특징점 및 방향 특징에 기반한 멀티모달 지문 매칭

논 문
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Multimodal Fingerprint Matching Based on Minutiae Points and Directional Features

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Abstract – A simple multimodal fingerprint recognition method based on two types of feature vectors such as minutiae points and directional features is proposed, where Directional Filter Bank (DFB) is used to extract directional features. Experimental results show that the proposed method can effectively combine minutiae- and DFB-based methods and produce a better matching capability in the poor quality fingerprint image.

Key Words : Minutiae points, Directional features, Multimodal recognition, Poor quality fingerprint image

1. introduction

Most of the automated fingerprint identification systems rely on one of the two transitional approaches i.e., minutia-based methods [1] and image-based methods [2]. Minutia-based methods first locate the minutiae points in a given fingerprint image and match the relative placement of minutia points in a stored template fingerprint. However, these methods have several disadvantages. First, it is not easy to extract minutia points automatically and accurately. Second, the number of minutia points available may not be sufficient, especially in system using a small-size fingerprint sensor. Third, this method depends heavily on preprocessing and post-processing in order to extract the reliable minutiae points from a fingerprint image. On the other hand, image-based methods usually extract the features directly from the fingerprint image without any complicated process such as a minutia point detection. In spite of the above mentioned problems, minutia -based methods have been used in the fingerprint identification system due to their superior matching capability. The excessive processing time may be reduced by introducing the advanced hardware techniques. However, minutia-based methods show an inferior performance due to insufficient minutiae points detection, especially in the poor quality fingerprint image. Accordingly, this paper proposes a simple multimodal fingerprint recognition method that can improve the matching capability of a minutiae-based method by combining an image-based method based on directional filter bank (DFB). In [3], a multimodal system was classified into five categories. The proposed method is included in a category, "multiple representation and matching algorithms for the same input biometric signal".

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2. Minutiae-based method

The minutiae point extraction consists of three steps- preprocessing, minutiae extraction, and post-processing. After extracting minutiae points, false minutiae points which were introduced in the fingerprint image due to noise factors were removed in post-processing. First, Gabor filtering was employed to effectively preserve the ridge structures while removing noise, where the orientation field and the ridge frequency of the fingerprint image are used important parameters in the construction of the Gabor filter. For the orientation estimation, we divided the input fingerprint image into non-overlapping blocks with size $w \times w$ (8×8) and compute the gradient $G_x(u,v)$ and $G_y(u,v)$ at each pixel (i,j) which is the center of the block. In this paper, a Sobel operator is used to compute the gradients. The orientation field $O(i,j)$ is estimated as follows [1]

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

In order to perform smoothing, the orientation field $O(i,j)$ is converted into a continuous vector field, i.e., $\Phi_x(i,j)=\cos(2O(i,j))$ and $\Phi_y(i,j)=\sin(2O(i,j))$. Finally, we use Gaussian smoothing operator to smooth the orientation field and obtain the resulting vector field.

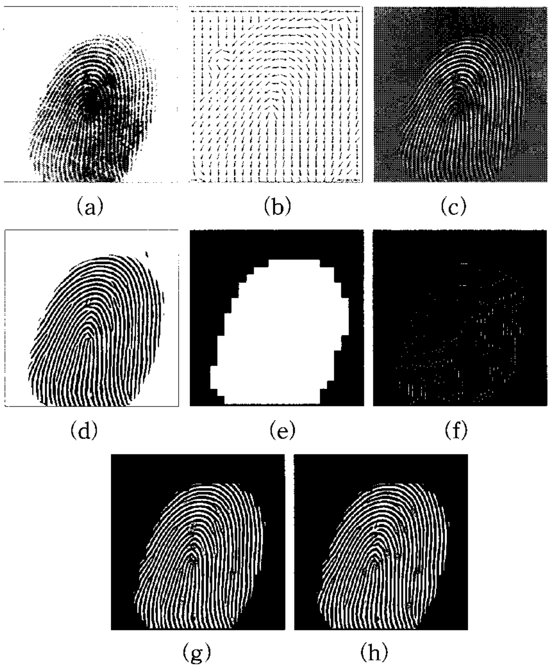


Fig. 1 Procedure for Minutiae-based approach. (a) poor-quality fingerprint image, (b) orientation field, (c) Gabor filtered image, (d) binarized image, (e) extracted foreground region, (f) thinned image, (g) extracted minutiae points, (h) removed false minutiae points

$\Phi_x'(i,j)$ and $\Phi_y'(i,j)$. The smoothed orientation field O' is computed as follows [1] (see Fig. 1(b))

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

In this paper, the ridge frequency $RF(i,j)$ was computed by the reciprocal of the average inter-ridge distance in a 32×32 block of fingerprint image. The average inter-ridge distance is approximately 10 pixels in a 500 dpi fingerprint image. Finally, Gabor filtering is performed to obtain the enhanced image EI in the spatial domain by convoluting the image with a mask size of 16×16.

$$EI(i,j) = \sum_{u=-w_x/2}^{w_x/2} \sum_{v=-w_y/2}^{w_y/2} G(u,v;O'(i,j),RF(i,j))N(i-u,j-v) \quad (3)$$

Where O' is the orientation field, F is the ridge frequency, N is the normalized image, and (w_x, w_y) is the mask size (see Fig. 1(c)). Then the fingerprint image binarization was performed to improve the brightness level between the ridges and valleys (see Fig. 1(d)). It is important to separate the foreground regions from the background regions because the false minutiae points can be extracted from the background regions. Thus, to separate the foreground regions, the proposed method divided the fingerprint image into non-overlapped blocks with size $w \times w$ (16×16) and compute the variance of each block as follow

$$Var(I) = \frac{1}{W^2}\sum_{i=0}^{W-1}\sum_{j=0}^{W-1}(I(i,j) - Mean(I))^2 \quad (4)$$

If the variance of a block is less than the threshold value, it is regarded as a background region (see Fig. 1(e)). After extracting the foreground regions, a thinning algorithm is performed on the inverted image of Fig. 1(d) using THIN function provided in Matlab (see Fig. 1(f)). Finally, minutiae points are extracted (see Fig. 1(g)), then false minutiae points are removed (see Fig. 1(h)) [4].

3. Directional Filter Bank-based method

The directional features are extracted from the fingerprint image using a directional filter bank (DFB), which effectively decomposes an image into several directional subband images [2]. For a input image with $N \times N$ size, eight subbands with $N/2^{n-1} \times N/2$ and $N/2 \times N/2^{n-1}$ sizes are obtained as shown Fig. 2.

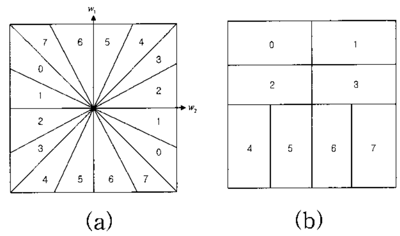


Fig. 2 (a) Wedge-shaped directional subbands of input, (b) eight subband outputs

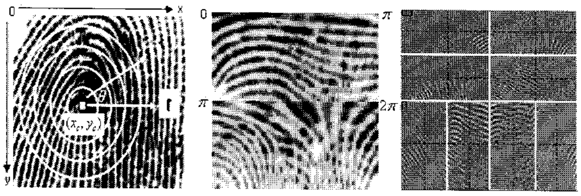
For the feature extraction, first of all, the proposed method found a ROI from the fingerprint image using a reference point. In this paper, a new reference point detection method based on the orientation field of Fig. 1(b) is proposed. The algorithm is briefly described as follows. 1) Transform the orientation field O' of Eq. (2) into the degrees to make Fig. 3(b). 2) Find the edge map of O' with an edge operator such as Sobel, Prewitt, or Roberts (see Fig. 3(c)). 3) Detect the candidate reference points from the obtained edge map using the same method employed to find a valid ridge ending in Section 2. 4) Remove false reference points through the same method used in Section 2 to remove false minutiae points. Finally, the proposed method can detect the reference point as shown in Fig. 3(a). Note that the methods used in Steps 3) and 4) may be replaced by other methods which can find a valid ridge ending and can remove false reference points. However, the reference point detection rate of the proposed method was about 90%, so the rest that could not be detected were rejected from the test set, Therefore, the proposed method needs to more improve the detecting rate in future study. As shown in Fig. 4, ROI is extracted with the found reference point, and its Cartesian coordinates are converted into Polar coordinates to facilitates the procedure of compensation for rotation.

$$r = \sqrt{(x-x_c)^2 + (y-y_c)^2} - w_s, \quad \theta = \tan^{-1}(-(y-y_c)/(x-x_c)) \quad (5)$$

Where W_B is the width of one band. Thus, a rotation compensation can be achieved by just a horizontal shift

(a) (b) (c)

Fig. 3 Reference point detection. (a) detected reference point, (b) orientation component, (c) edge map



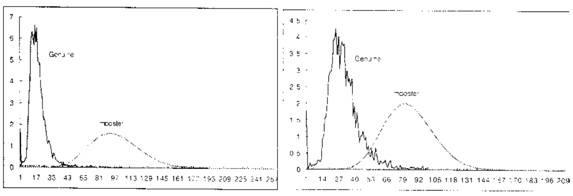
(a) (b) (c)

Fig. 4 (a) Extracted ROI, (b) converted ROI to polar coordinates, (c) decomposed (b) to eight bands

of the subband images of Fig. 4(b) [2]. After applying DFB to Fig. 4(b), eight subbands are obtained, where each subband is simply divided into 4 subblocks to compute the energy. In the proposed method, the half of 32 subblocks is selected in terms of the dominant energy, where each subblock S_i selected is divided into small-subblocks ($n=36$) $S_{i,n}$ to be used in the fingerprint matching (see Fig. 4(c)). Finally, each energy value $E_{i,n}$ of $S_{i,n}$ is computed as follow

$$E_{i,n} = \frac{1}{k_n}\left(\sum_{k_n}\left|F_{i,n}(x,y) - \overline{F}_{i,n}\right|\right) \qquad (6)$$

where k_n is the size of $S_{i,n}$, and $\overline{F}_{i,n}$ is the mean of energy values of $F_{i,n}(x,y)$ in $S_{i,n}$. $E_{i,n}$ is used in a matching process which is performed based on Euclidean distance between the input and template feature vectors. As shown in Fig. 5, the method using subblocks with the dominant energy has better performance than the method using all subblocks.



(a) (b)

Fig. 5 Genuine and imposter distribution. (a) using subblocks with the dominant energy, (b) using all subblocks

4. Experimental results

In this paper, the database, which contains 1024, was used for the experiment instead of the standard database. The image size was 388×374 and had been captured with 256 gray levels using an inkless fingerprint scanner in the Lab. For a multimodal fingerprint matching, minutiae-base method combined with DFB-based method to improve the matching capability in the poor quality fingerprint image. Basically, we designed a superior minutiae point detecting algorithm which was used as a main method in the fingerprint matching. While instead of minutiae-based method, DFB-based method was used to overcome the degradation of the matching rate happening in the poor quality fingerprint image. About 20% of test images were classified as the poor quality image depending on human visual. For the classified images, DFB-based method was used to improve the matching rate. As shown in Fig. 6, the proposed method shows a better performance compared to minutiae-based method of Section 2.

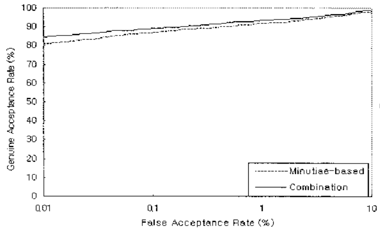


Fig. 6 ROC curve for two methods

5. Conclusion

This paper shows a possibility of combination minutiae- and DFB-based methods to improve the matching capability in the poor quality fingerprint image. In the future study, we will focus on more enhancing the matching capability of the proposed method. To do this, we should classify the poor quality fingerprint images as several levels and make selecting rules to decide which method is suitable to improve the matching capability.

감사의 글

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