A Novel Fingerprint Singular Point Detection Algorithm

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Abstract: - In this paper, a novel approach for detection of singular points, the core and delta points, in fingerprint images is proposed. There have been many approaches introduced in the design of feature extraction. Based on orientation field, Firstly, we divide it into blocks to compute the Poincaré Index. Then, the blocks which may have singularities are detected in the block images. Experiment show the present algorithm is robust than the traditional method on poor quality images.

Key-Words: - fingerprint  core  delta  point orientation  Poincaré Index

1 Introduction
In recent years, fingerprints are most widely used for personal identification. Fingerprint images are direction oriented patterns formed by ridges and valleys. The singular point area is defined as a region where the ridge curvature is higher than normal and where the direction of the ridge changes rapidly. In most fingerprint identification algorithms and fingerprint classification algorithms, extracting the number and the precise location of SPs is of great importance.

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 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. 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.

We propose a multi-scale detection algorithm for singular points in fingerprint images based on both the continuous orientation field and the modified Poincaré Index. 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.

2 Image Segment
The boundary region, surrounding the actual fingerprint in the image, inherently contains discontinuities in the ridge pattern since beyond that boundary is background with relatively constant (but often noisy) pixel intensity. To address the border discontinuities, the fingerprint is segmented from the background.

We use the blockwise average grayscale and standard deviation to segment the images. The block is considered as foreground if its grayscale mean and standard deviation satisfy some predefined threshold, otherwise, the background. Then two iterations of dilation and erosion are used to remove holes resulting from inhomogenous regions. All the process discussed below is carried out on such foreground regions.

3 The Direction Field
A fingerprint has a well-defined direction field [4]. To compute the direction field, we define the ridge direction of a pixel as 8 directions.

![Fig.1 eight directions](image)

To decide the ridge direction of each pixel in the image, we compute the average grey value in direction \(i\) (\(i=1,\ldots,8\) means one of the 8 directions) in a 9x9 window with the pixel as the centre. 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 \(j\) (\(j=1, 2, 3, 4\)) contains direction \(j\) and \(j+4\). The absolute value of the difference of the mean grey value is calculated in each group as:

\[
|\text{diff} j | = |G[i] - G[j]| \quad (j=1, 2, 3, 4)
\]

Set the two directions in the group with the largest difference value as possible ridge direction. If \(i_{\text{max}}\) and \(i_{\text{max}}+4\) are possible ridge directions. The ridge direction in the pixel is decided by

\[
i_{\text{max}} = \arg \left\{ \max_{i=1,2,3,4} \text{diff} (i) \right\}
\]

(2)

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

\[
o(x, y) = \begin{cases} 
  i_{\text{max}} & \text{if } |\text{Grey} - G[i_{\text{max}}]| < |\text{Grey} - G[i_{\text{max}} + 4]| \\
  i_{\text{max}} + 4 & \text{otherwise}
\end{cases}
\]

(3)

Where Grey is the grey value at this pixel.

To reduce noise, the point direction field is smoothed. A local window of size 17x17 is taken around each pixel, keeping it as the central 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 \(i (i=1,\ldots,8)\) and set this number as \(N[i]\). The mean direction of the block is:

\[
O(x, y) = \arg \left\{ \max_{i=1,\ldots,8} N[i] \right\}
\]

(4)

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

We divided the continuous field into small blocks of size 9x9 and set the ridge direction of each pixel in the block as 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 \(i (i=1,\ldots,8)\) and set this number as \(N_i\). The mean direction of the block is:

\[
M (i, j) = \arg \left\{ \max_{i=1,\ldots,8} N[i] \right\}
\]

(5)

The block orientation field is a matrix and every pixel is estimated as \(j(j=1,\ldots,8)\).

4 The Poincaré Index Value

Many methods have been proposed to detect the singular points in fingerprint images, while the Poincaré index which is derived from continuous curves is the most popular one. As for digital fingerprint images, a double core point has a Poincaré index valued as 1, a core point as 1/2 and a delta point as −1/2.

Let \(\theta(x,y)\) denote the direction 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:

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

(6)

where

\[
\Delta(k) = \begin{cases} 
  \delta_1(k) & \text{if } |\theta(x,y,\mod N) - \theta(x,y)| < \frac{\pi}{2} \\
  \delta_2(k) & \text{if } |\theta(x,y,\mod N) - \theta(x,y)| \geq \frac{\pi}{2}
\end{cases}
\]

(7)

\[
\delta_1(k) = \theta(x(y+k) \mod N, y+x+k) - \theta(x, y)
\]

(8)

and it goes in a counter-clockwise direction from 0 to \(N-1\). For our method, \(N\) is 4 (Fig.3).
We compute the Poincaré Index at pixel in the \((i,j)\) by the modified version of Poincaré Index \((9)\), and the corresponding value is \(\text{Poincare}(i,j)\). 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. In order to calculate simply, the direction yards from 0 to 7 is used to compute the Poincaré Index.

\[
\Delta(k) = \begin{cases} 
\delta(k) & \text{if } |\delta(k)| < \frac{\pi}{2} \\
\delta(k) + \pi & \text{if } \delta(k) \leq -\frac{\pi}{2} \\
\delta(k) - \pi & \text{if } \delta(k) \geq \frac{\pi}{2}
\end{cases}
\]

(9)

**5. Singular point detection**

If \(\text{Poincare}(i,j) = 0.5\), the block \(M(i,j)\) may contain a core point; If \(\text{Poincare}(i,j) = -0.5\), the block \(M(i,j)\) may contain a delta point; Otherwise, the block \(M(i,j)\) doesn’t contain singular points.

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 \(\text{Poincare}(x,y)\). The direction yards from 0 to 7 is also used for computing the Poincaré Index.

If \(\text{Poincare}(x,y) = +0.5\), the point is a core point;

If \(\text{Poincare}(x,y) = -0.5\), the point is a delta point;

Otherwise, the point is not a singularity.

If the number of core points \(N_c\) is more than 2 or the number of delta points \(N_d\) is more than 2, we smooth the continuous orientation field until the number of core points or delta points is lesser than 2.

The singularity detection algorithm described above has been tested on the fingerprint images in the FVC2002 database. We choose the typical fingerprint image which is shown in Fig.4. In Fig.8, the white blocks contain the core points and the black blocks contain the delta points.
5 Conclusion
In this paper, a novel method based on the point orientation field and the block orientation field is presented 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 for real fingerprint images shows that the proposed method provides accurate results, which would facilitate fingerprint identification and fingerprint classification afterwards.

References: