Palmprint Texture Analysis based on Low-Resolution Images for Personal Authentication

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Abstract

Biometrics identification is an emerging solution for solving security problems in our networked society. A new branch of biometric approach - palmprint technology, whereby the lines and points can be extracted from our palm for personal authentication, was proposed several years ago. In this paper, we develop a new feature extraction method based on low - resolution palmprint images. A 2-D Gabor filter is used to obtain the texture information and two palmprint images are compared in term of their hamming distance. The experimental results illustrate the effectiveness of our method.

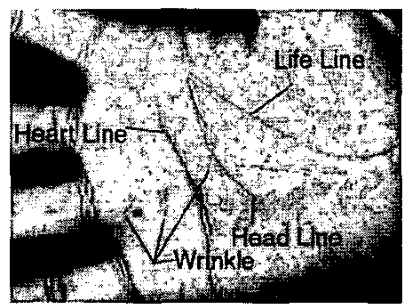

Figure 1. A palmprint image with line definitions.

1. Introduction

Palmprint identification can be divided into two categories, *on-line* and *off-line*. For off-line identification, all palmprint samples should be inked on a paper, and then transmitted into a computer with a scanner. Since the relative high-resolution of the off-line palmprint image (up to 500 dpi), some techniques applied to fingerprint images could be used for the off-line palmprint recognition, where lines, datum points and singular points would be extracted [1]. The researches of off-line palmprint recognition were the main focus in the past few years [2-5]. For on-line palmprint identification, the samples can be directly obtained by a palmprint input equipment. It is evident that on-line identification is more important for many real-time applications of personal authentication. Recently, a CCD camera-based palmprint capture device has been developed in Biometrics Research Center, Hong Kong [6,13]. Fig. 1 shows a palmprint image captured by our self-designed capturing device, which low-resolution technique (65 dpi) is adopted to reduce an image size. In this paper, we attempt to develop a new feature extraction method based on such a low-resolution image for personal authentication.

An on-line palmprint identification system can be examined by the following steps:

1) Image acquisition — Obtain a palmprint image by the capturing device.
2) Preprocessing — Determine a coordinate system and extract the central part from the given palmprint image.
3) Feature extraction — Find some stable and unique features.
4) Pattern matching — Decide whether two palmprints are from the same person.
5) Data storage — Save the features from the registered images for their comparisons.

An on-line palmprint system runs on at least two of three modes — enrollment, identification and verification. In the enrollment mode, a new user's palmprint feature is extracted and then stored in a database for later comparisons. In the identification mode, an input palmprint must pass though image acquisition, preprocessing and feature extraction. The feature extracted is compared with all records in a given database. The difference between the identification and verification modes is if each user must have a user ID and his/her palmprint can only be compared with all the features belonging to the same user ID.

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This paper is organized as follows: palmprint image preprocessing is discussed in Section 2; Section 3 explores palmprint feature extraction with texture analysis; palmprint matching and experimental results are given in Sections 4 and 5, respectively; finally, some conclusions are provided in Section 6.

2. Palmprint Image Preprocessing

The goal of preprocessing is to obtain a sub palmprint image for feature extraction and to eliminate the variation caused by the rotation and translation. Five main steps are defined as below (see Fig. 2).

Step 1: Apply a lowpass filter to an original image. Then, using a threshold, T_p, is used to convert this original image to a binary image as shown in Fig. 2(b). Mathematically, this transformation can be represented as

$$B(x,y)=1 \text{ if } O(x,y)*L(x,y) \geq T_p, \quad (1)$$

$$B(x,y)=0 \text{ if } O(x,y)*L(x,y) < T_p, \quad (2)$$

where $B(x,y)$ and $O(x,y)$ are the binary image and the original image, respectively; $L(x,y)$ is a lowpass filter such as Gaussian, and "*" represents an operator of convolution.

Step 2: Extract the boundaries of the holes, $(F_ix_j\ F_iy_j)$, (i=1,2,3), between fingers using a boundary tracking algorithm. The start points, $(Sx_i\ Sy_i)$, and end points, (Ex_i, Ey_i), of the holes are then marked in the process (see Fig. 2(c)).

Step 3: Compute the center of gravity, (Cx_i, Cy_i), of each hole with the following equations:

$$Cx_i = \frac{\sum_{j=1}^{M(i)} F_i x_j}{M(i)}, \quad (3)$$

$$Cy_i = \frac{\sum_{j=1}^{M(i)} F_i y_j}{M(i)}, \quad (4)$$

where $M(i)$ represents the number of boundary points of the hole, i. Then, construct a line that passes through (Cx_i, Cy_i) and the midpoint between (Sx_i, Sy_i) and (Ex_i, Ey_i). The line equation is defined as

$$y = x\frac{(Cy_i - My_i)}{(Cx_i - Mx_i)} + \frac{My_iCx_i - Mx_iCy_i}{Cx_i - Mx_i}, \quad (5)$$

where (Mx_i, My_i) is the midpoint between (Sx_i, Sy_i) and (Ex_i, Ey_i). Based on these lines, three key points, (k_1, k_2, k_3), can easily be detected (see Fig. 2(d)).

Step 4: Line up k_1 and k_3 to get the Y-axis of the palmprint coordinate system, and make a line through k_2, which is a perpendicular to the Y-axis to determine the origin of the palmprint coordinate system (see Fig. 2(e)). This coordinate system can align different palmprint images.

Step 5: Extract a sub image with a fixed size on the basis of the coordination system, which is located at a certain part of the palmprints for feature extraction (see Fig. 2(f)).

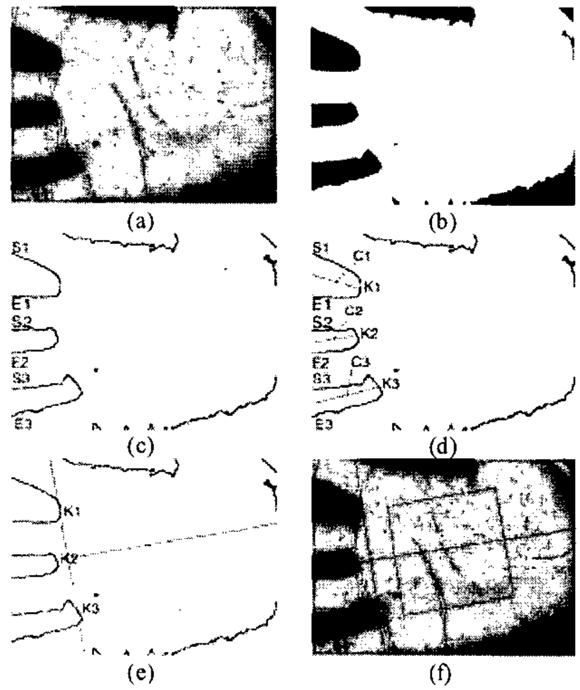

Figure 2. The main steps of preprocessing. (a) Original image, (b) Binary image, (c) Boundary tracking, (d) Key points (k_1, k_2 and k_3) detecting, (e) The coordinate system, and (f) The central part of the palmprint image.

3. Texture Analysis and Feature Extraction

Generally, there exist some principal lines, wrinkles and ridges in a palmprint image [1,5] (see Fig. 1). Some algorithms such as the stack filter [8] can extract the principal lines. However, these principal lines do not contribute adequately to high accuracy because of the similarity of these principal lines between different people. Wrinkles play an important role in palmprint identification but accurately extracting them is still a difficult task. This motivates us to apply texture analysis to palmprint recognition. The Gabor filter, an effective tool for texture analysis, has the following general form,

$$G(x,y,\theta,u,\sigma) = \frac{1}{2\pi\sigma^2}\exp\left\{-\frac{x^2+y^2}{2\sigma^2}\right\}\exp\{2\pi i(ux\cos\theta + uy\sin\theta)\}, \quad (6)$$

where $i=\sqrt{-1}$; u is the frequency of the sinusoidal wave; θ controls the orientation of the function and σ is the standard deviation of the Gaussian envelope. In the experiments, u, θ and σ are set as 0.1833, $\pi/4$ and 2.8090, respectively. Gabor filters are widely used in texture analysis and biometrics [9-12]. In order to provide more robust to brightness, the Gabor filter be turned to zero DC with the application of the following formula:

$$\tilde{G}[x,y,\theta,u,\sigma] = G[x,y,\theta,u,\sigma] - \frac{\sum_{i=-n}^{n}\sum_{j=-n}^{n} G[i,j,\theta,u,\sigma]}{(2n+1)^2}, \quad (7)$$

where $(2n+1)^2$ is the size of the filter. In fact, the imaginary part of the Gabor filter automatically has zero DC because of odd symmetry. This adjusted Gabor filter will convolute with the central part of a palmprint. Each point in the resultant image is coded to two bits, (b_r, b_i), by the following inequalities,

$$b_r=1 \text{ if } \mathrm{Re}[\tilde{G}[x,y,\theta,u,\sigma] * I] \geq 0, \quad (8)$$

$$b_r=0 \text{ if } \mathrm{Re}[\tilde{G}[x,y,\theta,u,\sigma] * I] < 0, \quad (9)$$

$$b_i=1 \text{ if } \mathrm{Im}[\tilde{G}[x,y,\theta,u,\sigma] * I] \geq 0, \quad (10)$$

$$b_i=0 \text{ if } \mathrm{Im}[\tilde{G}[x,y,\theta,u,\sigma] * I] < 0, \quad (11)$$

where I is the central part of a palmprint image. Note that this feature extraction method only stores the phase information in the feature vector.

4. Palmprint Matching

In order to clearly describe the matching process, each feature vector will be considered as two 2-D feature matrixes, real and imaginary. Palmprint matching is based on a normalized hamming distance. Let P and Q be two palmprint feature matrixes. The normalized hamming distance can be described as,

$$D_o = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N}\left(P_R(i,j) \otimes Q_R(i,j) + P_I(i,j) \otimes Q_I(i,j)\right)}{2N^2}, \quad (12)$$

where P_R (Q_R) and P_I (Q_I) are the real part and the imaginary part of P (Q), respectively; the result of Boolean operator, "$\otimes$", is equal to zero if and only if the two bits, $P_{R(I)}(i,j)$, equal to $Q_{R(I)}(i,j)$, and the size of the feature matrixes is $N \times N$. It is noted that D_o is between 1 and 0. For perfect matching, the matching score is zero. In order to further reduce the variation of the translation, Eq. 12 can be improved by

$$D_{\min} = \min_{|s|<S, |t|<T} \frac{\sum_{i=\max(1,1+s)}^{\min(N,N+s)} \sum_{j=\max(1,1+t)}^{\min(N,N+t)} \begin{pmatrix} P_R(i+s,j+t) \otimes Q_R(i,j) + \\ P_I(i+s,j+t) \otimes Q_I(i,j) \end{pmatrix}}{2H(s)H(t)} \quad (13)$$

where $S=6$ and $T=6$ control the range of horizontal and vertical translation of a feature in the matching process, respectively, and

$$H(s) = \min(N, N+s) - \max(1, 1+s). \quad (14)$$

The matching score, D_{min}, can support a translation matching; nevertheless, it still suffers from the variation of rotation of the images. Therefore, all the sub images of the registered images are rotated by some degrees (-6°, -4°, -2°, 0°, -2°, -4°, -6°) and then the features of the images are extracted. As the result, our palmprint matching process can handle different rotation and translation.

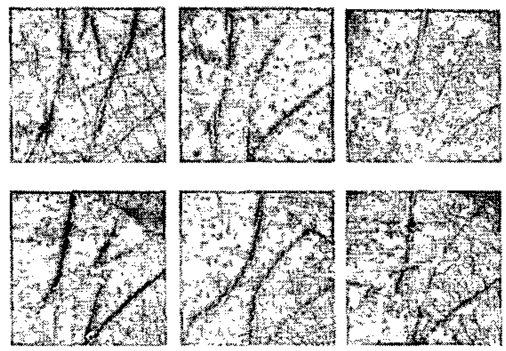

Figure 3. Typical images obtained from our database.

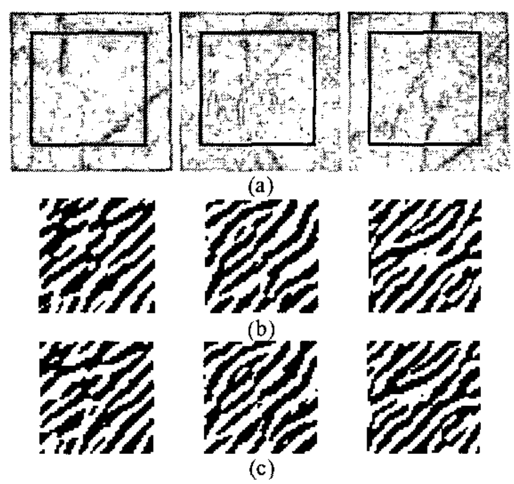

Figure 4. Original images and their features (a) Original images with the effective areas specified, (b) Features from the real part of the Gabor filter c) Features from the imaginary part of the Gabor filter.

5. Experimental Results

The database for testing our method contains 425 images from 95 persons. The sub images of the palmprint images is 64 by 64. Fig. 3 shows six typical sub images in our database with various texture features. Fig. 4 illustrates the real and imaginary parts of our features (PalmCode) described in Eq. 12 and the corresponding preprocessed images.

The performance of the proposed method under different the thresholds, *Tar*, which control the false accept rate and false reject rate is shown in Table 1. In this experiment, the imposter distribution and genuine distribution are generated by 1,083 and 769 comparisons, respectively. Fig. 5 shows the two distributions. When the threshold is 0.335, the false reject rate is 0.9% with 0% false accept rate. Some images are still not recognized with the proposed method because of non-linear distortion.

Table 1. Experimental results of the selected thresholds.

Threshold *Tar*	False accept rate (%)	False reject rate (%)
0.325	0.00	1.56
0.335	0.00	0.91
0.345	0.37	0.65
0.355	0.92	0.65
0.365	2.50	0.39
0.375	5.36	0.13

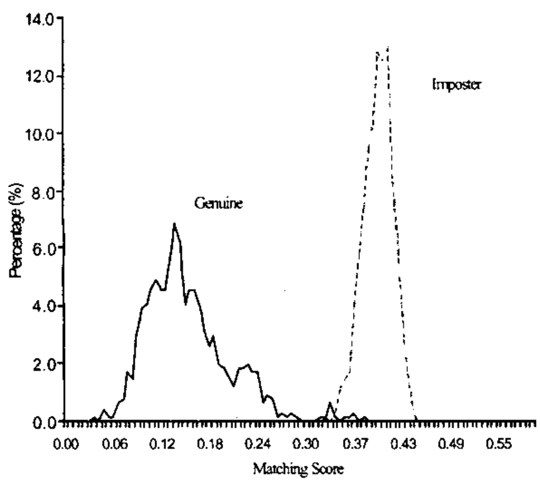

Figure 5. Imposter and genuine distributions of our experiments

6. Conclusion

This paper reports a new palmprint identification method using low-resolution images and texture-based feature extraction approach. A palmprint is handled as a texture image, and an adjusted Gabor filter is applied to capture the texture information. For the optimal cases in our database, the false reject rate is 0.91% with 0% false accept rate. The experimental results are encouraging.

Acknowledgments

The authors would like to thank Wenxin Li and Qingyun Dai at Biometrics Research Centre for their palmprint image collection. The work is partially supported with UGC(CRC) fund from the Hong Kong SAR Government and the central fund from The Hong Kong Polytechnic University.

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