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An Improved Fingerprint Singular Point Detection Algorithm Based on Continuous Orientation Field

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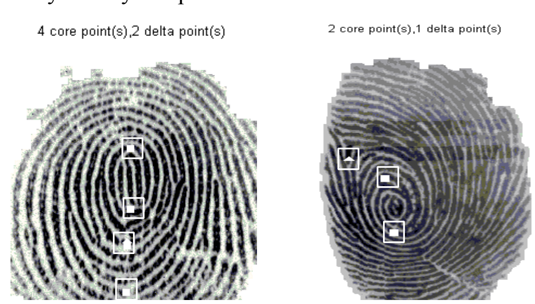
Abstract—**It is very important to detect singular points (core and delta) accurately and reliably for classification and matching of fingerprint. In this paper, an improved method for singularity detection in fingerprint images, which based on continuous orientation field, is proposed to improve accuracy of the position and reliability of the singularity. Firstly, the blocks which may contain singularities are detected by computing the Poincaré Index. Then, the singularities are detected in the block images. Experiment show that the proposed method can overcome the shortcoming of the traditional method to great extend and is robust to poor quality images.**

Keywords-fingerprint classification; singular point; orientation field; Poincaré Index

Ⅰ. INTRODUCTIONS

Fingerprint based identification has been one of the most successful biometric techniques used for personal identification. Each individual has unique fingerprints. A fingerprint is the pattern of ridges and valleys on the finger tip. Fingerprint classification is a coarse level partitioning of a large fingerprint database, where the class of the input fingerprint is first determined and subsequently, a search is conducted within the set of fingerprints belonging to the same class as the input fingerprint. In regard to fingerprint classification, only a portion of a fingerprint, called pattern area is of interest [1]. The pattern area of a fingerprint consists of those ridges encircled by typelines which is defined as the two innermost ridges that form a divergence tending to encircle or encompass the central portion of a fingerprint [2]. The pattern areas of loop or whorl types of fingerprints contain two types of singular points (core and delta). So it is very important to detect singular points accurately and reliably [3]. Nowadays, a practical method based on the Poincaré Index was always used for fingerprint singularities detection and a fingerprint has a well-defined orientation. The traditional detection based on the point orientation field can gain the accurate position of singularities, but the singular points are misjudged or not judged for the low quality image of the fingerprint sometimes (Fig.1.a) and the algorithm has a high computational complexity. However, the traditional detection based on the block orientation field can detect the existence of all the singular points, but can not locate the positions accurately (Fig.1.b). The classical formula to compute the Poincaré Index can present only the rotation angles, but not the rotation direction of the vector in the vector field exactly. In this paper, a multi-scale detection algorithm for singular points in fingerprint images based on both the continuous orientation field and the modified Poincaré Index is proposed. Firstly, the blocks which may contain singularities are detected by computing the Poincaré Index. Then, the singularities are detected in the block images accurately and reliably. So the new algorithm can locate the singularities at pixel level with an accuracy of only one pixel.



(a) (b)

Fig.1. (a) The result of singularity detection by the point orientation

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field (4 core and 2 delta points);(b)The result of singularity detection by the block orientation field(2 core points and 1 delta point)

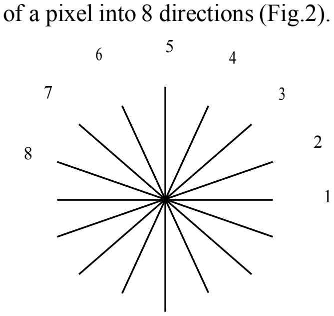
Ⅱ. IMAGE SEGMENTATION

Since most of the fingerprint images consist of the print itself, background and some handwritten letters or lines which may produce false singular points, it will be better to reduce the image to the print area only.

The blockwise average grayscale and standard deviation are used to segment the images. The block is considered as foreground if its grayscale mean and standard deviation satisfy some predefined standard, otherwise, the background. Then two iterations of dilation and erosion as stated by Gonzalez and Woods (1993) are used to remove holes resulting from inhomogenous regions. Also, such a segmented result will be used in the pseudoridge tracing step to define the stop boundary. All the process discussed below is carried out on such foreground regions.

Ⅲ. THE POINT ORIENTATION FIELD OF FINGERPRINT IMAGE

In general, a fingerprint has a well-defined orientation field [4]. To estimate the orientation field, we divide the ridge direction of a pixel into 8 directions (Fig.2).



(a)

6		5		4		3		2
7		6	5	4	3	2		1
		7				1		
0		0		*		0		0
		1				7		
1		2	3	4	5	6		7
2		3		4		5		6

(b)

Fig.3. 8 ridge directions of a pixel

To decide the ridge direction of each pixel in the image, we compute the average grey value in direction i (i=0, 1,…,7 means one of the 8 directions) in a 9×9 window with the pixel as the centre. In other words, we compute the average grey value of the pixels labelled "i" and obtained G[i]. The 8 mean grey values are divided into 4 groups with the two directions in each group perpendicular to each other. Group j (j=0, 1, 2, 3) contains direction j and j+4. The absolute value of the difference of the mean grey value is calculated in each group as:

$$G_{diff}[j] = | G_{mean}[j] - G_{mean}[j+4] | \quad (j=0,1,2,3) \qquad (1)$$

Set the two directions in the group with the largest difference value as possible ridge directions. If

$$i_{\max} = \arg\left\{ \underset{i\in\{0,1,2,3\}}{Max}(G_{diff}(i)) \right\} \qquad (2)$$

then i_{max} and i_{max+4} are possible ridge directions. The ridge direction in the pixel is decided by

$$D(x,y) = \begin{cases} i_{\max} & if\ | Grey - G[i\max] | \\ & <| Grey - G[i\max+4] | \\ i_{\max+4} & otherwise \end{cases} \qquad (3)$$

Where Grey is the grey value at this pixel.

Ⅳ.THE CONTINUOUS ORIENTATION FIELD OF FINGERPRINT IMAGE

To reduce the effect of noise, the point orientation field is then smoothed. A local window of size 17×17 is taken around each pixel keeping it at the centre of the window. We set the ridge direction of each pixel in the window as the direction of that pixel, that is, the mean direction of all the pixels in the window. To obtain the mean direction of a window, we calculate the number of pixels in the window where ridge direction is estimated as i(i=0,1,…,7) and set this number as $N[i]$. The mean direction of the block is:

$$O(x,y) = \arg\left\{ \underset{i=\{0,1,\ldots,7\}}{Max}(N[i]) \right\} \qquad (4)$$

The smoothed point orientation field $O(x,y)$ is also called the continuous orientation field [5].

Ⅴ. DIVIDING THE CONTINUOUS ORIENTATION FIELD INTO BLOCKS

We partition the continuous field into small blocks of size 9×9 and set the ridge direction of each pixels in one block as the direction of that block, that is, the mean direction of all the pixels in the block. To obtain the mean direction of a block, we calculate the number of pixels in the block where ridge direction is estimated as i(i=0,1,…,7) and set this number as Ni. The mean direction of the block is:

$$M(i,j) = \arg\left\{ \underset{i=\{0,1,\ldots,7\}}{Max}(Ni) \right\} \tag{5}$$

The block is a unit, so the block orientation field is a matrix and every pixel is estimated as j(j=0,1,…,7).

Ⅵ. COMPUTING THE POINCARE INDEX VALUE OF THE BLOCK ORIENTATION FIELD

A Poincaré method Index

An elegant and practical method based on the Poincaré Index was proposed by Kawagoe and Tojo (1984), while the Poincaré Index which is derived from continuous curves is the most popular one [8]. As for digital fingerprint images, a double core point has a Poincaré Index valued as 1, a core point 1/2 and a delta point -1/2. So, the Poincaré Index is used first to find all the possible singular points in the orientation field. Let $P(x,y)$ denote the gray level of the pixel (x,y) in an $M\times N$ fingerprint image. The Poincaré Index at pixel (x,y) which is enclosed by a digital curve (with N points) can be computed as follows:

$$Poincare(x,y) = \frac{1}{2\pi}\sum_{k=0}^{N-1}\Delta(k) \tag{6}$$

where

$$\Delta(k) = \begin{cases} \delta(k) & |\delta(k)| < \frac{\pi}{2} \\ \delta(k)+\pi & \delta(k) \le -\frac{\pi}{2} \\ \pi-\delta(k) & \delta(k) \ge \frac{\pi}{2} \end{cases} \tag{7}$$

$$\delta(k) = \theta(x_{(k+1) \bmod N}, y_{(k+1) \bmod N}) - \theta(x_k, y_k). \tag{8}$$

and it goes in a counter-clockwise direction from 0 to N-1.For our method, N is selected as 4 (Fig.3).

(x-1,y)	(x-1,y+1)
(x,y)	(x,y+1)

Fig.3. The mask of detecting singular points

B Computing the Poincaré Index value at pixel of M(i,j)

We compute the Poincaré Index at pixel in the $M(i,j)$ by the modified version of Poincaré Index(9), and the corresponding value is $Poincare(i,j)$. The modified version of Poincaré Index can present not only the rotation angles, but also the rotation direction of the vector in the vector field, exactly. For our method, the closed digital curve is selected as 4 pixels (Fig.3). In order to calculate simply, the directional yards from 0 to 7 is used for computing the Poincaré Index.

$$\Delta(k) = \begin{cases} \delta(k) & |\delta(k)| < \frac{\pi}{2} \\ \delta(k)+\pi & \delta(k) \le -\frac{\pi}{2} \\ \delta(k)-\pi & \delta(k) \ge \frac{\pi}{2} \end{cases} \tag{9}$$

Ⅶ. DETECTING THE BLOCKS WHICH MAY CONTAIN SINGULARITIES

a) If $Poincare(i,j) = +0.5$, the block $M(i,j)$ may contain a core point;

b) If $Poincare(i,j) = -0.5$, the block $M(i,j)$ may contain a delta point;

c) Otherwise, the block $M(i,j)$ doesn't contain singular points.

Ⅷ. SINGULAR POINTS DETECTION

The blocks which may contain singularities are detected by our method. Then the Poincaré Index at pixel (x,y) which is enclosed by a digital curve of 4 pixels can be compute in the detected blocks(Fig.4), and the corresponding value is $Poincare1(x,y)$. The directional yards from 0 to 7 is also used for computing the Poincaré Index.

a) If $Poincare1(x,y) = +0.5$, the point is a core point;

b) If $Poincare1(x,y) = -0.5$, the point is a delta point;

c) Otherwise, the point is not a singularity.

If the number of core points Nc is more than 2 or the number of delta points Nd is more than 2, we smooth the continuous orientation field according to section Ⅳ until the sum of core points is lesser than 2 and the sum of core points is lesser than 2.

Ⅸ. EXPERIMENTAL RESULTS (IMAGES OBTAINED IN EACH STEP CARRIED OUT)

The singularity detection algorithm described above has been tested on the fingerprint images in the FVC2004 database. From the experimental results, we choose the typical fingerprint images which are shown in Fig.4. The white blocks may contain the core points and the black blocks may contain the delta points in Fig.8.

Fig.4. The original fingerprint images

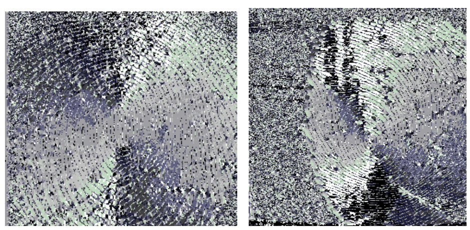


Fig.5. The point orientation field of fingerprint image

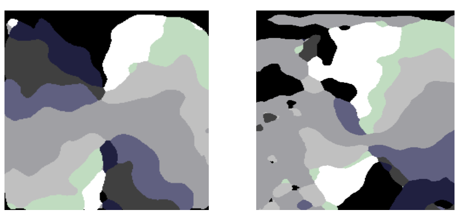


Fig.6. The continuous orientation field of fingerprint image

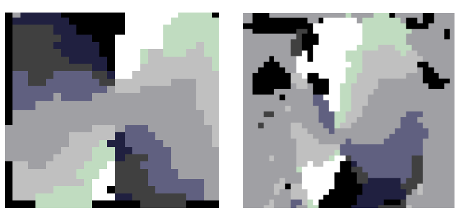
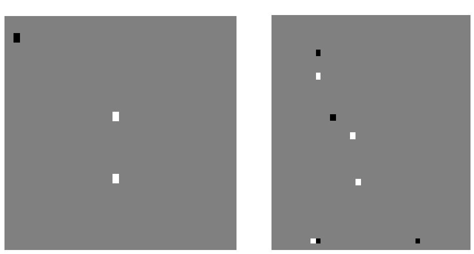


Fig.7. The orientation field of divided blocks



(a) (b)

Fig.8. The blocks which may contain singularities: (a) 3 blocks; (b) 8 blocks

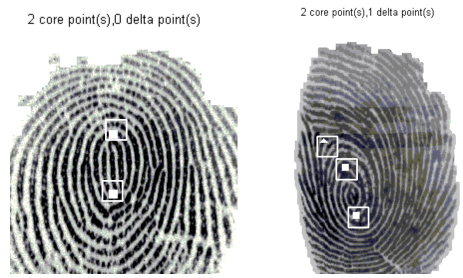


Fig.9. Singular points found

(square as core and triangle as delta)

X. CONCLUTIONS

In this paper, a novel method combining the point orientation field and the block orientation field is proposed with a higher accuracy to overcome the shortcoming of the traditional methods. The main benefit of this algorithm is its fast running speed, because we don’t have to calculate the Poincaré Index value at every pixel and only detect the singularities in the effective region. Experimental results on the FVC2004 database demonstrate the performance of the proposed algorithm. If good enhancement methods are applied to the image, the result should be improved further.

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