Singular Point Detection in Fingerprint Image

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Abstract

Singular point detection is an important task in many Automatic Fingerprint Identification Systems (AFIS). There already exists many singular point detection algorithms, Most of them can efficiently detect the core point when the image quality is fine, but when the image quality is poor, the efficient of the algorithm degrades rapidly. In this paper, we present a new singular point detecting algorithm based on Multi-Resolution Direction Field (DF). First we use the low resolution DF to find an area that includes singular point, then we use high resolution direction field to search the precise position of the singular point. Experiment results show that the detection precise is rather high, even with a poor quality image.

1.Introduction

Fingerprint-based identification has been used for a very long time. Owning to their uniqueness and immutability, today, fingerprints are the most widely used biometrics features. Most AFIS are based on minutiae matching[1].According to the dependence of the core point, fingerprint matching algorithms are divided into two groups, core-based match algorithm and noncore-based match algorithm. The core-based match algorithm depends on core point to alignment the feature vector, and the noncore-based match algorithm depends on other alignment method such as local structure. Although core-based match algorithm is more efficient than the noncore-based algorithm, the main problem of the core-based algorithm is how to precisely localize the core point.

There already exist lots of algorithms that deal with the singular point detection in literature. In [1], V.S.Srinivasan presents a singular point detection method based on orientation histogram, which is robust to noise, but the precision of the detection result is low. In [2], Marius Tico present a wavelet based multi resolution method, which can localize the singular point in 2*2 pixel width window. However, because of involving wavelet decomposition and dealing the direction field in pixel, it is time consuming, and not suitable for real time application. In [3], Asker M. Baze presents a singular point detect algorithm based on high resolution direction field, which first computes a high resolution direction field, then detect the singular point based on Poincare index. However, because of computing high resolution direction field, the algorithm efficient is rather low. In [4], Jain presents a Poincare index based method to localize the singular point, this algorithm can only detect a little window which includes the singular point. Moreover, most of above singular point detect algorithms can efficiently detect the core point when the image quality is fine, when the image quality is poor, the efficient of the algorithm degrades rapidly. Some algorithms also include post processing step in order to remove false singular points detected.

In this paper, we present a new singular point detection algorithm which can precisely localize the singular point and does not need post processing step. It mainly involves two steps: first, using low resolution direction field to find a rough area that include core point, then using high resolution direction field of the area which found in the first step to precisely localize the singular point. The estimation of direction field is presented in section 2, and in section 3, the method of detecting singular point is presented. In section 4, the experiment results of the algorithm are shown. At last, in section 5, the results and further work are given.

2.Direction Field

The direction field estimation method presented by Jain[4] is used in this paper, the algorithm mainly involves four steps as below:
1)First, separate the image in W*W block.
2) Then compute the gradient of each block.

$$V_x(i,j) = \sum_{u=i-\frac{w}{2}}^{i+\frac{w}{2}} \sum_{v=j-\frac{w}{2}}^{j+\frac{w}{2}} 2G_x(u,v)G_y(u,v)$$

$$V_y(i,j) = \sum_{u=i-\frac{w}{2}}^{i+\frac{w}{2}} \sum_{v=j-\frac{w}{2}}^{j+\frac{w}{2}} \{G_x^2(u,v) - G_y^2(u,v)\} \qquad (1)$$

$$\theta(i,j) = \frac{1}{2}\tan^{-1}\left(\frac{V_x(i,j)}{V_y(i,j)}\right)$$

3) Use the formula (1) to estimation the direction of each block. W is the width of a block.
4) At last, carry out some smooth on the direction field

After those steps, we can get the smooth direction field as figure 1 show.

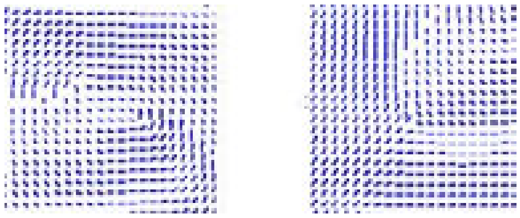
a) core b) delta

Figure 1. DF near the singular point

3. Core Point detection

As mentioned above, we estimate the direction field based on block level, therefore how to select the block width is a key factor. If the divided block is too small, the localization precise is high, but the algorithm is affected by noise greatly, and the efficient of the algorithm is very low. If the block is too large, the algorithm is robust to noise, but the localization precise is low. Therefore, we make a trade-off between precise and the efficient of the algorithm. First, we use low resolution direction field to roughly localize the singular point area, then we recompute high resolution direction field of the area that we have detected in first step and detect the singular point based on high resolution direction field. Because we used same method to detect core and delta point, here we just describe how to localize the core point, the same method can be used to detect delta point.

3.1 Low-Resolution DF based core point detection

In [2], Marius Tico presents a algorithm which can detect the singular point. The algorithm computes direction of image in pixel level first, and then carries out on the direction field. However the efficient and robust of the algorithm is not very well. Here we just use this method to cursorily localize the singular point area. The main steps of the algorithm are described as follow:

1) Compute the x and y gradient of the orientation

$$\begin{bmatrix} J_x(x) \\ J_x(x) \end{bmatrix} = \nabla\theta(x,y) = \begin{bmatrix} \dfrac{\partial\theta(x,y)}{\partial x} \\ \dfrac{\partial\theta(x,y)}{\partial y} \end{bmatrix} \qquad (2)$$

2) According to Green Theorem, we use surface integral to replace the closed line-integral.

$$G = \sum_{\partial A} J_x + J_y = \sum_{A} \left(\frac{\partial J_y}{\partial x} - \frac{\partial J_x}{\partial y}\right) \qquad (3)$$

Where A is a integral area and ∂A is the contour of A. In Asker M. Bazen's algorithm, the Poincare index is calculated, where the integral of around the core is π and $-\pi$ around delta point. and integral of the rest image is equal to 0. Therefore, we can detect the possible area that includes the singular point.

Through experiment, we find that the Poincare index is not very effective in our situation, therefore, we modify the algorithm. Instead of computing the Poincare index of the image, we calculate the gradient change rate of the image and regard the point where has maximum gradient change rate as the singular point. Therefore we modify the step 2 as follow:

$$M = \sum_{A} \sin(G) = \sum_{A} \sin\left(\sum_{A} \left(\frac{\partial J_y}{\partial x} - \frac{\partial J_x}{\partial y}\right)\right) \qquad (4)$$

With this modification, we select the point which has maximum value of M as the singular point. In [1] V.S. Srinvasan presents a method to distinguish core and delta based on the analysis of the direction character near the singular point, which is used in this paper.

3.2High-Resolution DF based core point detection

In 3.1, the singular point is detected, however, the output of the algorithm is just a position near core point. In order to precisely localize the core point, we use high resolution direction field. Around the point we get in 3.1, we select a 64*64 area, and use the algorithm in 2 to compute the direction field of this area, and set W as 2. Then we get a high resolution direction field. Although we can carry out the algorithm of 3.1 again, through experiment we find that the result is not very well. Therefore we have to find new detecting algorithm to improve the performance of the algorithm.

Notice that direction near the core point change rapidly, we can use this character to localize the core point. There are many corner detecting algorithms that can be used to detect the core point. In [5], ZhiQiang Zheng presents many corner detection algorithms based on gray level analysis. The algorithms deal with the gradient change rate, and select a threshold, output all the maximum point. Here, considering the direction field near the core point, we can use the algorithm to detect the maximum change rate of the direction field near core point. Therefore the algorithm in [5] are modified to detect the core point through direction field. The main steps of the algorithm are:

1) Computing the direction field O of 64*64 block with the 2*2 window.

2) Computing the gradient of the direction field $O_x(x,y)$, $O_y(x,y), O_{xx}(x,y)$ and $O_{yy}(x,y)$.

3) Computing $O_x^2(x,y)$, $O_y^2(x,y), O_{xx}^2(x,y)$ and $O_{yy}^2(x,y)$

4) Computing K(x,y),

$$K(x,y) = G(\sigma, x, y) \otimes \Delta_0(x,y),$$

Where $\Delta_0(x,y) = \frac{O_x^2 O_{yy}^2 + O_y^2 O_{xx}^2}{(O_x^2 + O_y^2)^2}$ and

$$G(\sigma, x, y) = \frac{1}{2\pi\sigma^2} e^{(x^2+y^2)/2\sigma^2} \quad (\sigma = 1.0) \qquad (5)$$

5) Computing the core point measure

$$\Delta = O_x^2 O_{yy}^2 + O_y^2 O_{xx}^2 - k(x,y) * (O_x^2 + O_y^2)^2 \qquad (6)$$

The maximum of Δ is selected the core point. Because this algorithm deal with a 64*64 block of the image, it is fairly fast. The specific algorithm and it's mathematical foundation are in [5].

4.Experiment result

Generally, singular point detection algorithm performance can be evaluated with the detection precision and the algorithm's efficient.

The method presented in this paper is tested and compared with Asker's method. The fingerprint images that we used were captured by veridicom fingerprint chip and an image size is 300*300 pixel. Table 1 shows the comparison of the time consuming between the present method and the Asker's method.

Table 1 The time of the singular point detection on Pentium 550MHz PC

	Direction field (seconds)	Singular point detect(seconds)	Total(seconds)
Present method	0.10	0.07	0.17
Asker method	0.82	0.16	0.98

Table 2 shows the comparison of detection result.

Table 2 the comparison of detection result

	Success(numbers)	Fail(numbers)
Present method	198	2
Asker method	190	10

Figure 2 shows the examples of core point detection based on multi-resolution method, and figure 3 shows the core point detection based on single resolution method of the same fingerprint. The result show that the present method has higher precise than the single resolution, meanwhile it avoids the large compute time consuming and is robust to noise.

Moreover, the algorithm can precisely localize the core point in the noise image, figure 4 shows the results of present algorithm detection on the noise image and the results of single-resolution based method. Therefore, we can draw the conclusion that the present algorithm more robust than Asker's method, meanwhile we do not need the post process steps to remove the false core point detected.

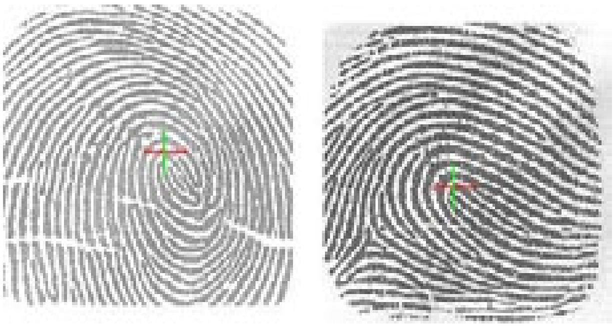

Figure 2. Results of core point detection based on multi-resolution method

Figure 3. Results of core point detection based on single resolution method

a) b)

Figure 4. Results of core detection under poor image quality. a) Results of present algorithm; b) Results of single-resolution algorithm

5.Conclusion

In this paper, we present a new singular point detection method, which is efficient and has higher precision. This method first uses low resolution to detect a small area that includes the singular point, then uses the high resolution direction field to localize the singular point precisely. Experiment results show that present method has higher precision and is fairly robust to noise. Moreover the present algorithm is very efficient and suitable for an online system.

References

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