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Fingerprint Segmentation Algorithm Based on Fourier Transform

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Abstract: On the basis of the study of the spectral characteristics of the fingerprint image, a fingerprint image segmentation algorithm based on Fourier transform is proposed. Fingerprint image is divided into blocks to calculate Fourier transform, the average value of the Fourier transform amplitude of the sub block image is accepted as the feature for segmentation. Using K-mean clustering to divide the feature into two categories, and the original fingerprint image is segmented. The experimental results show that the proposed algorithm has good adaptability to kinds of fingerprint images, and it can achieve satisfactory segmentation results. When the speed of the algorithm is pursuit, the fixed threshold which is constituted by golden ratio can be adopted, it can also achieve very good segmentation results.

Keywords: fingerprint segmentation; Fast Fourier Transform (FFT); K-mean clustering; golden ratio

1 Introduction

The application of automatic fingerprint identification system is in various fields. In different areas, its use is different no matter where it uses, the end is through the extraction of features to match the fingerprint images. So the accuracy of feature extraction is the key to affect the performance of automatic fingerprint identification system. The fingerprint image is formed by the acquisition equipment. Because of the limitation of acquisition equipment and dry or wet finger, there will be some noise to affect the subsequent feature extraction and matching during the process. Automatic fingerprint recognition systems usually need to reduce the impact of noise by pre-processing. Fingerprint image segmentation is an important part of preprocessing. What fingerprint segmentation do is to make the noise area or the fingerprint region where is different to recover (referred to background area) removed from the image, and leave the region where subsequent work needs. This can ensure that feature extraction and fingerprint matching will be effectively carried out, as far as possible to avoid the interference of background area to the subsequent processing, and then improve the performance of the entire fingerprint identification system [1]. The aim of fingerprint segmentation is to reduce the computation time and improve the correct rate for the following steps. The fingerprint segmentation algorithm directly affects the accuracy rate of fingerprint identification system and the efficiency of the whole system. So the fingerprint segmentation should to be done as early as possible to achieve its own purposes. Usually the process of fingerprint segmentation is done before the preprocessing of fingerprint.

At present, the main stream method of fingerprint image segmentation is to divide the whole image into a series of non overlapping blocks, and then extract numbers of feature from every piece, finally, we can determine whether each small piece is a foreground or a background area according to the extracted features [2]. There are some other methods that regard each pixel as a small piece, and then calculate the characteristics of each pixel to split the fingerprint image. These features include: Statistical characteristics of gray value (such as average gray and gray variance) [3-5], local direction features (such as coherence of orientation) [6] and palm-line features (such as ridge frequency) [7, 8].

Studied on the fingerprint image, we can find that the clear fingerprint region is the area where ridges and valleys alternately present, and there isn't this feature in the background area and the area where the ridge is not clear. So we can inspect the correlation characteristic of the frequency domain information of the fingerprint image as the index of the fingerprint image segmentation. This article proposed a new algorithm on the existing basis, which is a fingerprint image segmentation algorithm based on Fourier transform. We can use fast Fourier transform to each block of fingerprint image, and calculate mean value of every amplitude, and then use k-means clustering algorithm to divide them into two categories, finally we can achieve the purpose of the fingerprint image background segmentation.

2 Proposed Algorithm

2.1 Fourier spectral analysis of fingerprint image

The purpose of fingerprint image segmentation is to eliminate the areas where do not contain the fingerprint ridge or the regions that are not clear, so the subsequent algorithm can focus on the clear area, which can improve the work efficiency of the system and the accuracy of feature extraction. As the difference between the fingerprint image foreground and background region, looking at the spectrum characteristic of fingerprint image, we find that it has a good distinction in the previous background image to use Fourier transform amplitude for image in block.

Divide the fingerprint image into the size of $w \times w$ non-overlapping small pieces, setting f(p, q) to represent the gray value of the fingerprint image f in the block location(p, q) , doing fast Fourier transform(FFT) to each

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image, the results $F\_blk(m, n)$ of the block in the position (m, n) is:

$$F\_blk(m,n) = \sum_{p=0}^{w-1}\sum_{q=0}^{w-1} f(p,q) \times e^{-j\,2\pi\left(\frac{pm}{w}+\frac{qn}{w}\right)}$$

Where $m, n = 0,\ 1,\ \ldots,\ w-1$.

Then calculate the mean value F_blk_mean to amplitude of each point in the block of $F\_blk(m, n)$

$$F\_blk\_mean = \frac{1}{w \times w}\sum_{m=0}^{w-1}\sum_{n=0}^{w-1}|F\_blk(m,n)|$$

Studied the amplitude of each Fourier transformation, from the display in figure 1(b), we cannot see the obvious difference between the previous background. After analysis we find that the main reason is that each image has a center amplitude after doing Fourier transform, the center amplitude corresponds to the direct current(DC) component of the Fourier spectrum, the amplitude is far greater than other position, and the difference between each block is not significant, and the amplitude of the Fourier spectrum of the image rapidly decreases with the increase of the frequency. Therefore, the DC component plays a leading role in the form of image display, and the other high-frequency items can be reflected hardly. But calculate the average value of each Fourier transform results, and equal all the points to the mean value, can basically distinguish clear ridge area and background area. Such as the display in the picture 1(c).

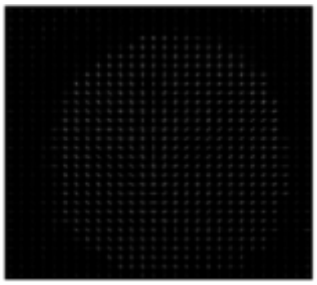
(a)Original fingerprint image

(b)FFT amplitude in block

(c) Mean value of FFT amplitude in block

Figure 1: The spectrum of fingerprint image doing FFT in block

In order to eliminate the influence of DC maximum amplitude, we can see the previous background blocks show obvious differences after removing the DC component from the result of each Fourier transform, and then calculate the average of amplitude in each block, which shows a good distinction between the previous background. Figure 2(a) is to remove the DC component from FFT amplitude of each block in figure 1(b), that is to say the result using "zero" to instead of; Figure 2(b) is the result of the mean value of the FFT amplitude of the blocks removed from the DC maximum, that is to say the result of the mean value of the block in figure 2(a).



(a) Doing FFT to each block removed the DC component

(b) The mean value of the FFT amplitude after removing the DC component

Figure 2: The FFT amplitude after removing the DC component

Fourier transformation is the image from the spatial domain to the frequency domain, and the frequency of the image is the indicator of the intensity of the gray level change in the image. The spectrum got from the image which has done the two-dimensional discrete Fourier transform, is the image gradient distribution map. Of course, there is no one-to-one correspondence between the points on the spectrum map and the image, but the Fourier spectrum of each image can represent the characteristic of the image frequency domain. The bright spot of light and shade in a spectrum, is the strength of the difference between the point and the neighborhood in fact, which is the size of the gradient, and the size of the frequency of the point. Generally speaking, the image gradient is large, the brightness is strong, or else the brightness is weak. If the image spectrum map has more dark points, the actual image is soft, the difference between the points and the neighborhood is not big, the gradient is relatively small. On the contrary, if the image spectrum map has more bright points, the actual image is sharp, the edge is clear and the difference between the two sides of the border is larger. For the fingerprint image, it contains the foreground area of the clear fingerprint, ridge and valley lines appear alternately, so there are more bright points, and the mean amplitude of FFT is greater, corresponding to the bright area of figure 1(c) and figure 2(b). While the background of fuzzy region or without fingerprint has little bright point, and the mean amplitude of FFT is relatively small, for the dark area of figure 1(c) and figure 2(b).

According to the above analysis, it is feasible and effective to use the average value of the block FFT amplitude (F_blk_mean0) after removing the DC component as the feature of the fingerprint image segmentation.

2.2 The processing of segmentation threshold

From Figure 2 (b), it can be seen that the background of the fingerprint image has a clear distinction. But it is worth studying how to select the threshold with general applicability of the segmentation. Many algorithms select the threshold according to the experience, but the image has different

characteristics, such as gray contrast background form (gray background, white background, background ladder) and proportion of previous background, such differences make the experience threshold difficult to apply for all the images, and the operator's experience is not the same for different threshold selection.

In this paper, the automatic threshold selection method is studied from the view of image spectrum. Tried a variety of threshold selection methods, but the results are not satisfactory. Considering its simple and fast convergence speed of the K-mean clustering algorithm[9, 10], we use the K-mean clustering algorithm to divide all the F_blk_mean0 into two categories, after the experimental analysis.

The basic idea of K clustering algorithm is as follows: choose k (the number of clusters) points as the initial cluster centers, and then divide all the objects in the data set into k classes, update of all kinds of center through the iterative calculation, until the convergence of the algorithm is to a certain end conditions, finally output the clustering results. The basic steps of the algorithm are as follows:

Step 1: All the F_blk_mean0 constitute the data set to be clustered, set the number of categories k=2, randomly selected data set of 2 data as the initial cluster center;

Step 2: Select Euclidean distance as the distance criterion, return each sample of the data set to the nearest class sequentially. That is, the current point and the difference between the cluster center is small, classified it into that category.

Step 3: Calculate the average value of all the samples in each class, and take the average value as a new cluster center.

Step 4: If the clustering center is no longer changing, the iteration is over, or turn to step (2) to continue.

As can be seen from the above algorithm process, the essence of K means clustering is to make minimum in inner-class distance, and maximum between class distance. The algorithm also conforms to the principle of background segmentation of fingerprint image. Therefore, it is reasonable to use K means clustering to classify the previous background of fingerprint image.

3 Fingerprint image segmentation algorithm based on Fourier transform

Through the above analysis, a segmentation algorithm of fingerprint image based on the Fourier transform (FFT) is proposed. The algorithm does FFT to each block of fingerprint image, and then calculates the mean value of each FFT amplitude has been removed the DC component, makes the mean value as the segmentation features. Using k-means clustering to divide the characteristics into two categories, on behalf of the fingerprint image foreground and background regions respectively, to realize fingerprint image segmentation.

Algorithm steps are as follows:

Step 1: Divide the fingerprint images into non overlapping blocks, due to the count Fourier transformation needs is power of two, and each fingerprint block should contain at least a ridge and a valley line, this paper divide the fingerprint image into 16*16 blocks. If the original size of the fingerprint image cannot just achieve the whole point, the image size should be redefined as the closest size before the sub block processing.

Step 2: Do fast Fourier transform (FFT) to each image block and take the amplitude, find the maximum value of each FFT amplitude, the position value is set to "0", and then, calculate the average value of the block FFT.

Step 3: Using K means clustering algorithm, divide all the FFT block means into two categories.

Step 4: Output the results of segmentation.

4 Experimental results

In this paper, the algorithm is programmed in MATLAB environment, and a large number of fingerprint images in FVC standard fingerprint database are carried out segmentation experiment. To validate the performance of algorithm, it makes comparison with the variance segmentation algorithm for fingerprint image in the text [3], and variance gradient segmentation algorithm in the text [4]. In order to compare the basic results of algorithm, we do not do the post processing the text [3] and text [4] proposed, and the block scale of each algorithm is set to 16*16.

It is the original fingerprint of FVC database in the (a) of figure 3 to figure 6; Figure (b) is the result of fingerprint image segmentation algorithm based on gray scale variance of text [3], and it does not do the post processing of isolated blocks; Figure (c) is the result of fingerprint variance gradient segmentation algorithm of text [4], doesn't do the post-processing of open and close operation; Figure (d) is the result of algorithm based on Fourier transform of this paper.

From the segmentation results, we can see that the fingerprint images in figure 3 and figure 4 are very clear, the three methods can make better segmentation. By the way of contrast, there are many free fingerprint region reserved by the algorithm of variance gradient of text [4]. It is caused by the selection of block scale. In order to compare the segmentation performance of different algorithms, the block scales in the three algorithms are set to be the same value, and the gradient method is more suitable for small size. It has a large contrast in the previous background in the fingerprint image of figure 5, variance method and the algorithm in this article can well extract the fingerprint foreground area. But for the larger ridge edge brightness changes in the region, the segmentation algorithm in this article is better than the other two algorithms. In the fingerprint images of figure 6, the background contains much noise which has obvious changes in the gray. The segmentation algorithm of gray variance and variance gradient will lead to incorrect segmentation of this type of noise, and form isolates or scattered foreground blocks. The algorithm in this paper is not sensitive to this type of noise, and can accurately and completely extract the fingerprint area. Experimental results show that the algorithm has good adapt ability to all kinds of complex background, can achieve good segmentation results, and can completely reserve the fingerprint foreground area.

(a) Original fingerprint image

(b) Result of variance method in text [3]

(c) Result of Variance gradient method in text [4]

(d) The results of the paper algorithm

Figure 3: Segmentation results of fvc2002\DB1_B\101_1.tif

(a) Original fingerprint image

(b) Result of variance method in text [3]

(c) Result of Variance gradient method in text [4]

(d) The results of the paper algorithm

Figure 4: Segmentation results of fvc2002\DB4_B\101_1.tif

(a) Original fingerprint image

(b) Result of variance method in text [3]

(c) Result of Variance gradient method in text [4]

(d) The results of the paper algorithm

Figure 5: Segmentation results of fvc2004\DB3_A\1_1.tif

(a) Original fingerprint image

(b) Result of variance method in text [3]

(c) Result of Variance gradient method in text [4]

(d) The results of the paper algorithm

Figure 6: Segmentation results of fvc2000\DB3_B\101_1.tif

During the experiment, we found an interesting phenomenon. Calculating the mean value of each block of

FFT amplitude which has removed the DC component, we can get a value F_blk_mean0. Take 0.382 times of the interval length as the segmentation threshold, and then set the image whose F_blk_mean0 is bigger than the threshold as the foreground, the others as the background. In this way, we can get similar results with the aforementioned K mean clustering. If all the F_blk_mean0 are mapped to the interval [0,255], naming as F_blk_mean1, the fixed threshold is $T = 0.382 \times 255$. The segmentation process can be described as follows:

$$I_{out}(i,j) = \begin{cases} f(i,j), & F\_blk\_mean1(i,j) > T \\ 255, & F\_blk\_mean1(i,j) \le T \end{cases}$$

$I_{out}(i,j)$ stands for the output image, which is the gray value of the position (i,j) in the result image;

$f(i,j)$ is the gray value of the original image in the position (i,j).

The cause of this phenomenon should be attributed to the excellent quality of the golden section rate (0.382=1-0.618). The fingerprint images in (a) to (d) of figure 7 correspond to figure 3 to figure 6, whose segmentation results are used with this fixed threshold. Seen from the figure, we can see the threshold can achieve good segmentation of the fingerprint image, and the effect is similar to K mean clustering algorithm. Because it doesn't need to do clustering algorithm, using fixed threshold segmentation processing is faster than the K mean clustering algorithm. Therefore, when the speed of the algorithm is pursuit, it can be considered to use the fixed threshold to complete the segmentation operation.

Figure 7: Segmentation results of fixed threshold

5 Conclusions

The fingerprint image segmentation directly affects the accuracy and efficiency of extraction. At present, the commonly used algorithms always use the time domain characteristics of the fingerprint image as the segmentation parameters, such as the gray scale variance, the direction consistency and the gray gradient. The segmentation threshold is selected by experience, and it is difficult to guarantee the segmentation results. This paper proposes a fingerprint image segmentation algorithm based on Fourier transform. In this algorithm, the fingerprint image is divided into blocks to do FFT, and then calculate the mean value of each block FFT amplitude removed the DC component, and take them as the features of the segmentation. Using K means clustering to divide the features into two categories. The two categories represent the foreground and background regions of fingerprint image, which can be used to realize the fingerprint image segmentation.

The experimental results show that the algorithm has good adaptability to all kinds of fingerprint images, can accurately segment the background area, and completely reserve the foreground region. When the speed of the algorithm is pursuit, using the golden section rate to construct a fixed threshold, selecting the length of the segmentation feature interval (1-0.618) times as the segmentation threshold, can get the segmentation results with the K mean clustering.

In figure 2(a) of fingerprint image spectrum, frequency distribution of the image is the center point as the center of symmetry distribution. There are two bright spots about the center of symmetry in the fingerprint region, the two attachment direction perpendicular to the ridge direction and the two bright spots spacing and ridge frequency have certain relationship. How to make use of these characteristics effectively will be the further study of this paper.

References

[1] M. Zhang, Research and realize of segmentation algorithm of fingerprint image. [Master Dissertation].Shandong Normal University, 2014.

[2] F. An, Pre-processing and segmentation of fingerprint image based on image quality assessment. [Master Dissertation]. Southwest University.2013.

[3] X. Cai, Adaptive segmentation of fingerprint image based on variance, in *Journal of Xi'an University of Posts and Telecommunications*, 2009，14(3):44-47.

[4] D. Fan, B. Sun, J. Feng, Adaptive fingerprint segmentation based on variance and its gradient, in *Journal of computer-aided design & computer graphics*, 2008,20(6):742-747.

[5] M. Huang, Y. Liu, An improved gray level co-occurrence fingerprint image segmentation algorithm, in *Journal of Changsha University of Science and Technology (Natural Science)*, 2016,13(1):75-80.

[6] X. Huang, P. Su, P. Bai, Algorithms for an Automatic Fingerprint Identification System Based on Oriented Filtering and Segmentation, in *Journal of Image and Graphics*, 2002,7(A)(8):829-834(in Chinese)

[7] S. Wang, W. Zhang, Y. Wang, New Features Extraction and Application in Fingerprint Segmentation, in *Acta Automatica Sinica*, 2013,29(4):622-627.

[8] K. Cao, E. Liu, A.K. Jain. Segmentation and Enhancement of Latent Fingerprints: A Coarse to Fine Ridge Structure Dictionary. *IEEE Transactions. on Pattern Analysis & Machine Intelligence* 2014:1-14.

[9] X. Tao, J. Xu, L. Yang, etc, Improved Cluster Algorithm Based on K-Means and Particle Swarm Optimization, in *Journal of Electronics & Information Technology*, 2010,32(1):92-97.

[10] A.K. Jain, Data clustering: 50 years beyond k-means, in *19th International Conference on Pattern Recognition*, Tampa, USA, 2010: 651-666.