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Edge Map-Based Fingerprint Reference-Point Detection

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Abstract – A new reference point location method based on an edge map is proposed, where an orientation map is defined and used to find the edge map. Experimental results show that the proposed method can effectively detect the core point in poor quality and arch-type fingerprint images and produces better results in terms of the detection rate and accuracy than the sine map-based method.

Key Words : Reference-point detection, orientation map, edge map

1. Introduction

In most fingerprint-based verification or identification systems, a reference point is established and used to extract fingerprint features which are robust to translation or rotation. Generally, a core point, one of the singularities of a fingerprint, is used as such a reference point [1-4]. The Poincar index method is one of the most commonly used techniques to detect the core point [1]. This method works well in good quality fingerprint images, however, it fails to detect the core point in poor quality and plane arch-type fingerprint images. To solve these problems, the sine map-based method was proposed by Jain et al. [2]. This method can detect the core point even in poor quality and arch-type fingerprint images. Accordingly, this paper presents a new reference point location method that can detect a reference point in all types of fingerprint images using an edge map, and compares its performance to the sine map-based method.

2. Edge map-based core point detection

The algorithm details are described as follows.

1) Compute the gradients $G_x(i,j)$ and $G_y(i,j)$ at each pixel using Sobel operator.

2) Estimate the orientation $O(i,j)$ at each pixel using a window size of $w \times w$ instead of the block level:

$$O(i,j) = \frac{1}{2}\tan^{-1}\left[\frac{\sum_{u=i-w/2}^{i+w/2}\sum_{v=j-w/2}^{j+w/2} 2G_x(u,v)G_y(u,v)}{\sum_{u=i-w/2}^{i+w/2}\sum_{v=j-w/2}^{j+w/2}(G_x^2(u,v)-G_y^2(u,v))}\right] \quad (1)$$

3) Smooth the orientation field $O(i,j)$. In order to perform smoothing, the orientation field is converted into a continuous vector field, i.e., $\Phi_x(i,j) = cos(2O(i,j))$ and $\Phi_x(i,j) = sin(2O(i,j))$. Finally, we use Gaussian smoothing operator to smooth the orientation field and obtain the resulting vector field $\Phi_x'(i,j)$ and $\Phi_y'(i,j)$. Note that the smoothing operation is performed at the pixel level using a window size of 24×24 instead of the block level. A window size used was determined experimentally. However, a smaller or larger window size can be used to smooth the orientation field as well. We obtained the much same result by using a window size of 20×20 or 30×30 as we obtained by using a window size of 24×24.

4) The smoothing orientation field O' at each pixel is computed as follows:

$$O'(i,j) = \frac{1}{2}\tan^{-1}\left(\frac{\Phi'_y(i,j)}{\Phi'_x(i,j)}\right) \quad (2)$$

5) Find an orientation map using the following equation:

$$O'_s(i,j) = \frac{O'_{degree}(i,j)}{180} \times c$$

$$O'_o(i,j) = \begin{cases} 255 & if\ O'_s(i,j) > 255 \\ O'_s(i,j) & otherwise, \end{cases} \quad (3)$$

First of all, $O'(i,j)$ is transformed into the degrees to be used as pixel values, and then it is scaled $(O'_s(i,j))$ to make the orientation map $O'(i,j)$ as shown in Eq. (3). Here, c is the scale factor that controls the

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brightness range of the orientation map. Note that the orientation map is not sensitive to changing of the scale factor c. The second column images in Fig. 1 show the orientation maps for four types fingerprint images except the arch-type. In this paper, the whorl and twin loop were collapsed into one class.

6) Find the edges from the orientation maps in Fig. 1 using Sobel operator. To eliminate the discontinuities of the edges, we search for the edges in a 3×3 window centered at each pixel *(i,j)*. If the edge exists one or more in the window, they are regarded as the edges. The third column images in Fig. 1 show the edge maps $O_e'(i,j)$ obtained. After labeling the edge map, we extract the region with the maximum area among regions started from the upper parts(vertical image size/3) of the labeled image. The core point can be determined simply by finding a point located in the lowest part of that region. As shown in Fig. 1, the proposed algorithm has an excellent core point detecting capability with much higher accuracy.

In case of arch or tended arch types, some fingerprints have continuous edges in the region found above as shown in the third column images in Fig. 2. If at least one edge is found from outside of the doted lines(see the third column images in Fig. 2(a)), it is regarded as a special case, and a new method is used to detect the core point. In this paper, a margin from the image boundary isset to 30 pixels. As shown in the second column image in Fig. 2 (a), the edge map is binarized and a horizontal line with the smallest width on the binary image is found. Finally, its y-coordinate is assigned as a Y-coordinate of the core point. Note that the y-coordinates of the edges in the third column images in Fig. 2 are used as start points to find the horizontal line with the smallest width. In order to find a X-coordinate of the core point with much higher accuracy, we use the edge map instead of the binary image which has too much width on vertical lines. Thus, in the third column images of Fig. 2, the X-coordinate of the core point can be determined simply by finding a x-coordinate on the Y-coordinate of the core point. If the horizontal line with the smallest width was found more than one, the largest y-coordinate was regared as a Y-coordinate of the core point.

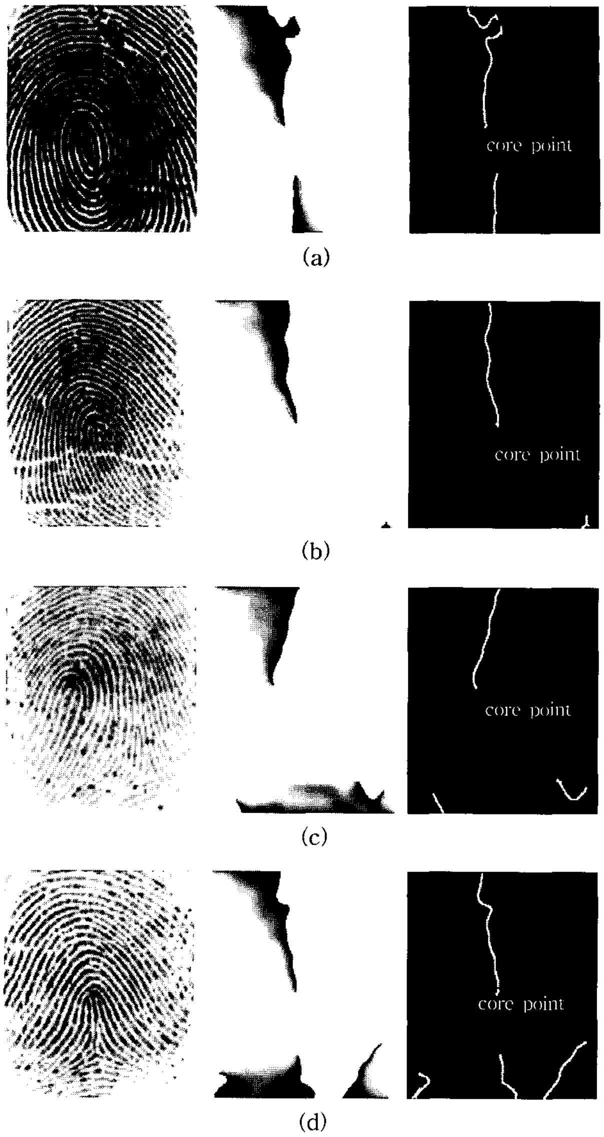
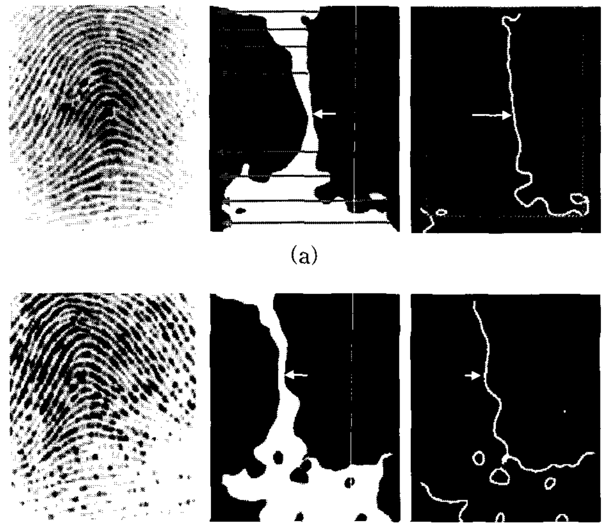


Fig. 1 Detected reference points using orientation map and edge map. (a) whorl, (b) right loop, (c) left loop, (d) tended arch

3. Experimental results

In this paper, the database, which contains 512 (images per finger), was used for the experiment instead of the standard database. The image size was 292×248 and had been captured with 256 gray levels using an inkless fingerprint scanner in the Lab. In particular, the database has many more poor-quality fingerprintsin the right loop-type.

Table I shows the distribution of the fingerprint classes in the database. Table II shows the detection rates for the sine map-based method used in [5] and proposed method. As shown in Table II, the proposed method produced much better detection rates than the sine map-based method for all types of fingerprints. Especially for the right loop-type which has many more poor quality fingerprints, the detection rate of the proposed method was superior to that of the sine map-based method which worked well in the poor quality fingerprints. Even for arch-type fingerprints, the proposed method showed slightly better performance compared to the sine map-based method. In addition, the proposed method was able to accurately detect a reference point as shown in Fig. 1 and 2. The processing time was less than 100 ms. Note that the proposed method did not use any coordinate shift to locate the core point properly.



(a)

(b)

Fig. 2 Procedure for reference point detection in edge map with continuous edges

Table I Distribution of fingerprint classes

	Left loop	Right loop	Arch	Tended Arch	Whorl	Total
Number	147	133	59	29	144	512

Table II Detection rate for each method (%)

	Left loop	Right loop	Arch	Tended Arch	Whorl	Total
Sine-map	92.5	88.7	78.0	90.0	94.2	90.2
Proposed	94.6	96.7	81.0	100.0	98.0	95.0

4. Conclusion

A new and effective reference point detection method was proposed based on the edge map. The proposed method shows much better detection rates for all types compared to the sine map-based method, especially in poor quality fingerprint images. In addition, the proposed method can accurately locate the reference point without any shift the core point.

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