LETTER

Finger Vein Verification Based on Neighbor Pattern Coding

Wenming YANG†a), Guoli MA†b), Nonmembers, Weifeng LI†c), Member, and Qingmin LIAO†d), Nonmember

SUMMARY We propose a neighbor pattern coding (NPC) scheme with the aim of exploiting the structural feature fully to improve the performance of finger vein verification. First, one-pixel-wide edge is obtained to represent the direction of the binary vein pattern. Second, based on 8-neighbor pattern analysis, we design a feature-coding strategy to characterize the vein edge. Finally, the edge code flooding operation is defined to characterize all of other vein pixels according to the nearest neighbor principle. Experimental results demonstrate the effectiveness of the proposed method.

key words: finger vein, structural feature, neighbor pattern coding

1. Introduction

Recently, Finger vein verification has become a hot topic because of the following advantages [1]. A vein pattern is the network of blood vessels underneath the skin and needs to be captured by infrared light, thus making it nearly immune to forgery. Moreover, the small size and high flexibility of the finger make it easy to capture finger images, which improves the feasibility of finger-based biometrics. Hence, finger vein pattern offers secure and reliable features for personal verification.

Finger vein pattern extraction is a vital step because the captured finger vein images are low contrast and contain many fuzzy regions. Compared with conventional methods such as the matched-filter method [2], the repeated line tracking method [3] is more robust to noise. However, this method suffers from pseudo-vein regions. Our previous work proposed a modified repeated line tracking method [4] and could approximately overcome the above problems. The strategy consists of several steps. First, one probability map is created through local adaptive thresholding. Second, a modified line tracking algorithm is proposed to get another probability map. Finally, directional neighborhood analysis is designed to obtain the final binary map. Experimental results show that the method can extract a vein pattern out of low-quality images effectively.

After vein pattern extraction, we obtain a binarized vein map, which depicts where the blood vessels exist. Template matching is usually performed immediately following vein extraction. Unfortunately, direct template matching without further feature extraction can not represent structural information such as vein direction and curvature fully. To the best of our knowledge, no investigation about further feature extraction of the binarized vein image has been reported in the literature.

In this paper, we focus on investigating possible features that can best represent binarized vein patterns. The 8-neighbor pattern is exploited and enhanced using a neighbor pattern coding (NPC) scheme. Experimental results on our database including 220 subjects demonstrate its effectiveness.

2. Neighbor Pattern Coding Scheme

According to human visual properties, it can be noted that features of finger vein are as follows, vein location, direction, width, minutiae features, and vein curvature. These features do not have the same discriminative power in verification. Direct binary template matching ignores the potential distinctive features such as vein direction.

2.1 Motivation of NPC

Figure 1 and Fig. 2 illustrate the motivation of NPC. As shown in Fig. 1, (a) and (c) are vertical and horizontal vein segments respectively, which are totally different and shouldn’t be matched at all. In the binary images, shadowed ‘1’ denotes vein pixel and the other area represent the background. Based on the binary images, direct template matching leads to 4 matched pixels. Considering directions of the two segments, we use integer ‘2’ and ‘9’ to differentiate them. Using coded maps (b) and (d), the number of matched pixels can be reduced to zero. After coding, pixel value represents direction information besides location. Detail of coding strategy is presented in the Sect. 2.2.2. Figure 2 explains that Edge code can not be used for matching directly. As shown in Fig. 2, (a) and (c) are vertical vein edges from two different images of the same finger. They should be matched perfectly. However, the edge code maps result in very few matched pixels. Code flooding maps, shown in (b) and (d), increase matched pixels significantly. Detail of flooding operation is presented in the Sect. 2.2.3.
2.2 Implementation of NPC

We propose NPC scheme to exploit and enhance the 8-neighbor pattern. NPC scheme consists of three steps: edge detection, coding strategy, and flooding. Figure 4 (a)–(d) illustrates the steps of NPC.

2.2.1 Edge Detection

Direction of binary vein can be represented by its edge. To code the direction of vein, edge should be obtained at first. In our scheme, we employ the Sobel edge detector to produce the one-pixel-wide edge.

2.2.2 Coding Strategy

Because the pattern of 8-neighbor pixels can extract local feature fully, we devise a coding strategy to describe it.

Edge pixel is denoted as ‘1’ while the others have the value of ‘0’. For the 8-neighbors of each edge pixel, the number of non-zero pixels is 2 in most cases. To extract the local structure of the vein image, we focus on the case where the number is 2.

Let $P$ denote one edge pixel. When 2 non-zero pixels exist in the 8-neighbor of $P$, there are 28 ($\binom{8}{2} = 28$) different patterns of their distribution. Four different neighbor patterns are shown in Fig. 3 (a)–(d). Each pattern can be assigned a unique integer such as 1, 2... 28. Then each edge pixel can get an integer code according to which pattern its 8 neighbors exhibit.

2.2.3 Flooding

After edge coding, the coded edge map is obtained. However, edge code neglects the direction information carried by pixels within the edge. What’s more, the effect of edge detection depends heavily on binarization. To improve the robustness of matching, edge code is extended to the whole vein according to the nearest neighbor principle. That is, each non-edge pixel gets code from its nearest pixels. The order of choosing among the 8 nearest neighbors has been shown in Fig. 3 (e). Once a non-zero neighbor is detected, the non-edge pixel acquires its code and the algorithm proceeds to the next non-edge pixel. The algorithm terminates until all the non-edge pixels have been coded. This algorithm is denoted as ‘flooding’.

2.3 Analysis of NPC

The general idea of NPC is to add the discriminative orientation information to the binary vein pattern. Feature map used in direct binary matching only represents whether vein vessels exist while that of NPC scheme contains both the existence and orientation of vein vessels. In this sense, NPC is a way to characterize the orientation of all binary foreground pixels. Therefore, NPC can exploit more discriminative feature than direct matching.

Unlike palmprint [6], finger vein network is a structural feature and not rich in texture or creases. The finger vein image contains irregular shading and noise [3], which can be eliminated approximately using our previous work [4]. However, as shown in Fig. 4 (e), the shading and noise are coded and matched as discriminative features in the CompCode scheme [6]. Therefore, in terms of vein trait, NPC can provide more reliable feature coding than Miura method [3] and CompCode scheme [6].
3. Experimental Results

Following the NPC method, template matching is utilized for verification. For corresponding points in two feature maps $A$ and $B$, we assume they are matched if they are non-zero and equal. Calculating the total number of matched points, the similarity between $A$ and $B$ is defined as follows.

$$R(A, B) = \frac{2S(M)}{S(A) + S(B)}$$ (1)

$$M(i, j) = \begin{cases} 1 & A(i, j) \neq 0 \& A(i, j) = B(i, j) \\ 0 & \text{else} \end{cases}$$ (2)

Where $S(X)$ refers to the total number of non-zero pixels in the image of $X = A, B$. $R(A, B)$ is the similarity function and $M$ is the matched image.

Shift ($\pm 15$ pixels, 1 pixel for each step) and rotation ($\pm 5^\circ, 0.5^\circ$ for each step) adjustment is performed when calculating the similarity. Our capturing device confines the finger in a small rectangular area and gets it to touch a small bar with the fingertip. This special design ensures that the above adjustment is enough. After obtaining similarity for each adjustment, we choose the largest one as the final result.

To test the proposed method, we have used the database collected based on our previous work [4], which is composed of 440 images from 220 different subjects. One subject provides 2 images of the same one finger during two sessions with interval of about dozens of seconds. Thus, the numbers of genuine matchings and imposter matchings are 220 and 48180, respectively.

3.1 Effectiveness of NPC

In this experiment, NPC is compared with NPC without flooding and direct matching. Their EERs (equal error rate) are listed in Table 1. The result demonstrates that by using NPC without flooding the EER can be reduced from 2.61% to 1.92%. Flooding operation can further reduce the EER to 1.28%. The experimental results demonstrate that NPC can extract structural feature of binary vein pattern effectively.

3.2 Performance Evaluation of NPC

Many researchers solve the recognition problem in the transformed domain [5]–[8]. Among them, gabor filter based methods achieve better results. In this experiment, NPC is compared with Miura method [3], CompCode [6] and ImCompCode&MagCode [8]. The receiver operating characteristic (ROC) curve, which shows the relationship between false acceptance rate (FAR) and false rejection rate (FRR), is depicted in Fig. 5. The EER values for NPC, Miura method, CompCode and ImCompCode&MagCode are 1.28%, 2.74%, 3.99%, and 2.70% respectively. The result shows that NPC outperforms the other three methods.

4. Conclusion

A new structural feature extraction method named NPC for finger vein pattern is proposed. It consists of three steps: edge detection, coding strategy and flooding. Experimental results show that the proposed method is very effective. It can also be applied to other line-shaped biometrics.

Acknowledgments

The authors would like to thank the support of Shenzhen Basic Research Project (No.JC201006030866A).

References

[1] A. Kumar and Y. Zhou, “Human identification using finger images,” IEEE Trans. Image Process., vol.21, no.4, pp.2228–2244, 2012.
[2] A. Hoover, V. Kouznetsova, and M. Goldbaum, “Locating blood vessels in retinal images by piecewise threshold probing of a matched filter response,” IEEE Trans. Med. Imaging, vol.19, no.3, pp.203–210, 2000.
[3] N. Miura, A. Nagasaka, and T. Miyatake, “Feature extraction of finger vein patterns based on repeated line tracking and its application to personal identification,” Mach. Vis. Appl., vol.15, no.4, pp.194–203, 2004.
[4] W. Yang, X. Yu, and Q. Liao, “Personal authentication using finger vein pattern and finger-dorsa texture fusion,” ACM Int. Conf. on Multimedia (ACM Multimedia’09), pp.905–908, Oct. 2009.
[5] J. Yang and X. Zhang, “Feature-level fusion of fingerprint and finger-vein for personal identification,” Pattern Recognit. Lett., vol.33, pp.623–628, 2012.
[6] A.W.K. Kong and D. Zhang, “Competitive coding scheme for palmprint verification,” Proc. Int. Conf. on Pattern Recognition, vol.1, pp.520–523, 2004.
[7] J. Wang, W. Yau, A. Suwandy, and E. Sung, “Person recognition by fusing palmprint and palm vein images based on Laplacianpalm representation,” Pattern Recognit., vol.41, pp.1514–1527, 2008.
[8] L. Zhang, L. Zhang, D. Zhang, and H. Zhu, “Online finger-knuckle-print verification for personal authentication,” Pattern Recognit., vol.43, pp.2560–2571, 2010.