Palmprint Recognition Based on Fourier Transform*

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Abstract: Palmprint recognition aims at finding out the palmprint template from the database, which is from the same palm as a given palmprint input. Feature extraction plays an important role in the recognition process. In this paper, we propose a new feature extraction method by converting a spatial domain palmprint image into a frequency domain image using Fourier Transform (FT) and representing palmprint features in the frequency domain. The extracted features are used as indexes to the palmprint templates in the database and the searching for the best match is leaded by these features in a layered fashion. The experimental result shows that the proposed FT based feature extraction method is effective in terms of accuracy and efficiency on our palmprint database.

Key words: palmprint; personal identification; biometrics; fourier transform; feature extraction

Computer based personal identification, also known as biometrics computing began in 1970s. At that time, the first commercial system called Identimat was developed, which measured the shape of a hand and looked particularly at finger length. In the mean time, fingerprint based automatic checking systems are widely used in law enforce. Retina and iris based systems were introduced in the mid 1980s. Today's speaker identification biometrics have their roots in technological achievements of the 1970s; while signature identification and facial recognition are relative newcomers to the industry[1].

Now worldwide, there are many applications of biometrics being used or considered. Most of the applications are still in the stage of testing and are optional for end users. Any situation that allows an interaction between man and machine is capable of incorporating biometrics. Such situations may fall into a range of application areas such as computer desktops, networks, banking, immigration, law enforcement, telecommunication networks and monitoring the time and attendance of staff. Fraud is an ever-increasing problem and security is becoming a necessity in many walks of life[2,3].

In this paper, we present our initiative work on palmprint retrieval method, which is a new attempt and necessary complement to the existing biometrics techniques. Not like hand geometry based system that measures a hand's size and finger length, palmprint is concern with the inner surface of a hand and looks particularly at line patterns and surface shape. A palm is covered with the same kind of skin as finger tips and is larger in size than a finger tip, hence it is quite natural to think of using palmprint to recognize a person, but little has been done to palmprint based personal identification[4].

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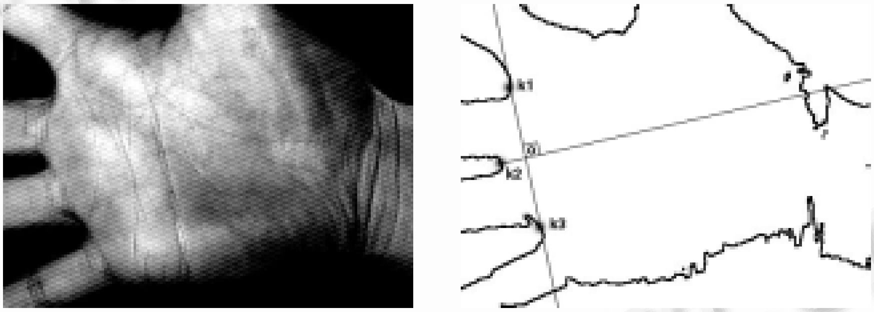
The rest of this paper is organized as follows. Section 1 presents the preprocessing process for rotation and shift correction and fixed size sub image extraction. The proposed feature extraction method using Fourier Transform is introduced in Section 2. Section 3 presents the feature matching and palmprint identification method. Section 4 and Section 5 summarize the experimental results and highlights the conclusions, respectively.

1 Palmprint Preprocessing

When a palmprint is captured, its position, direction and stretching degree may vary from time to time, even from the same palm. It is necessary to align all the palmprints and normalize their sizes for further feature extraction and matching.

In order to align the palmprints, we define a right angle coordination system, which is based on three key points between fingers: k1 (intersect between index and middle finger), k2 (intersect between middle and forth finger), k3 (intersect between forth and fifth finger). The basic steps of palmprint alignment are defined as follows: (1) Use a threshold to convert from the original gray level image into a binary map; (2) Apply a Gaussian filter to smooth the binary map; 3) Trace the boundary of the holes between fingers; (4) Calculate the center of gravity of the holes and decide the three key points k1, k2, and k3; (5) Line up k1 and k3 to get the Y-axis of the palmprint coordination system and make a line through k2 and the perpendicular to Y-axis to determine the origin of the palmprint coordination system; (6) Rotate the image to make the Y-axis on the vertical direction. Figure 1 shows the original image and coordination system decided.



(a) Original image (b) Decided coordination system

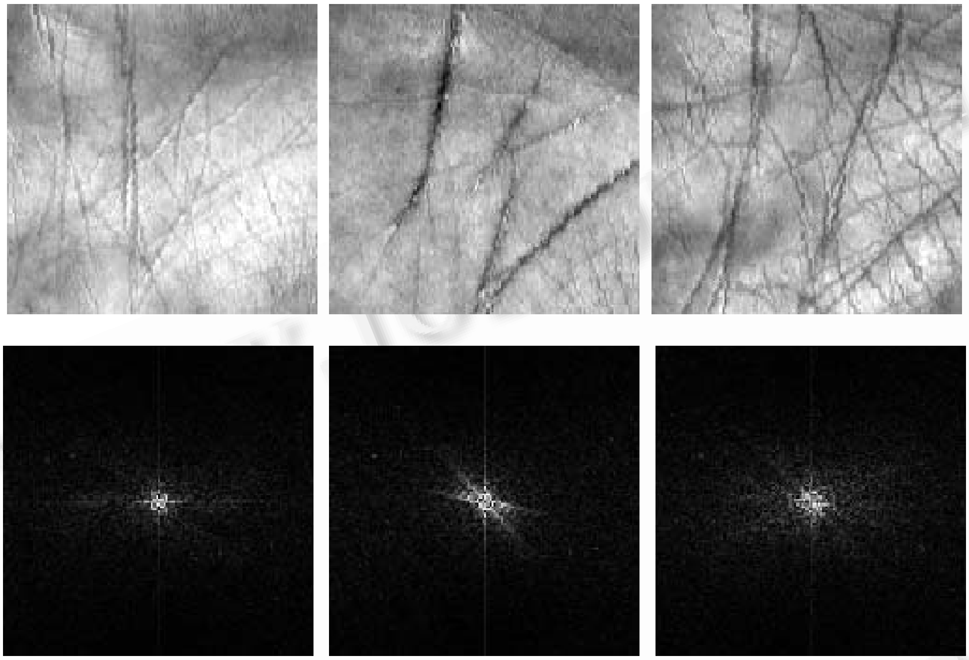
Fig.1 Original image and its coordination system

It is very natural that palms are not of the same size, but this results in the difficulty to feature extraction and matching. In order to solve this problem, only a sub area of a palmprint image is used in feature extraction. All the palmprints are cut off a fixed size sub image from the same location. The sub image size and location are determined according to lots of observations. The principle to decide the size and location of the sub image is to make sure that most palmprint features are still within this area and all the palmprints have that piece of sub image.

2 Palmprint Feature Extraction Using Fourier Transform

2.1 Palmprint features exhibited in the frequency domain

Fourier Transform has been widely discussed and applied in image processing[5~10]. In our palmprint identification, Fourier Transform is used in feature extraction. This is because there exist some correspondences between palmprint features on a spatial domain image and those on a frequency domain image. In general, the stronger the creases are on a spatial domain image, the less compact the information is on a frequency domain image. And if a palmprint image in the spatial domain has a strong line, in the frequency domain there will be more information in the line's perpendicular direction. As a result, Fig.2 shows three typical palmprints and their correspondence frequency domain images, where Fig.2(a) is a palmprint without strong creases and its frequency domain image shows that the information is centralized in the center, which is the high frequency area; Fig.2(b) is a palmprint with two clear and strong creases and its frequency domain image shows that there exists rich information on the direction perpendicular to the creases; and Fig.2(c) is a palmprint with the full of strong creases and its frequency domain image shows that the information is not as centralized as that in Fig.2(a).



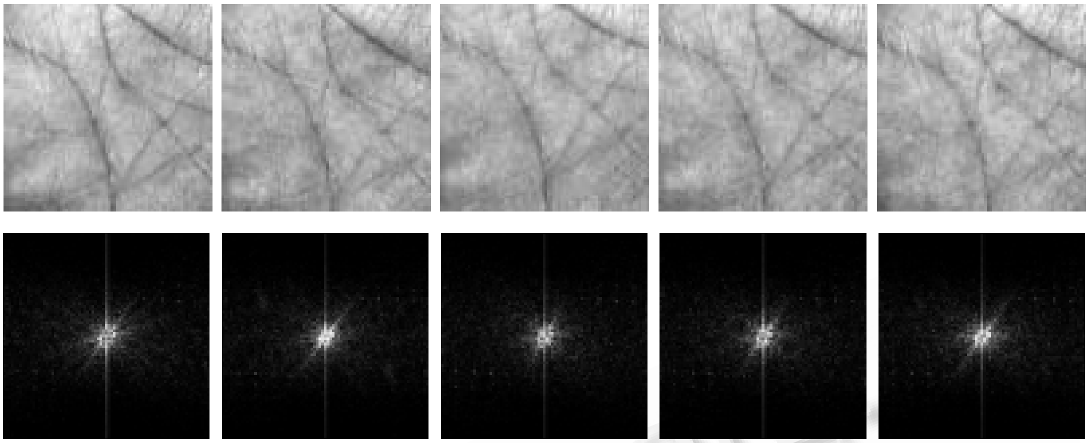
(a) (b) (c)

Fig.2 Plamprints and their frequency domain images

In our palmprint identification, if feature extraction is conducted in the frequency domain, it is important that similar palmprints remain resemble to each other when converted in to frequency images. As an illustration, Fig.3 shows three groups of palmprints and their correspondent frequency images. They are from the same palm, similar palms and different appearance palms. Figure 3(a) is a group of palmprints from the same palm and the frequency domain images are very similar to each other. Figure 3(b) is a group of palmprints which are from palms different but having close appearance and the frequency images are also close within this group. Figure 3(c) is a group of palmprints which are from totally different palms and there exists clear difference among the palmprints in this group.

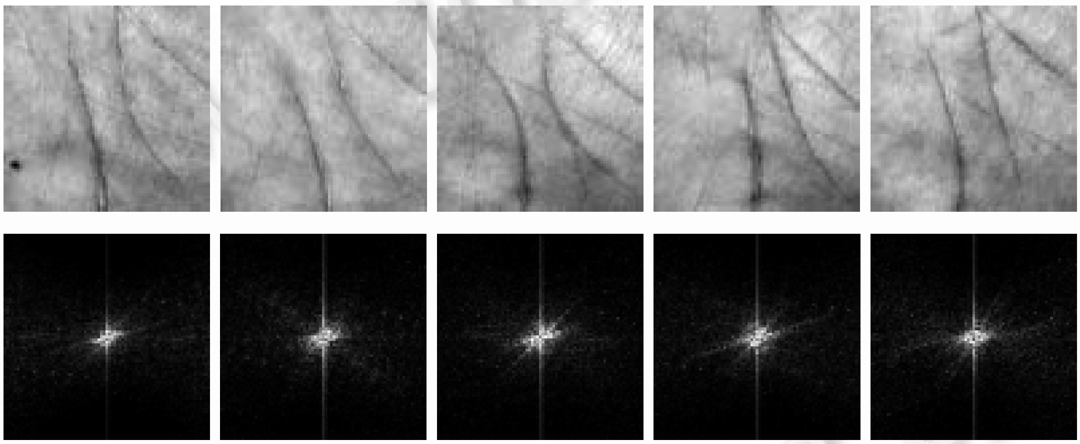
2.2 Palmprint feature representation

Palmprint feature representation is to describe the features in a concise and easy-to-compare way. If we use polar coordination system (r,θ) to represent the frequency domain images, the energy change tendency along r shows the intensity of a palmprint's creases and that along θ shows the directions of a palmprint's creases. Therefore, we may use a statistical method to represent palmprint's features.



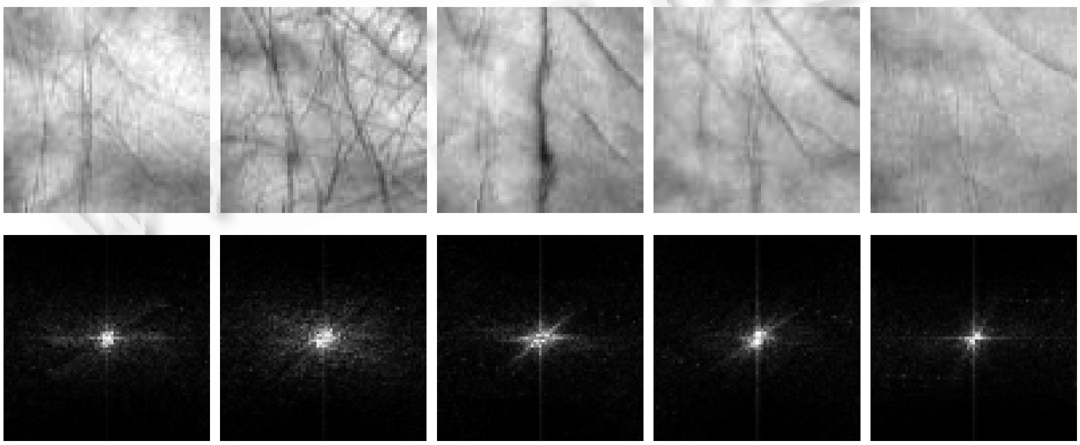
A-1 A-2 A-3 A-4 A-5

(a)



B-1 B-2 B-3 B-4 B-5

(b)



C-1 C-2 C-3 C-4 C-5

(c)

Fig.3 Palmprints from different groups and their frequency domain images

The image can be converted from a right angle coordination system into a polar coordination system by

$$I'(r,\theta)=I(64+r\cos\theta,64+r\sin\theta),\quad 0\le r\le 64\quad 0\le\theta\le\pi, \tag{1}$$

where I is the image under right angle coordination system and I' is the image under polar coordination system.

In order to represent a palmprint's crease intensity, the frequency domain image is divided into small parts by a series of circles which have the same center, as shown in Fig. 4(a). The energy in each ring like area is defined as

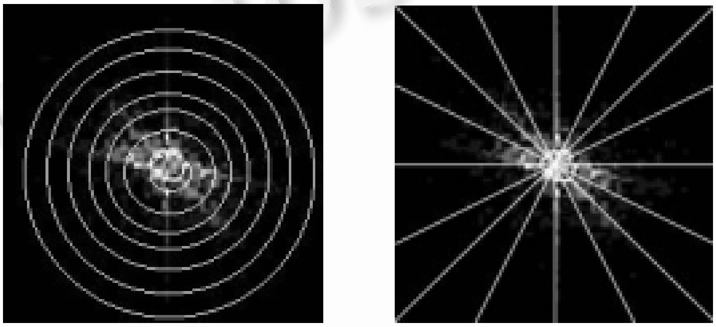
$$R_i=\sum_{\theta=0}^{\pi}\sum_{r=8(i-1)}^{8i}I'(r,\theta),\qquad i=1,2,...,8 \tag{2}$$

where I' is the sub image under polar coordination system. In the following of this paper, R_i(i=1,2,…,8) is called R feature.

In order to represent a palmprint's crease direction, the frequency domain image is divided by a series of lines that go through the center of the image, as shown in Fig.4(b). The energy in each fan like part is defined as

$$\theta_i=\sum_{\theta=(i-1)}^{i}\sum_{r=0}^{64}I'(r,\theta\pi/8),\qquad i=1,2,...,8 \tag{3}$$

In the following of this paper, θ_i (i=1,2,…,8) is called θ feature.



(a) (b)

Fig.4 Segmentation of frequency domain images

3 Palmprint Matching and Palmprint Identification

3.1 Feature matching by R and θ

Feature matching computes the distance between two palmprint feature sets. Because a palmprint is represented by R feature and θ feature, feature matching becomes calculating the distance between R features and θ features.

Let RX_i (i=1,2,…,8) and RY_i (i=1,2,…,8) represent two R feature sets. The distance DR_{xy} between RX_i (i=1,2,…,8) and RY_i (i=1,2,…,8) is defined as:

$$DR_{xy}=\frac{1}{8}\sum_{i=1}^{8}|RX_i-RY_i|\ . \tag{4}$$

Let θX_i (i=1,2,…,8) and θY_i (i=1,2,…,8) represent two θ feature sets. The distance $D\theta_{xy}$ between θX_i (i=1,2,…,8) and θY_i (i=1,2,…,8) is defined as:

$$D\theta_{xy}=\left(1-\frac{l_{xy}l_{xy}}{l_{xx}l_{yy}}\right)\times 100\ , \tag{5}$$

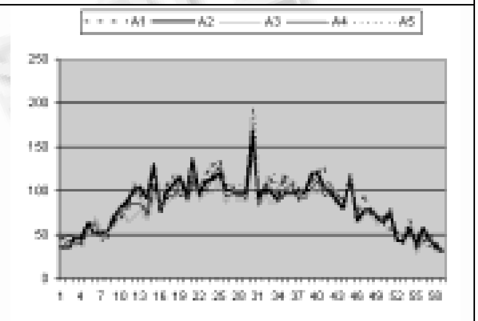
where

$$l_{xx}=\sum_{i=1}^{8}\left(\theta X_i-\frac{1}{8}\sum_{i=1}^{8}\theta X_i\right)^2\ , \tag{6}$$

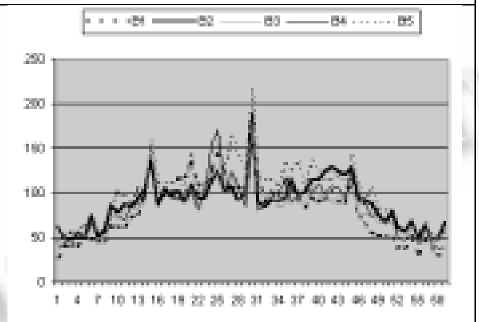
$$l_{yy}=\sum_{i=1}^{8}\left(\theta Y_i-\frac{1}{8}\sum_{i=1}^{8}\theta Y_i\right)^2, \tag{7}$$

$$l_{xy}=\sum_{i=1}^{8}\left(\theta Y_i-\frac{1}{8}\sum_{i=1}^{8}\theta Y_i\right)\left(\theta Y_i-\frac{1}{8}\sum_{i=1}^{8}\theta Y_i\right). \tag{8}$$

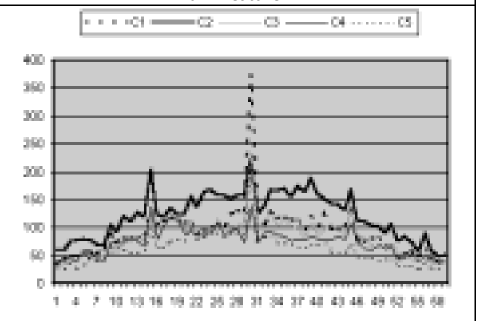
The scope of $D\theta_{xy}$ is between 0 and 100. The smallest distance is 0 and the largest distance is 100. Figure 5 shows R and θ features of those palmprints shown in Fig.3. For group A, which includes the samples from the same palm, the average distance of R features is 3.7 and the θ features are very close to each other. For group B, which includes the samples from similar palms, the average distance of R features is 9.4 and the θ features are close to each other. For group C, which includes the samples from palms with different appearances, the average distance of R features is 20.0 and the θ features are far from each other. Both R feature and θ feature are used in feature matching and palmprint identification.

	R Feature (Average distance=3.7)								θ Feature
A-1	57	48	63	59	56	62	56	60	
A-2	56	53	62	59	58	58	48	57	
A-3	52	50	57	54	52	57	53	60	
A-4	56	43	57	56	58	62	57	56	
A-5	59	47	59	58	67	59	57	61	

(a)

	R Feature (Average distance=9.4)								θ Feature
B-1	43	39	45	55	53	63	62	74	
B-2	45	54	56	60	67	72	67	67	
B-3	63	49	56	58	52	58	53	51	
B-4	65	39	54	49	52	68	57	69	
B-5	55	49	61	56	66	81	76	80	

(b)

	R Feature (Average distance=20.0)								θ Feature
C-1	48	46	56	68	69	64	62	64	
C-2	66	77	91	89	87	87	77	80	
C-3	63	46	55	47	54	62	61	61	
C-4	50	36	48	47	49	54	49	51	
C-5	33	30	37	40	43	44	43	49	

(c)

Fig.5 Comparison of features from different plamprint groups

3.2 Palmprint identification in a layered fashion

Palmprint identification is to search in the database in order to find the palmprint that is from the same palm as the input one. Two key issues involved in the searching are accuracy and efficiency. Accuracy represents that at what rate the searching result is correct and efficiency reflects how fast the final output can be given. Now that a palmprint is represented by R feature and θ feature, these features are used as indexes to the palmprint database. The searching is carried out in a layered fashion, R feature is used to lead the first round searching and a candidate set is obtained, then θ feature is applied to lead the second round searching and a final output is given after the second round searching. Using R feature to lead the first round searching is due to its relatively short comparing time.

4 Experimental Results and Analysis

The following experiments are designed for testing the accuracy and efficiency of the proposed method. The data collection process involves three steps: (1) Find 500 people of different ages, sexes and occupations. (2) Capture six palmprint samples from each person. (3) Randomly pick up one from the six samples to set up the database, which has 500 templates. (4) Use the left 2500 samples (each person has five) as the testing set. All the palmprints are from right hand and are captured with the same palmprint capture device. Palmprint samples from the same palm may be with a little rotation and shift. The size of all the palmprint images is 320×240.

The testing process is that for each sample in the testing set, find out the template in the database, which is captured from the same palm. The output for a query may be correct or not correct and we count the number of correct answers to evaluate the proposed method's accuracy. Also the response time is recorded to evaluate the efficiency of the proposed method. Table 1 shows the testing result.

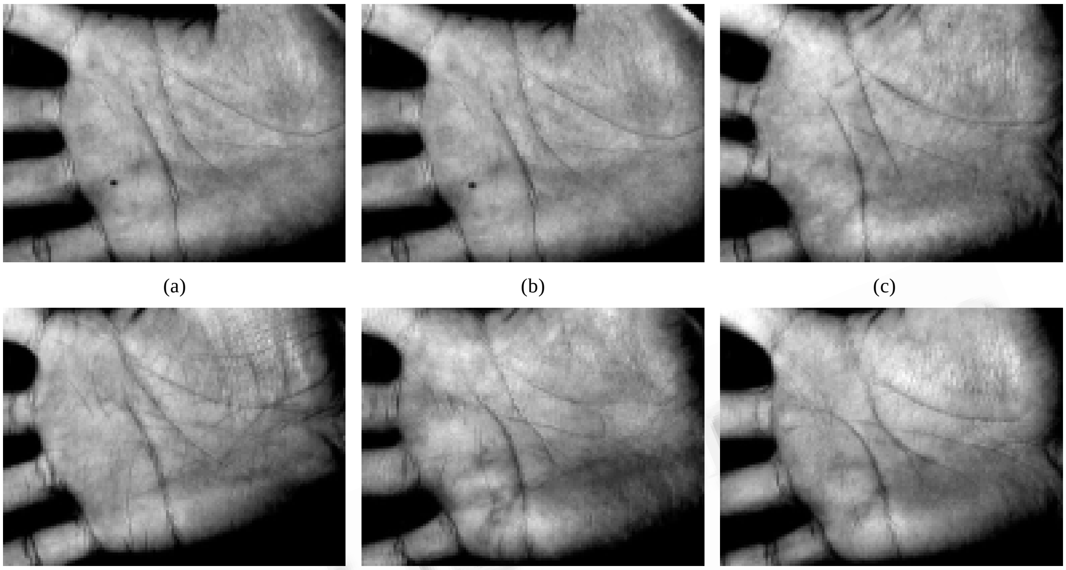
Table 1 The result of performance testing

Templates in the database	500
Attempts in testing	2500
Correct answers	2387
Identification rate (%)	95.48
Average response time (s)	2

The identification accuracy is 92.5% and the shortest response time is 1.2 seconds, the longest response time is 3.7 seconds and the average is 2 seconds. Fig. 6 shows an identification example, (a) is the input s ample and (b)~(f) are templates selected by the first round searching and (b) is the final output decided by the second round searching.

5 Conclusion

Palmprint retrieval provides a new way for authentication identity. It has the advantages of easy to capture, short response time, small feature size, low hardware cost, no emotional coupling with criminal records. In this paper, we introduce a Fourier Transform based feature extraction and representation method for palmprint retrieval. A palmprints is first converted into the frequency domain image and then feature extraction is conducted in the frequency domain. Different features are used to lead a layered fashion searching for the best match of the input palmprint from the database. Experiments are carried out in order to measure the performance of the proposed method. It shows that the proposed palmprint identification method is with high performance in terms of accuracy and efficiency on our palmprint database.



(a) (b) (c)

(d) (e) (f)

Fig.6 The input palmprint(a) and the top five(b)~(f) similar palmprint templates selected from the database

References:

[1] Miller, B. Vital signs of identity. IEEE Spectrum, 1994,32(2):22~30.

[2] Jain, A., Bolle, R., Pankanti, S. Biometrics: Personal Identification in Networked Society. Kluwer Academic Publishers, 1999.

[3] Zhang, D. Automated Biometrics——Technologies and Systems. Kluwer Academic Publishers, 2000.

[4] Zhang, D., Shu, W. Two novel characteristics in palmprint verification: datum point invariance and line feature matching. Pattern Recognition, 1999,33(4):691~702.

[5] Titchmarsh, E.C. Introduction to the Theory of Fourier Integral. New York: Oxford University Press, 1948.

[6] Cooley, J.W., Lewis, P.A.W., Welch, P.D. Historical notes on the fast Fourier transform. IEEE Transactions on Audio and Electroacoustics, 1967,AU-15(2):76~79.

[7] Cooley, J.W., Lewis, P.A.W., Welch, P.D. Application of the fast Fourier transform to computation of Fourier integrals. IEEE Transactions on Audio and Electroacoustics, 1967,AU-15(2):79~84.

[8] Brigham, E.O. The Fast Fourier Transform. Englewood Cliffs, NJ: Prentice-Hall, 1974.

[9] Andrews, H.C. Computer Techniques in Image Processing. New York: Academic Press, 1970.

[10] Gonzalez, R.G., Woods, R.E. Digital Image Processing. Addison-Wesley Publishing Company, 1993.

基于傅立叶变换的掌纹识别方法

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摘要: 掌纹识别是指由计算机自动识别哪些掌纹图像来自同一只手掌,哪些来自不同的手掌.在掌纹识别中,特征提取算法的优劣至关重要.提出了一种基于傅立叶变换的掌纹特征提取方法.该方法的基本思想是先将掌纹图像应用傅立叶变换转换到频域,然后在频域中进行特征提取和描述.提取出来的特征备用来索引掌纹数据库,以便当一个新的掌纹图像被输入时,可以很快确定该手掌是否已经在掌纹库中注册.该方法可以用来做基于人体生物特征的身份识别,在安全领域有广泛的应用前景.实验验证了该方法的有效性.

关键词: 掌纹;特征提取;傅立叶变换;身份验证;生物识别技术

中图法分类号: TP391 文献标识码: A