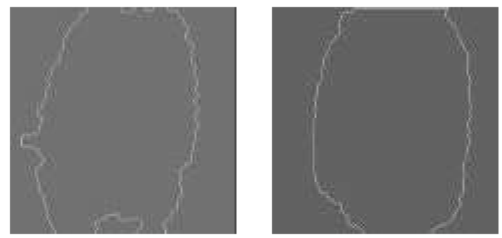


Fig. 8: The contour of the region

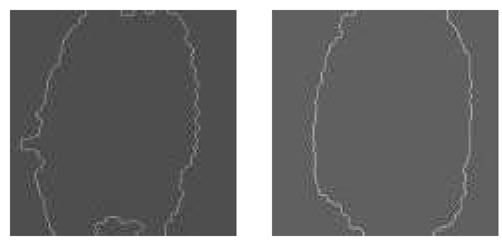


Fig. 9: The contour of the region after thinning

7. To filter out the isolated blocks, we processing the blocks by mathematical morphological open operator.
8. There may be only one or several target region. We need to find the largest one which contains the fingerprint image.
9. Searching for the contour of the target area and assigning it to the variable mask.
10. Removing the burl of the contour and thinning the contour, otherwise the edge will be broken in the follow tracking phase. The results are shown in Fig. 9.
11. Tracking the contour of the target region and recording their coordinates, by array x, y respectively.
12. Doing Fourier transform to x and y respectively:

$$X = fft(x) \tag{15}$$

$$Y = fft(y) \tag{16}$$

13. Taking into account that thecontour line changes slowly, so we process the array x and y with

Table 1: Comparison of segmentation algorithms

	Spurious			Lost			
	Our method	var	coh	Our method	var	coh	Really
a	3	5	3	3	7	5	21
b	2	5	7	8	13	12	49
c	5	10	6	6	7	8	26
d	4	9	8	7	5	7	29
e	2	6	9	5	7	8	31
f	7	7	10	5	9	6	32
g	4	6	9	6	7	8	28
h	4	7	5	4	6	5	17
Avg	3.88	6.87	7.13	5.5	7.63	7.38	29.12

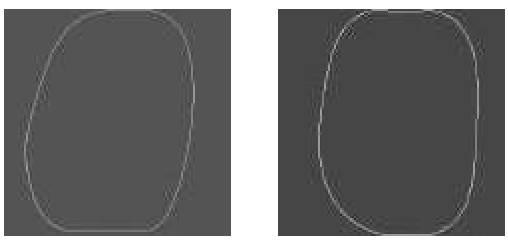


Fig. 10: The final contour of the region

Fig. 11: The fingerprint image after segmented

low-pass filter. The low-pass filter is very simple, just set the high-frequency part of them to zero as shown in (17)and (18).Then we carried out inverse Fourier transform to X and Y. x and y are the contour line coordinates, such as shown in (19) and (20).

$$X = X, if X \le 10, otherwise X = 0 \quad (17)$$

$$Y = Y, if Y \le 10, otherwise Y = 0 \quad (18)$$

$$x = ifft(X) \quad (19)$$

$$y = ifft(Y) \quad (20)$$

14. The contour of the segmented fingerprint image is smooth. The foreground region is in the internal of the contour and the background part is outside of the contour.

EXPERIMENTAL RESULT

Our method has been tested on low quality images. Some fingerprint images have been processed and shown in Fig. 12. These images are difficult to be segmented by other algorithms. Figure 12 (b) and (c) show the segmentation results using traditional methods, which are implemented by gray scale variance and direction coherence. When removing spurious minutiae in the invalid blocks, most boundary minutiae have not been to get rid of. Figure 12(d) show the segmentation results of the proposed method. Compared Fig. 12(b) and (c) with (d), we find that the boundary minutiae can be filtered out.

We use the accuracy of minutiae detection to compare segmentation algorithms. The accuracy of minutiae detection can be evaluated by the number of lost minutiae and the number of spurious minutiae [9]. The smaller the number, the more accurate the algorithm is. The number of lost minutiae and the number of spurious minutiae on each experimental image are listed in Table 1.

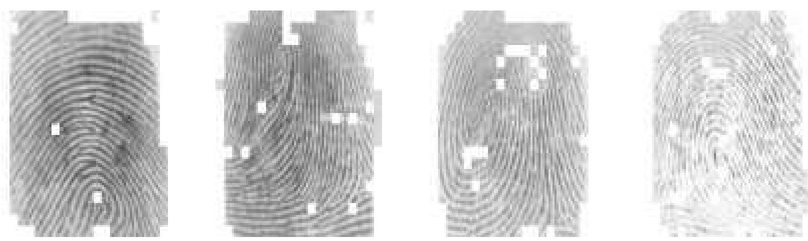
CONCLUSIONS AND DISCUSSION

In this paper, our goal is to propose a segmentation algorithm which can extract the boundary line of the ridge area. The proposed algorithm is based on point feature for fingerprint image of varied qualities. It can eliminate the smudged regions separated by meaningful boundary in the segmented fingerprint image. The experimental results compared with those of previous methods show that our algorithm produces better results than the common technique such as the segmentation based on directional image and the segmentation based on variance.

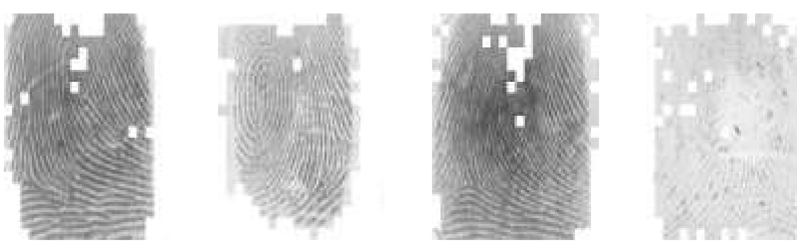
(a) (b) (c) (d)

(e) (f) (g) (h)

(1) Original fingerprint images

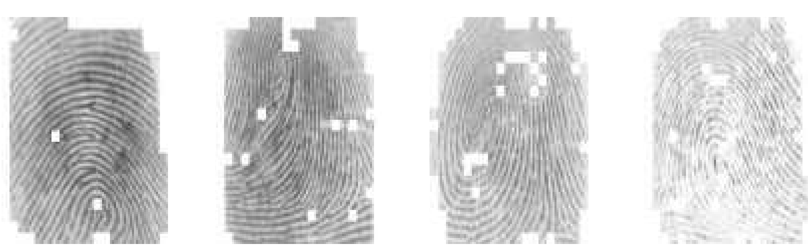


(a) (b) (c) (d)

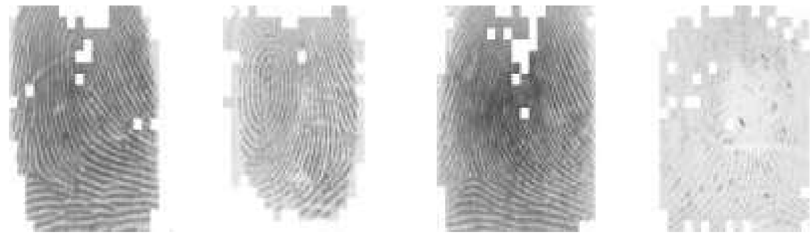


(e) (f) (g) (h)

(2) Segmented by gray scale variance



(a) (b) (c) (d)



(e) (f) (g) (h)

(3) Segmented by direction coherence

(a) (b) (c) (d)

(e) (f) (g) (h)

(4) Segmented by our algorithm

Fig. 12: Comparison of these algorithms

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