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Efficient Gradual Segmentation of Fingerprint Images

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Abstract: - A new algorithm for fingerprint image segmentation is presented. Gradual segmentation algorithm and multi segmentation features are used to segment fingerprint image in two steps. First we get the whole fingerprint region from image, and then the well-defined region and recoverable corrupted region are segmented from first step result. Region-growing method is introduced in first step to make the algorithm more robust. This algorithm can take more accurate segmentation for various types of images based on large numbers of the experiments.

Key-words: - fingerprint segmentation; seed block; region-growing; gradual segmentation

1 Introduction

Fingerprint is one of the commonly used biometric feature used as a personal identification tool for a long time. The major reasons are due to its unchangeable and uniqueness properties.

The fingerprint image segmentation in ridge and valley regions heavily influences the performances of the minutiae extraction process and hence the performances of the identification. The segmentation process classifies each image pixel in one of the two aforementioned regions. The binary image obtained follows to be used further by subsequent processes in order to detect and classify the minutiae points.

Different authors have addressed the problem of fingerprint image segmentation before. A segmentation technique based on the iterative application of a Laplacian operator and a dynamic threshold is proposed in [4]. In [5] directional filtering in conjunction with an empirical selected threshold is used for fingerprint binarization. A segmentation method based on the detection of gray level minima along an orthogonal direction to the ridge orientation is proposed in [6]. In general they privilege either the photometric properties of the pixels or their spatial properties. Almost all proposed methods of fingerprint segmentation require a global or local threshold to discriminate between the ridge and valley regions. In most of the cases the threshold is more or less arbitrarily chosen based on a restricted set of images. So most of the algorithms are restricted to some types of the images and influenced much by the margin of the images.

In this paper, a new gradual algorithm for fingerprint image segmentation is presented. First the whole fingerprint region is got from the image by a gradual segmentation algorithm using local gray level feature presented in section 2, then the well defined region and recoverable corrupted region are segmented from first step result by a multi segmentation feature algorithm presented in section 3. Region-growing method is introduced in first step to make the algorithm more robust. In section 4, we give some experiments' results. We get conclusions in section 5.

2 Region-growing based segmentation

Giving fingerprint image is a matrix, the image can be partitioned to $M \times N$ blocks. The size of each block is $W \times W$ pixels. Commonly $W = \lambda$, λ is the average distance of the ridges. Let $G_B(m,n)$ denote the average gray level of the block $B(m,n)$, let $D_B(m,n)$ be the gray level's deviation of the block with $0 \le m < M$ and $0 \le n < N$. Define the following variables to evaluate the image's fingerprint region and the background.

Define G_{Mean}, D_{Mean} as the average gray level and deviation of all the blocks.

$$G_{Mean} = \frac{1}{M \times N} \sum_{n=0}^{N-1} \sum_{m=0}^{M-1} G_B(m,n) \qquad \text{Formula (1)}$$

$$D_{Mean} = \frac{1}{M \times N} \sum_{n=0}^{N-1} \sum_{m=0}^{M-1} D_B(m,n) \qquad \text{Formula (2)}$$

Define D_{Frg}, D_{Bkg} as the estimated deviation of the fingerprint region and the background.

$$D_{Frg} = \frac{S_{Frg}}{N_{Frg}} \qquad D_{Bkg} = \frac{S_{Bkg}}{N_{Bkg}} \qquad \text{Formula (3) (4)}$$

In formula 3, S_{Frg} is the sum of all blocks' deviation with $0 \le D_B(m,n) \le D_{Mean}$, N_{Frg} is the amount of blocks. In formula 4, S_{Bkg} is the sum of all blocks' deviation while $0 \le D_B(m,n) \le D_{Frg}$, N_{Bkg} is the amount of blocks.

Define D_{Thd} as the estimated deviation of the transition region.

$$D_{Thd} = \frac{S_{Thd}}{N_{Thd}} \qquad \text{Formula (5)}$$

In formula 5, S_{Thd} is the sum of all blocks' deviation while $D_{Bkg} < D_B(m,n) < D_{Frg}$, N_{Thd} is the amount of blocks.

In this step, we use a region-growing algorithm to deal with various fingerprint images. The basic idea of this algorithm is: finding a special block in the fingerprint region, called seed block, the seed blocks' region is called seed region. Scanning a seed block's 8 neighbors, if they meet the growing conditions, they are added to the seed blocks' set. The algorithm stops until non-block matches the conditions.

In this paper, we define the initial seed blocks $B(m,n)$ with $D_B(m,n) > D_{Mean}$. Always we select $D_B(m,n) \approx D_{Mean}$. The initial seed block needs to be limited to the fingerprint region to reduce the disturbing of various boundaries.

Here we give 3 typical region-growing conditions. Let $N_{Seed}(m,n)$ denote the seed blocks' amount of the block $B(m,n)$'s neighbor. Block $B(m,n)$ is not a seed block.

① If $N_{Seed}(m,n) \ge 2$ and $D_B(m,n) \ge D_{Thd}$, $B(m,n)$ is a new seed block separated the background and unusable region from image.

② If $N_{Seed}(m,n) \ge 4$ and $G_B(m,n) \le G_{Mean} - \frac{\sqrt{D_{Mean}}}{4}$, $B(m,n)$ is a new seed block growing from fringe to center.

③ If $N_{Seed}(m,n) \ge 5$ and $G_B(m,n) \le G_{Mean}$, $B(m,n)$ is a new seed block in center region.

The region-growing condition determines the result of the segmentation. See Fig. 1, the algorithm segments the fingerprint region from the noisy background. The recoverable corrupted region are reserved, these region and the well-defined region will be segmented in next step.

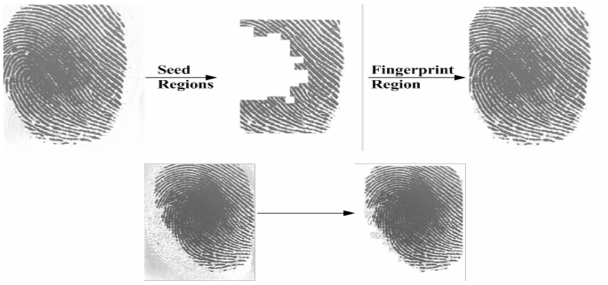

Figure 1: the sample of the first segmentation

3 Eliminate the unrecoverable region

In this step, the contrasts of the local ridges and valleys are used to identify and segment the unrecoverable fingerprint region. Before this step, the blocks need to be serialized to make all the contrasts in a stable level.

The statistical researches show that the local directional field based x-axis projection of the gray level in the clear fingerprint region and the recoverable region is an approximate sine wave distributing.

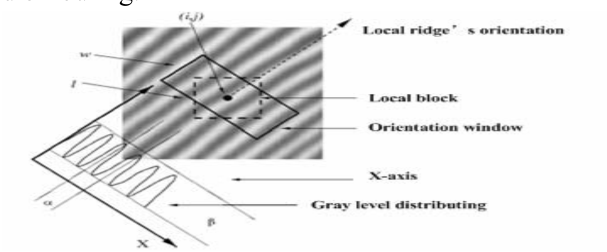

Figure 2 the x-axis projection

In Fig.2, (i,j) is the central pixel of block $B(m,n)$. Supposing the block size is $W \times W$ pixels, the length of the orientation is L and the width is W. $L = 2\lambda$ and $W = \lambda$ are acceptable choices, λ is the average distance of the ridges. Let the $X_{mn}[k]$ ($k = 0,...L-1$) be the projection.

$$X_{mn}[k] = \frac{1}{W}\sum_{d=0}^{W-1} G(u,v) \quad \text{Formula (6)}$$

$$u = i + (d - \frac{W}{2})\cos\theta + (k - \frac{L}{2})\sin\theta \quad \text{Formula (7)}$$

$$v = j + (d - \frac{W}{2})\sin\theta + (\frac{L}{2} - k)\cos\theta$$

$G(u,v)$ is the gray level of (u,v) ($d = 0,...W-1$). Θ is the local direction of the block. The distributing of $X_{mn}[k]$ ($k = 0,...L-1$) is an approximate sine distributing for the clear region and the recoverable region. This feature can be used to classify the unrecoverable region.

Define the contrast of the local ridges and valleys $C_B(m,n)$ as the average difference between the max and min value in $X_{mn}[k]$ .Using this definition, we get the condition of segmentation:

$$C_B(m,n) > C_{Thd} \quad \text{Formula (8)}$$

$$C_{Thd} = \frac{S_C}{N_C} \quad \text{Formula (9)}$$

In formula 8, C_{Thd} is a threshold computed by formula 9. S_C is the sum of the contrast while the block match the condition $0 \le C_B(m,n) \le C_{Mean}$. N_C is the amount of the blocks. C_{Mean} is the average contrast of the fingerprint region.

If $C_B(m,n)$ match the conditions, block $B(m,n)$ is a clear or recoverable fingerprint region. Else block $B(m,n)$ is an unrecoverable region.

4 Experiments and Results

We use about 2000 various fingerprint images to test the results contrasting the algorithms in paper [2] and [3]. A sample is shown in Fig. 3.

In Fig. 3, image (a) and (b) are optical fingerprint images, the (a)'s margin of fingerprint and background is not clear, the (b)'s margin is black and the contrast is large. Image (c) is a CMOS fingerprint image; the image's fingerprint region is conglutinate much.

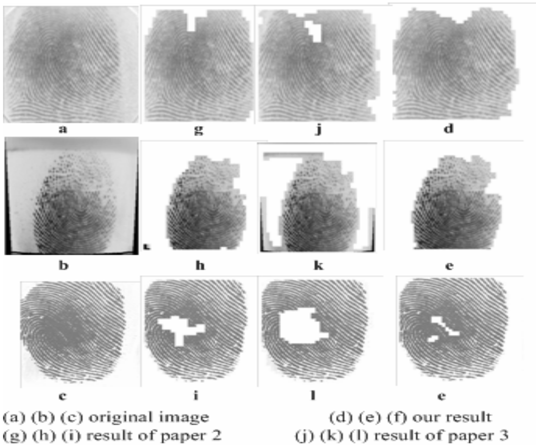

Figure 3 the sample of segmentation

The result is satisfied from fig 3. The algorithm segments the images more accurately; it is less influenced and suitable for various types. Image (i) and (k) show the segmentation is excess or lack by the algorithms in paper [2] and [3]. They are unapparent for the black margin or conglutinate fingerprint.

Figure 4 and table 1 show the further experiments using this method in minutiae extraction and fingerprint matching.

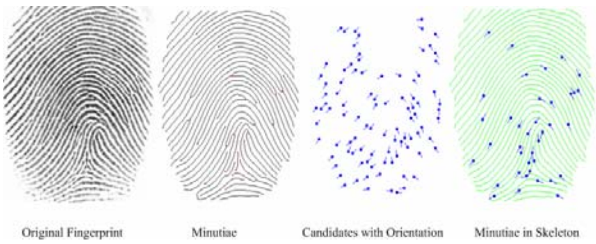

Figure 4 Minutiae Sample

Table 1 Matching Results in FVC2002 DB

	FMR100	FMR1000	ZeroFMR
DB1	4.15%	6.00%	7.39%
DB2	4.39%	6.57%	9.50%
DB3	11.25%	14.62%	18.00%
DB4	5.6%	9.6%	12.6%

Our method is competitive compared to the other methods. Our method has the highest radio of correctly detect minutiae which is very important for fingerprint matching.

5 Conclusion

In this paper, a new effective segmentation algorithm is presented. The algorithm is accurate and strong enough. It can segment fingerprint images of various types and the operating time is also acceptable. The segmentation processing is much influenced by the local directional field's domain precision and less influenced by the margin of the fingerprint region.

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