SIMPLE EFFECTIVE FINGERPRINT SEGMENTATION ALGORITHM FOR LOW QUALITY IMAGES

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Abstract

Fingerprint segmentation is one of the first and most integral pre-processing steps for any fingerprint verification system, and it determines the results of fingerprint analysis and recognition. In this paper, we have proposed a novel algorithm for fingerprint segmentation. The fingerprint image gradient are discussed and its application to fingerprint segmentation is presented. Firstly, Gauss filter is used to remove noise and then we utilize histogram equalization to enhance the contrast between background and foreground. Secondly, a novel gradient based method is adopted and then obtain the approximate foreground region of the fingerprint images. Finally, we smooth the image to eliminate the isolated pieces and block effect of fingerprints. The method acquires the threshold combining the basic gradient value distributing character. It is simple to implement and the performance of the proposed algorithm is evaluated on FVC2004 DB3 database. Experimental results show the new adaptive algorithm is effective and reliable, especially for fingerprint images of low quality.

Keywords: fingerprint segmentation; gradient; threshold; low quality image

1 Introduction

Fingerprints are the most widespread biometric features for personal recognition because of their uniqueness and unchangeability. In automatic fingerprint identification system (AFIS), the input fingerprint image needs to go through a series of processes, typically including segmentation, local ridge orientation estimation, singularity and core detection, enhancement, gaining the minutiae of the fingerprints and matching[1]. The first step of the whole system is fingerprint segmentation, so it is necessary to improve its performance. A captured fingerprint image usually consists of two components, which are called foreground region and background region. The foreground is the component that originated from the contact of a fingertip with the sensor[2]. The aim of fingerprint segmentation is to identify uninterested regions and unrecoverable poor quality fuzzy regions and exclude them as background, and the other part of the image as foreground. Since most feature extraction algorithms extract a lot of false features when applied to the noisy background area, fingerprint images segmentation is an important step in fingerprint recognition[3]. Effective fingerprint segmentation can not only reduce the computation amount for post processing steps in the system, but also improve the reliability of extracted features notably[1].

Up to now, many approaches of fingerprint segmentation have been adopted and we can summarize them as two types: unsupervised and supervised[4]. In unsupervised algorithms, a fingerprint segmentation threshold is set on detected features, such as local histogram of ridge orientation [5][6], mean and variance of gray value[7], features of normal distributional model[8][9], local frequency of ridges[10]. In supervised method, a simple linear classifier according to the training samples is used to classify features as part of the region of interest or the background[2][11]. However, these algorithms have high algorithm complexity and are time-consuming to some extent. In addition, the classification method based on a simply empirical threshold is not flexible and can not get ideal result, especially for low quality fingerprints. In order to develop a fast and efficient segmentation algorithm, we propose a novel fingerprint segmentation method based on the gradient of image. The gradient of fingerprint image characterizes not only the contrast of image but also the structure of furrows and ridges. And the computation of gradient doesn't need any prior information except for the pixel gray level value and is very fast[12]. Consequently, the gradient of fingerprints is suitable for segmentation. The method we design utilizes global gradient feature of each image as segmentation threshold based on block level, combining Gauss filtering and histogram equalization. Therefore, the threshold is automatic without the experience. After post-processing, it

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can get perfect results for low quality images, In this paper, we compare our technique with Mean and Variance based technique and normal distributional model based technique.

The rest of the paper is organized as follows. In Section 2, we introduce some traditional fingerprint segmentation algorithms and some related work. The new method will be described in detail in Section 3. In Section 4, experimental results of our technique compared with other techniques show the effectiveness of our algorithm. In Section 5, a brief conclusion and suggestions for future works are presented.

2 Related work

2.1 Traditional algorithm based on mean and variance

Mean and variance based algorithm 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]. But mean and variance based algorithm does not work well on too wet or too dry fingerprint images[9].

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

1) Divide the fingerprint image I into non-overlapping blocks with size M*N.

2) Compute the mean value $Mean_l$ for each block using Equation 1.

$$Mean_l = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N} I(i,j)}{M*N} \quad (1)$$

Where *I(i,j)* is the pixel gray value of the *ith* row and the *jth* column.

3) Use the mean value computed in step 2 to compute the variance value Var_l for each block from equation 2.

$$Var_l = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N} [I(i,j) - Mean_l]^2}{M*N} \quad (2)$$

4) Select empirically a threshold value working on different images. If the Var_l is greater than threshold value, the block is considered as foreground, on the contrary, that is background. Figure 1 show the segmented images based on mean and variance algorithm.

Figure1.1st Row: Fingerprint Images from FVC2004 database, 2nd Row: Mean and Variance Based Segmented Images

In [7], it presented an improved algorithm based on mean and variance by setting the threshold through a new way. It can get better result than the traditional one but is also inferior to low quality images.

2.2 The algorithm based on features of normal distributional model

In [9], the author presents the algorithm to integrate three kinds of image features (mean, variance and total variation), and all these is based on normal distributional model. Towards an image block, the gray values seemly obey the normal distribution from the top gray value declined to a decibel area, regarding it as the background[8]. The method selects the threshold adaptively. The block threshold could be gotten using the following formula:

$$T(i,j) = \max(i,j) * 10^{-D_b(i,j)*\alpha} \quad (3)$$

Here, *T(i,j)* is the block threshold, *max(i,j)* is the block maximum gray value. *Db(i,j)* is the degressive decibel, α is an empiric value, *Db* is defined as follows:

$$D_b = \omega_1 * K_1 + \omega_2 * \frac{1}{K_2} + \omega_3 * \frac{1}{K_3} \quad (4)$$

$$K_1 = Mean_l / Mean_g \quad (5)$$

$$K_2 = \sqrt{Var_l / Var_g} \quad (6)$$

$$K_3 = TV_l / TV_g \quad (7)$$

and

$$tv(i,j) = \left[\sum_{k=0}^{3} g^2(i,j,\frac{k\pi}{4})\right]^{\frac{1}{2}} \quad (8)$$

$$TV_l = \frac{1}{M*N}\sum_{i=1}^{M}\sum_{j=1}^{N} tv(i,j) \quad (9)$$

Where, $g(i,j,\frac{k\pi}{4})$ represents the gradient at the direction of $\frac{k\pi}{4}$ of the *pixels*. This algorithm makes use of local and global features to decide block threshold automatically and can get better result. However, it also have limitations for low quality image and has a high computational complexity.

3 The simple effective fingerprint segmentation algorithm

The algorithm in [7] defines the fingerprint segmentation threshold using mean and variance features. It shows better performance than traditional method but due to the defect of gray value character, it is unable to segment those fingerprint images with high noise. Defining the threshold with gradient can solve this problem. The local gradient values for fingerprint images can detect sharp change in the gray level value of background. And our algorithm is simple to perform. The flow chart of our method for fingerprint segmentation based on block level by gradient character is as figure 2.

3.1 Gauss filtering

In the process of collecting the fingerprints, noises are usually drawn into the fingerprint image for many reasons, such as inhalation of dust and spots on the sensor surface. Therefore, at the beginning of our method, the Gaussian filter is used to weaken this effect and improve the quality of the images. The two-dimensional Gaussian function is given as follows[13]:

$$G(x,y) = Ae^{-\frac{x^2+y^2}{2\delta^2}} \tag{10}$$

3.2 Histogram equalization

From the perspective of fingerprint image field, the aim of equalization is to make distribution of pixels' gray values be uniform by the gray operation. Because the histogram is used to describe the distribution of gray intensity, the histogram equalization is equal to operate the intensity in unit area. It extends the range of pixel grayscale and enhance the overall effect of fingerprint image contrast between background and foreground[13]. The result of the histogram equalization is shown as figure 3.

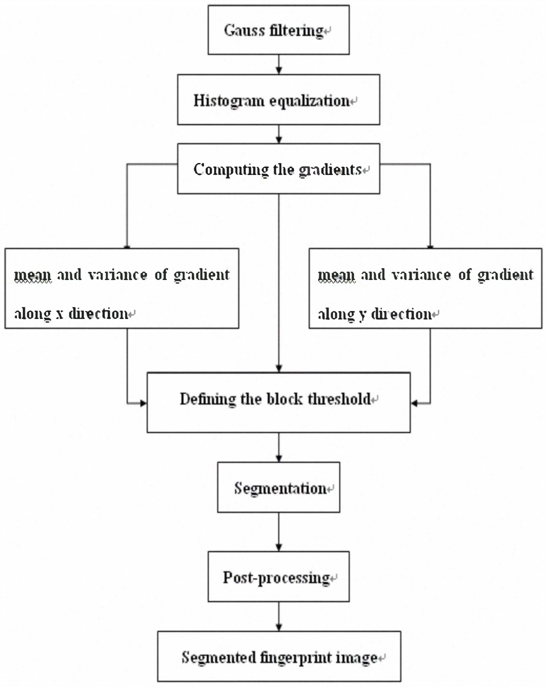

Figure 2 The flow chart of proposed algorithm

Figure 3 Fingerprints after equalization

3.3 Defining the block threshold

In order to set the block threshold effectively, we adopt the method combining the gradient according to x and y direction. And we will utilize both the global and local gradient values. Steps for defining the block threshold are summarized as follows:

1) Divide the input image I into non-overlapping blocks, size of *w*w*. For our experiments, we set w as 8.

2) Compute the gradients $\partial_x(i,j)$ and $\partial_y(i,j)$ at each pixel *(i,j)* which is the center of the block.

3) Calculate each block mean and variance value for x and y component of the gradient using the following equations:

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

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

4) Compute deviation for both *Mx* and *My* using the equations 13 and 14.

$$V_x = \frac{1}{\omega^2} \sum_{i=-\omega/2}^{\omega/2} \sum_{j=-\omega/2}^{\omega/2} (\partial_x(i,j) - M_x(I))^2 \qquad (13)$$

$$V_y = \frac{1}{\omega^2} \sum_{i=-\omega/2}^{\omega/2} \sum_{j=-\omega/2}^{\omega/2} (\partial_y(i,j) - M_y(I))^2 \qquad (14)$$

5) Compute the gradient variance's mean:

$$VM_x = \frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} V_x(i,j) \qquad (15)$$

$$VM_y = \frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} V_y(i,j) \qquad (16)$$

6) Calculate the specified regional variance estimate for x and y component of the gradient as follows:

$$VF_x = \frac{VS_x}{NS_x} \qquad (17)$$

$$VF_y = \frac{VS_y}{NS_y} \qquad (18)$$

Where *VSx* and *NSx* are defined respectively as blocks gradient sum and blocks gradient number along x direction on condition that $V_x \geq VM_X$. *VSy* and *NSy* are analogous to *VSx* and *NSx*.

7) The fingerprint segmentation threshold is represented by:

$$VT_x = \frac{VST_X}{NST_x} \qquad (19)$$

$$VT_y = \frac{VST_y}{NST_y} \qquad (20)$$

Here, we define *VSTx* and *NSTx* as blocks gradient sum and blocks gradient number along x direction in case of $VF_X \leq M_x$. *VSTy* and *NSTy* are the same as *VSTx* and *NSTx*.

If $V_x < VT_x$ and $V_y < VT_y$, the block is considered as background otherwise it belongs to foreground.

3.4 Post-processing

After segmentation after the above procedures, the foreground region and the background region are basally separated. However, there is still some isolated pieces and block effect in the rough results. That is because some blocks are incorrectly decided as foreground or background. In order to solve this problem, we utilized 5*5 filter to keep an account of how many foreground or background blocks around the corresponding block. And a labeling matrix Flag is received:

$$Flag(m,n) = N \qquad (21)$$

If the *block(m,n)* is foreground in the preliminary results, *N* is the number of foreground blocks around the block. All as the background. And if N is less than an empiric value, we defined the corresponding block to the reverse one.

4 Experiments results

In order to validate the actual performance of the improved algorithm described in the previous section, fingerprint images from FVC2004 DB3 databases are selected, which fingerprint images quality is poor. All the experiments were done under the circumstance VC 6.0. From the experimental results, the typical fingerprint images from fvc2004 DB3 were chosen in Fig 4. Segmentation results of our method compared with mean and variance based method in [7] and normal distributional model in [9] are shown as figure 5. From these examples, we can see that the proposed algorithm does locate the background correctly and segment fingerprint images effectively even from the noisy background. And it is clear that performance of segmentation has been improved for low quality fingerprints through comparing with the results made by various methods.

Figure 4 The original images from fvc2004 DB3

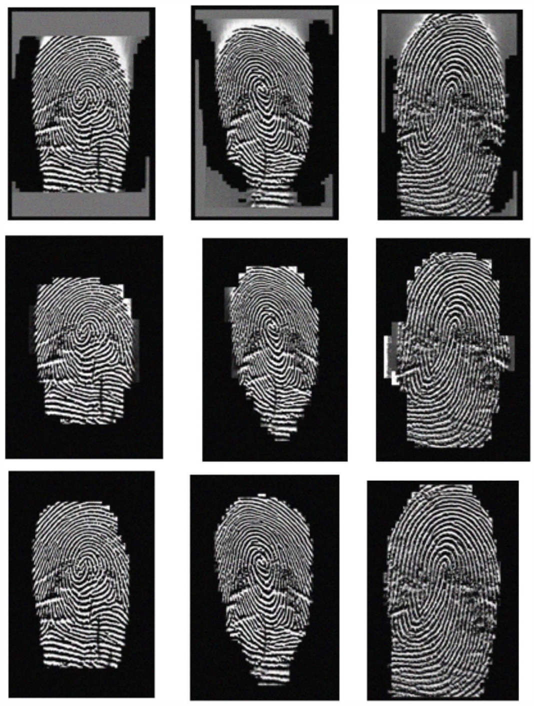

Figure 5 Results of fingerprint segmentation by different methods.

1st Row: The results based on improved mean and variance method in [7], 2nd Row: The results based on multiple features of normal distributional model in [9], 3rd Row: The results based on the proposed algorithm

5 Conclusions

In this paper, a new gradient based technique for fingerprint segmentation is proposed. Our segmentation algorithm detects the foreground by computing the local and global gradient values followed by a novel threshold defining method to extract it. In the proposed algorithm, mean and deviation of the image gradient is calculated. The regional and global features of fingerprint gradient according to x and y directions are used combining Gauss filtering and histogram equalization. Compared with other approaches, our algorithm is simpler to implementation and performs better for low quality fingerprints. Meanwhile, the segmentation threshold is computed automatically without the experience so it is adaptive to fingerprints. But it lacks the texture characteristics and investigating fingerprint images texture features will be next step in the near future.

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