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A New Fingerprint Image Segmentation Algorithm Based on ROI

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Abstract

We present a new fast and effective method of fingerprint image segmentation, which is different from traditio-nal methods that usually use some certain features to segment diversified images. Based on the region of inte-rest, an approach is introduce, which is specialized on preprocessing a certain kind of bad fingerprint images with a great many blurs, false traces and sweat spots. It just mimics the way of finding region of interest by human beings and locating the area of low intensities quickly. Experimental result shows a significant improve-ment in fingerprint segmentation performance.

Categories and Subject Descriptors (according to ACM CCS): I.4.6 [Image Processing and Computer Vision]: Segmentation.

1. Introduction

Fingerprint as one of the biometrics features has been used for a very long time owning to its uniqueness and immutability [ALR97, LYA98]. In recent years, fingerprint recognition technique has been widely applied in many fields including finance & securities, Security & Protection, E-business, work attendance checking, etc. With the challenge of high quality performance in accuracy and response rate, fingerprint recognition technique is gradually becoming the focus of application development after academic research. The uniqueness of the fingerprint can be identified by the characteristics and relationships of bifurcations and endings in the ridges or valleys. In order to compare two fingerprints, a set of invariant and discriminating features are extracted from the fingerprint images. Most verification systems providing a high security are based on minutiae matching [ALR97, THB97].

Because more powerful and intelligent image processing techniques are available with the development of computer technology, the automatic fingerprint identification system has become a reality. Unfortunately, noise, image deficiency and deformation may take reliable minutiae detection very difficult. In fact, the effectiveness of recognition is highly influenced by the result of image preprocessing. Image segmentation, whose task is to tell the valid region of fingerprint from the input image sampled by the sampling system, is at the beginning of the preprocessing and its output is the input of the latter steps (usually the enhancement algorithm). So the result of segmentation directly influences the accuracy of the latter steps. The reason is that once the sweat spots and false traces and other noise were ill-judged into the foreground, many false minutiae would be introduced, which leads to the failure of the matching algorithm. At the same time, once the areas of genuine fingerprint were cut off, the genuine minutiae would be lost, which also brings difficulty to the matching algorithm.

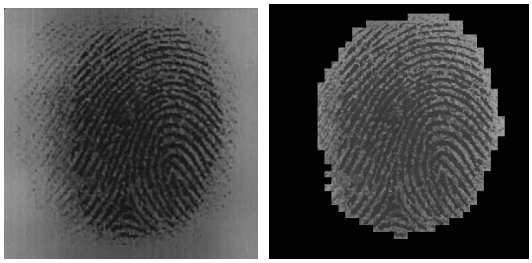
This paper proposes a simple and fast segmentation algorithm that is specialized in processing some low quality images after researching relative works. Result shows that this method has improved the reliability of the segmentation, and decreased the negative impact of the sweat spots and false traces on the fingerprint recognition.

2. Related works

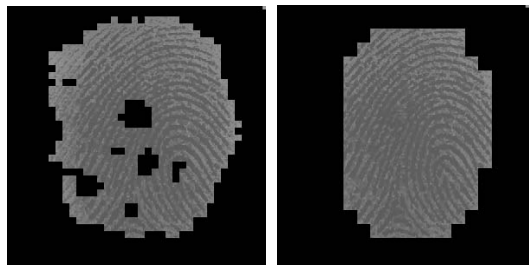
There are by far many literatures focused on the segmentation of fingerprint image. In paper [BNS87], fingerprint image has been divided into blocks and segmented by the gradient within each block. Paper [BB89] segments the image with a certain threshold according to the variance of each block. Paper [NSA95] uses the variance of the direction orthogonal to the ridge, while in paper [AS00], the image is segmented though the directional coherence. Asker in paper [AS01] adopts three common features - mean, variance and coherence and gives a systematic analysis on the effect. Sen Wang furthers his research by proposing two new features, contrast and main energy ratio [WZW03]. There are also many other methods, which use almost the same features mentioned above but different ways to get them combined or just simply use a threshold to implement the segmentation.

Generally speaking, these features and their combination give relatively satisfactory result of most fingerprint images, but there are still some limitations when dealing with quite noisy images such as false traces (see Figure1). In Figure1, there are a great many false traces around the border of the genuine fingerprint area. These false traces are quite different from either the speckle noise or the salt-like stochastic noise; they have strong directional information, and thus are inseparable by the contrast. So we cannot get the accurate segmentation by simply using the features mentioned above.

Moreover, in other fields of image processing, there also exist several methods focused on the histogram of gray level [XD03, NJM02]. They have much value in the application field. This paper refers to the idea of these methods and focuses on distinguishing the foreground from background rather than determining whether the region belongs to the fingerprint or not so as to get the image segmented correctly.



(a) (b)



(c) (d)

Figure 1: *(a) Original image from FVC2002 DB3;(b) method based on contrast; (c) method based on coherence; (d) ROIO method proposed by this paper.*

3. Preprocessing

There are some preprocessing steps before the segmentation. In order to make the algorithm integrated, we briefly introduced the steps.

3.1 Normalization

Because the quality of fingerprint images captured by fingerprint scanner is influenced by many facts. Firstly, dryness and wetness of finger can lead to the image too white or too black respectively. Cleanness of scanner, dryness and wetness of the weather can also make the image have differential gray distribution. So we firstly use normalization to remove the effects of sensor noise and finger pressure difference using the method presented in [LYA98].

$$I'(i,j)=\begin{cases} M_0+\sqrt{\dfrac{VAR_0(I(i,j)-M)^2}{VAR}} & if\ I(i,j)>M \\ M_0-\sqrt{\dfrac{VAR_0(I(i,j)-M)^2}{VAR}} & otherwise \end{cases} \quad (1)$$

where M , VAR and $I(i,j)$ are the mean, variance and image gray value. M_0, VAR_0 and $I'(i,j)$ are the desired mean, variance and image gray value.

3.2 Computation of direction field

Fingerprint image have abundant texture information, which plays important role in the image processing. The direction field estimation method presented by Jain[KA96] is used in this paper, the algorithm mainly involves four steps as below:

1. First, separate the image into W*W block.

2. Then compute the gradient of each block.

$$V_x(i,j) = \sum_{u=i-\frac{w}{2}}^{i+\frac{w}{2}} \sum_{v=j+\frac{w}{2}}^{j+\frac{w}{2}} 2G_x(u,v)G_y(u,v)$$
$$V_y(i,j) = \sum_{u=i-\frac{w}{2}}^{i+\frac{w}{2}} \sum_{v=j+\frac{w}{2}}^{j+\frac{w}{2}} (G_x^2(u,v) - G_y^2(u,v)) \quad (2)$$
$$\theta(i,j) = \frac{1}{2}\tan^{-1}\left(\frac{V_x(i,j)}{V_y(i,j)}\right)$$

where $G_x(u,v), G_y(u,v)$ is the gradient at each pixel (i,j), $\theta(i,j)$ is the orientation angle of the block centered in (i,j).

3. Use the formula (2) to estimation the direction of each block. w is the width of a block.

4. At last, carry out some smooth on the direction field

After these steps, we can get the smooth direction field as figure 2 show.

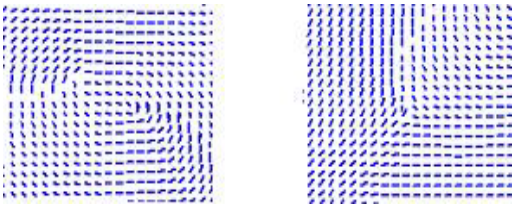


Figure 2: *examples of fingerprint direction field.*

3.3 Smooth the image

After normalization, we use a 3×3 Gauss-smooth template to smooth the image in order to reduce the influence of noises.

4. Region of interest oriented segmentation algorithm of fingerprint image

4.1 Aiming object of ROIO method

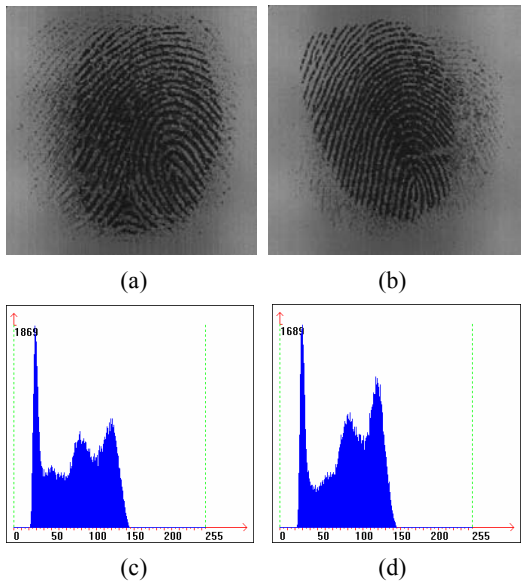
After examining the low quality images like Figure 1(a), we find that they share some common characters: there are multi-peaks distributed in the gray level histogram (see Figure 3). The low gray levels stand for the dark region of the image, which is easily perceived by eyes of human being's and so called "Region of Interest". High gray levels generally stand for the background information. There is relatively stable distribution in this area if all the images are sampled by the same set under the same conditions, which is very useful for us in image denoising. Between them, there are also some middle levels, which have diversified shapes in the distribution. It is always the place embedding lots of false traces, which is lower in gray level than the genuine fingerprint but higher than the background, and forming stripe imposer of fingerprint. Our goal is to locate the distribution of ROIO, and reduce the region we do not care, i.e. the region with no fingerprint, and then separate the foreground from the background of fingerprint image.

Therefore, we propose several hypotheses as follow:

I) The object that we should process using ROIO method has the following characters within the blocks: the area of false trace is very similar with the genuine fingerprint area in contrast and orientation; and we could not separate it from foreground easily.

II) In histogram, it has the character that there exist distinct peak in low gray level. "Distinct" means there are quite a number of pixels located in a consecutive interval of gray levels and have a sharp edge in the histogram.

III) A high quality fingerprint image should have the character that the gray levels of foreground are much lower than that of background and distribute centrally and uniformly.



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

Figure 3: *(a) and (b) are from FVC2002DB3, (c) and (d) are their histogram respectively*

4.2 Approach of ROIO method

The main idea of ROIO method is to identify the area covered by the genuine fingerprint through overexposure. Because it usually has low gray level and is sensitive to our eyes, we can distinguish its boundary from the background.

1. Compute the histogram function of the whole image, $Hist(t)$;
2. Smooth the histogram function with 1-order gauss operator for several times,

$$Hist'(t) = G(t) * Hist(t) \quad (3)$$

3. Locate the coordinate value t_p where the peak exists;
4. Fit the histogram value of the nearby domain $(t_p - \delta_1, t_p + \delta_2)$ of the peak with the quadratic polynomial $y = a_0 + a_1 x + a_2 x^2$. δ_1, δ_2 are the points which make the first order derivative of $Hist$ maximal.

$$\varphi(a_0, a_1, a_2) = \sum_{i=1}^{N} (y_i - (a_0 + a_1 x_i + a_2 x_i^2))^2 \quad (4)$$

where $N = \delta_1 + \delta_2$.

The object function at least square error is $Min\varphi(a_0, a_1, a_2)$, this is equal to find the solution of the following matrix equation:

$$\begin{pmatrix} 1 & \sum x_i & \sum x_i^2 \\ \sum x_i & \sum x_i^2 & \sum x_i^3 \\ \sum x_i^2 & \sum x_i^3 & \sum x_i^4 \end{pmatrix} \begin{pmatrix} a_0 \\ a_1 \\ a_2 \end{pmatrix} = \begin{pmatrix} \sum y_i \\ \sum x_i y_i \\ \sum x_i^2 y_i \end{pmatrix} \quad (5)$$

5. Select the greater solution as threshold T_{th} which fit for the equation $y(a_0, a_1, a_2; T_{th}) = 0$
6. Process the image like exposure, that is,

$$I'(i,j) = \begin{cases} 255 & if \quad I(i,j) > T_{th} \\ I(i,j) & else \end{cases} \quad (6)$$

Where $I(i,j)$ stand for the gray value of the input pixel (i,j)

7. Partition the image $I'(i,j)$ into blocks with size of w*w, w is the window size, which should not be too small. In this paper we set w with value 16;
8. Determine whether each block is the foreground block according to some criteria. In order to simplify the description of the algorithm, we adopt the simplest one as below:

$$\begin{cases} if \quad C(I'(i,j) \neq 255) > T & \text{B(m,n) is foreground} \\ otherwise & \text{B(m,n) is background} \end{cases} \quad (7)$$

where C is the number of the pixels whose gray value is not equal to 255 within $B(m, n)$, and T is an experiential value.

9. Perform post-processing in the segment result with morphological method to eliminate the isolated blocks.

5. Integrated segmentation algorithm of fingerprint image based on ROIO

We have mentioned that many segmentation methods based on gray level, such as variance, orientation, coherence and contrast etc. But according to our abundant experiments, there is no method that uses single feature to segment all kind of images. Asker at el. proposed a method [AS01] combined three features. Though it performs very well, there is still some certain type of images (Like Figure1(a)) that can't be managed well in segmentation. Therefore, we draw a conclusion that the well performed segmentation method in the intending fingerprint recognition system must be an integrated method combined with multi-features and multi-methods, where each method only process the domain which it specializes in [QPH02].

Thus, we adopt an integrated segmentation algorithm based on ROIO to process images of this type mentioned above and to gain a good performance in the system. The steps are showed below:

1) Normalize the input image.

2) Compute gray histogram of the image.

3) Determine whether it contains the character stated in the hypothesis II

3.1) If yes, then segment the image with ROIO method.

3.2) Otherwise, segment it with traditional method, here we adopt coherence method

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

$$O_y(i,j) = \sum_{u=i-\frac{w}{2}}^{i+\frac{w}{2}} \sum_{v=j-\frac{w}{2}}^{j+\frac{w}{2}} (G_x(u,v) - G_y(u,v))^2 \quad (8)$$

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

$$Coh = \sqrt{\frac{O_x^2(i,j) + O_y^2(i,j)}{O_E(i,j) * w * w}}$$

where Coh is a scale of image quality, we can segment the image by setting a threshold.

4) Perform post-processing to eliminate the isolated blocks.

6. Experiment result and analysis

In order to validate our segmentation algorithm based on ROIO method in processing low quality image with quite a few false traces, we choose the DB3 from the database of FVC2002. DB3 has a large number of low quality fingerprint images, including images with sweat spots, false traces and conglutination, which challenge the performance of the fingerprint recognition algorithm. There are nearly 200 out of 800 images, which have the similar character with Figure 1(a), and each of them has been tested with the method we proposed. Our algorithm has the following advantages: it can quickly determine whether it is suitable to use ROIO method; once it is fit for the method, it can give a fast and accurate segmentation result; otherwise, it still adopt traditional method to obtain high quality segmentation. Result shows that this algorithm has the advantages of cheap computing cost and accurate performance to those images with much false traces and noise.

We select two images to further describe the segmentation results and make comparison with other algorithms. Original images are showed in the Figure 3. The experimental results are showed in Figure4: (a) and (b) are results from improved contrast method, which are totally good but still imperfect in the border, where there are a few false traces; (c) and (d) are results from method based on coherence, which have notable false traces because of its strong directional coherence and too weak to immune from noise; (e) and (f) are the results from the method we have proposed in this paper, which is devised especially to deal with this kind of noisy images. In figure 5, we also give another five segmentation results using our program. We can see clearly from the result pictures that the area containing the genuine fingerprint has correctly segmented from the noisy background.

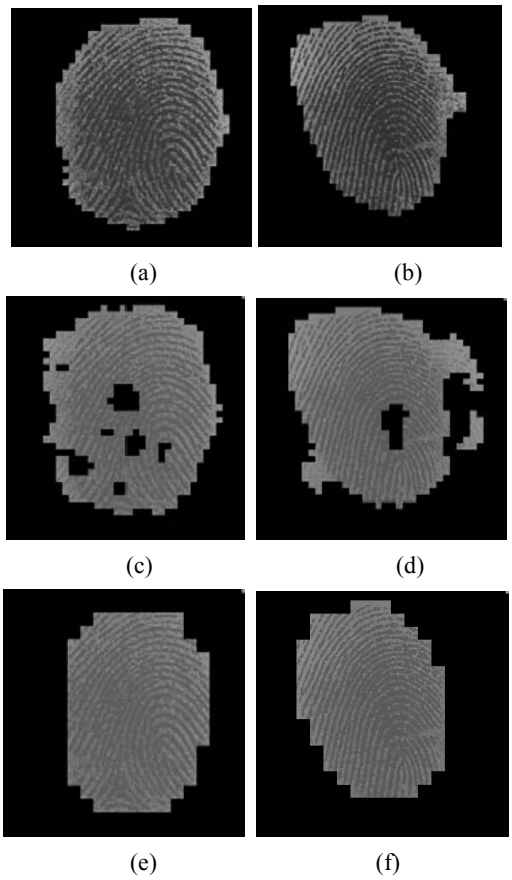
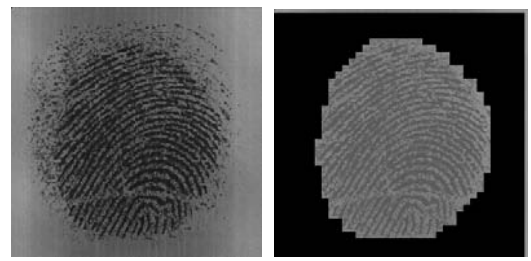


Figure 4: *Results of images from Figure3 processed by the methods based on contrast, coherence and our method respectively. (a) and (b) are the results of the method based on contrast, (c) and (d) are from method based on coherence, (e) and (f) are from our proposed ROIO method.*



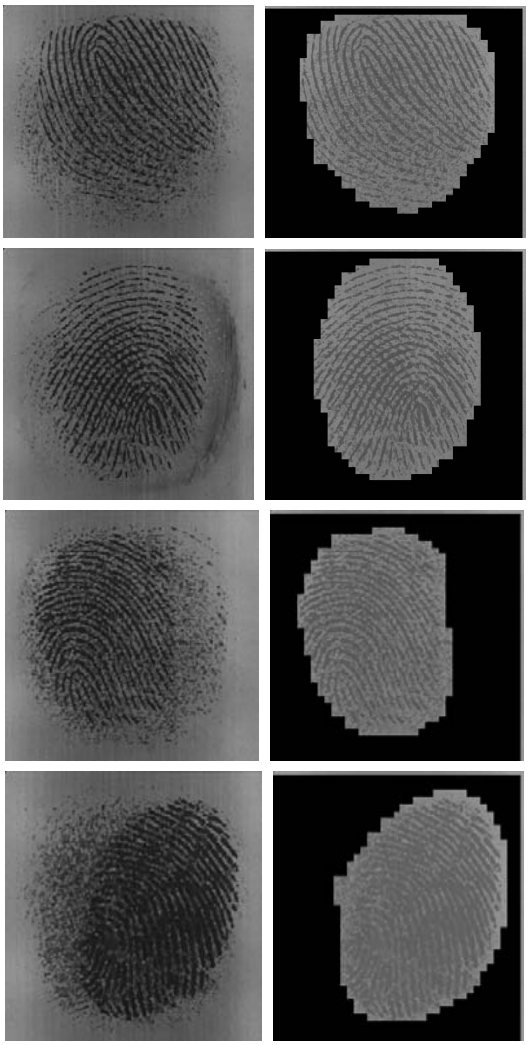


Figure 5: *Several segmentation results using our algorithm.*

7. Conclusion

This paper proposes a new method of fingerprint image segmentation based on region of interest. First, we examine the distribution character of the region of interest of our eyes. Then, we combine it with the existing method and devise a new method dealing with images of any quality, and performing fast and accurately. We also validate our method by giving some results compared with other methods.

This method is devised under the hypotheses stated at the beginning of this paper. As a method specialized in processing low quality images with false traces and sweat spots, it has strong point in the fingerprint recognition system.

In fact, this method uses the technique of exposure, which also has advantages in denoising and enhancement if we further our research in the field, so it offer us a new view of preprocessing of fingerprint image in the future.

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