Fuzzy Directional Element Energy Feature (FDEEF) Based Palmprint Identification

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Abstract

Palmprint is a novel biometric method to identify a person. Generally, there are two types of features in palmprint, i.e. structural features and statistical features. Structural features, such as lines, can characterize a palm exactly, but are difficult to be extracted and represented. Contrarily, statistical features can be extracted and represented easily, but are unable to reflect the structural information of a palmprint. The fact that the principal features of both Chinese character and palmprint are lines motivates us to try some methods of Chinese character recognition to identify palmprint. In this paper, we use the idea of an efficient Chinese character recognition method, directional element feature (DEF), to define a novel palmprint feature, named fuzzy directional element energy feature (FDEEF) which is a statistical feature containing some line structural information about palmprints. It can be extracted and represented easily and, at the same time, has a strong ability to distinguish palms. Two other low-dimensional features: global fuzzy directional element energy feature (GFDEEF) and block edge energy feature (BEEF) are also derived from FDEEF in this paper. The experimental results demonstrate the power of this method.

1. Introduction

Computer-aided personal identification becomes more and more important in this information era. Biometrics is one of the most important and reliable methods in this field [1]. Palmprint, as a new biometric feature, has several advantages compared with other ones: low-resolution imaging, low cost capture device, non-fake, stable line feature and easy self-positioning, etc. It is for this reason that palmprint identification draws more and more researchers' attention recently [2-5].

There are two kinds of elementary features in palmprint: structural features and statistical features. The former includes principle lines, wrinkles, datum points, and minutiae, etc. The first two, called line features, are the most robust and popular in palmprint recognition [2]. Texture energy belongs to statistical features. Structural features, especially the lines, can characterize a palmprint clearly. Consequently, they have a strong ability to discriminate palms. However, it is difficult to extract, represent and compare them. Furthermore, structural features cannot provide the strength of the lines which is very important when human identify palms. On the contrary, statistical features have the advantages such as easy extraction, representation and comparison. The shortcoming is that they involve little structural information of the palmprint. Thus their ability to identify a palmprint is not as good as that of the structural features.

Lines are the principal features of both Chinese character and palmprint. This fact motivates us to employ the methods of Chinese character recognition in palmprint identification. The directional elements feature (DEF), a statistical feature reflecting the structural information of the characters, is one of the most efficient methods in off-line handwritten Chinese character recognition [6–8]. In this paper, a modification of DEF, named fuzzy directional element energy feature (FDEEF), is presented. FDEEF is also a statistical feature containing some line structural information about palmprints, so it can be extracted and represented easily and, at the same time, has a strong ability to distinguish palms. Two other low-dimensional features: global fuzzy directional element energy feature (GFDEEF) and block edge energy feature (BEEF) are also derived from FDEEF in this paper.

The paper is organized as follows: In Section 2, DEF is reviewed briefly. Section 3 describes FDEEF in detail. GFDEEF and BEEF are derived from FDEEF in section 4. Section 5 contains the experimental results, and Section 6 gives the summary and future work.

2. Review of Directional Element Feature (DEF)

In this section, the directional element feature (DEF) [6-8], which is considered suitable for off-line handwritten Chinese character recognition, is described. The operation for extracting the DEF includes the following three steps.

2.1. Step 1: Contour Extraction

Suppose $I(i,j)$ be a regularized $N \times N$ binary Chinese character image in which the character is black and the background is white, that is:

$$I(i,j)=\begin{cases}0, & \textit{if point}(i,j) \textit{ belongs to a character},\\ 1, & \textit{Otherwise}.\end{cases} \quad (1)$$

A black pixel is on the contour of character if and only if one of its 8-neighbour pixels is white, i.e.

$$I(i,j) \textit{ is a contour point} \Leftrightarrow \bigvee_{\substack{u=\pm 1\\ v=\pm 1}} I(i+u, j+v) \wedge \overline{I(i,j)} \quad (2)$$

2.2. Step 2: Dot Orientation

In dot-orientation, one of the four types of line elements (horizontal, vertical, 45^0 diagonal and 135^0 diagonal) is assigned to each contour pixel. Let (i,j) and (k,l) be two neighbour black points, then the type of line elements assigned to point (i,j) can be decided as below:

Horizontal:	$i-k=0$ and $l-j=1$;
Vertical:	$j-l=0$ and $k-i=1$;
45^0 Diagonal:	$k-i=1$ and $l-j=1$;
135^0 Diagonal:	$k-i=1$ and $j-l=1$.

2.3. Step 3: Vector Construction

Consider an input pattern for which dot orientation has been completed. First, this pattern is divided into $M \times M$ blocks equally. Then, for each block, a four-dimensional vector (x_1,x_2,x_3,x_4) is defined where x_1,x_2,x_3,x_4 represent the element numbers of the four orientations respectively. So a $M \times M \times 4$ -dimensional vector feature can be obtained from the whole character image. This vector feature is called *directional element feature (DEF).*

3. Fuzzy Directional Element Energy Feature (FDEEF)

Compared with handwritten Chinese Character, palmprint images have their own property. Firstly, the palmprints are 256-grayscale images. In order to use the idea of Chinese character recognition methods, the line edges should be detected. Secondly, the points on the lines have more orientations. Finally, the thick of the lines are very important information when human identify palms. Therefore, we should not use DEF to identify palms directly. FDEEF, a modification of DEF for palmprint recognition, is described in this section. The operation for extracting the FDEEF also includes three steps.

3.1. Step 1: Line Edge Detection

Many algorithms [9] can be used to detect line edges (roof edges). However, the results of these algorithms don't reflect the width information of the detected lines that is important in palmprint identification. However, if we regard one line edge as two step-edges, the distance between them is the width of this line edge. That is, step edge detection algorithms do not lose the wide information of lines on palm. Therefore, the feature vectors constructed from the result of step edge detection algorithms are more suitable to describe palmprints than that of line edge detection algorithms. Consequently, a well-known step edge detection method, Canny algorithm [10-11], is used to detect edges in palmprint image in this section. An example of the detected edges is shown in Fig. 1(b). Fig. 1(c) and (d) show the magnitudes and angles of the edge points' gradients, respectively.

In following sections, Mag is the edge magnitude image in which the values of edge points are the magnitudes of their gradients and the values of other points are 0, and $Angle$ ($-90^0 \le Angle(i,j) < 90^0$) is the gradient angle image.

3.2. Step 2: Fuzzy Dot Orientation

The angle of point (i,j)'s gradient is denoted as $Angle(i,j)$ in above section, so the angle of the line element containing this point is:

$$Ang(i,j) = Angle(i,j) + 90^0, \quad (3)$$

obviously, $0 \le Ang(i,j) < 180^0$.

Let U be a collection of all edge points in a palmprint, and define four fuzzy line element sets, $F_{0^0}, F_{45^0}, F_{90^0}, F_{135^0}$, in U [12]:

$$F_{0^0} = \{\mu_{0^0}(i,j)/(i,j)\}, \quad (4)$$

$$F_{45^0} = \{\mu_{45^0}(i,j)/(i,j)\}, \quad (5)$$

$$F_{90^0} = \{\mu_{90^0}(i,j)/(i,j)\}, \quad (6)$$

$$F_{135^0} = \{\mu_{135^0}(i,j)/(i,j)\}, \quad (7)$$

where (i,j) is the coordinate of an edge point and $\mu_{0^0}(i,j), \mu_{45^0}(i,j), \mu_{90^0}(i,j), \mu_{135^0}(i,j)$ are the membership functions of point (i,j) in $F_{0^0}, F_{45^0}, F_{90^0}, F_{135^0}$ respectively:

$$\mu_{0^0}(i,j)=\begin{cases}\cos(2 * Ang(i,j)), & \begin{matrix}0^0 \le Ang(i,j) < 45^0\\ 135^0 \le Ang(i,j) < 180^0\end{matrix},\\ 0, & 45^0 \le Ang(i,j) < 135^0\end{cases}$$

$$\mu_{45^\circ}(i,j)=\begin{cases}\sin(2*Ang(i,j)), & 0^\circ \le Ang(i,j) < 90^\circ \\ 0, & 90^\circ \le Ang(i,j) < 180^\circ\end{cases}, \tag{8}$$

$$\mu_{90^\circ}(i,j)=\begin{cases}0, & \begin{array}{l}0^\circ \le Ang(i,j) < 45^\circ \\ 135^\circ \le Ang(i,j) < 180^\circ\end{array} \\ -\cos(2*Ang(i,j)), & 45^\circ \le Ang(i,j) < 135^\circ\end{cases}, \tag{9}$$

$$\mu_{135^\circ}(i,j)=\begin{cases}0, & 0^\circ \le Ang(i,j) < 90^\circ \\ -\sin(2*Ang(i,j)), & 90^\circ \le Ang(i,j) < 180^\circ\end{cases}, \tag{10}$$

(11)

where $Ang(i,j)$ is the angle of the line element containing the point (i,j).

The membership functions have following properties:

(a) For each point, at least two of its membership grades are zeros. For example, let the angle at point (i,j) be α, $45^\circ \le \alpha < 90^\circ$, according to Eq. (8) and (11), $\mu_{0^\circ}=0$, $\mu_{135^\circ}=0$.

(b) When α varies from 45° to 90°, μ_{45° decreases from 1 to 0 while μ_{90° increases from 0 to 1 (Eq. (9), (10)).

3.3. Step 3: FDEEF Construction

Just as the process of forming the DEF, the edge image of a palm is divided into $M \times M$ blocks equally and labelled as $1,\cdots,M \times M$. For the block labelled p, its four *fuzzy directional element energies* (FDEEs) are defined as below:

$$E^p_{0^\circ}=\sum_{i=1}^{m}(Mag(x_i,y_i)\times\mu_{0^\circ}(x_i,y_i))^2, \tag{12}$$

$$E^p_{45^\circ}=\sum_{i=1}^{m}(Mag(x_i,y_i)\times\mu_{45^\circ}(x_i,y_i))^2, \tag{13}$$

$$E^p_{90^\circ}=\sum_{i=1}^{m}(Mag(x_i,y_i)\times\mu_{90^\circ}(x_i,y_i))^2, \tag{14}$$

$$E^p_{135^\circ}=\sum_{i=1}^{m}(Mag(x_i,y_i)\times\mu_{135^\circ}(x_i,y_i))^2, \tag{15}$$

where m is the total number of the points in this block and $(x_1,y_1),(x_2,y_2),\cdots,(x_m,y_m)$ are the coordinates of these points (Fig. 1 (e) – (g)).

Four FDEEs in this block can form a four-dimensional vector, i.e. $(E^p_{0^\circ},E^p_{45^\circ},E^p_{90^\circ},E^p_{135^\circ})$. So a $M \times M \times 4$-dimensional vector feature can be obtained from the whole image:

$$V=(E^1_{0^\circ},E^1_{45^\circ},E^1_{90^\circ},E^1_{135^\circ},\cdots,E^{M\times M}_{0^\circ},E^{M\times M}_{45^\circ},E^{M\times M}_{90^\circ},E^{M\times M}_{135^\circ}). \tag{16}$$

In order to remove the effect of the illumination variance, this vector should be normalized by the total energy:

$$\tilde{V}=(e^1_{0^\circ},e^1_{45^\circ},e^1_{90^\circ},e^1_{135^\circ},\cdots,e^{M\times M}_{0^\circ},e^{M\times M}_{45^\circ},e^{M\times M}_{90^\circ},e^{M\times M}_{135^\circ}), \tag{17}$$

$$e^k_A=E^k_A\times\frac{1000}{\sum_{i=1}^{M\times M}(E^i_{0^\circ}+E^i_{45^\circ}+E^i_{90^\circ}+E^i_{135^\circ})}, \tag{18}$$

where $k=1,\cdots,M\times M$, $A=0^\circ,45^\circ,90^\circ,135^\circ$.

This normalized vector $\tilde{V}$ is called *fuzzy directional element energy feature (FDEEF)*.

Obviously, FDEEF is a statistical feature. But it can reflect the lines' strength in different directions at different spatial position on palm, that is, FDEEF contains the line structural information of a palmprint.

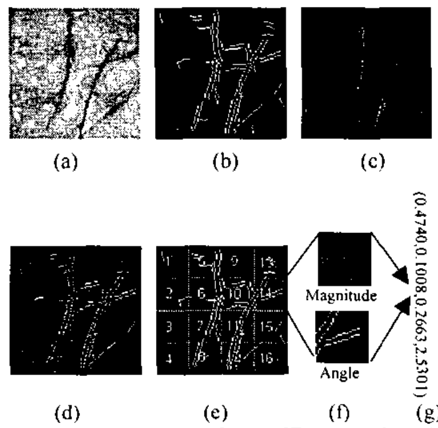

Figure 1. An example of FDEEF extraction. (a) The original palmprint image. (b) The binary edge image. (c) The edge magnitudes image. (d) The edge angle image. (e) Blocked edge image. (f) The magnitudes and angles of the edge points in block 14. (g) The four-dimensional vector formed from block 14.

4. Features derived from FDEEF

4.1. Global FDEEF (GFDEEF)

GFDEEF is a 4-dimensional vector denoted as $V_D=(e_{0^\circ},e_{45^\circ},e_{90^\circ},e_{135^\circ})$, which describes total normalized FDEEs of the whole palm:

$$e_{0^\circ}=\sum_{i=1}^{M\times M}e^i_{0^\circ},\quad e_{45^\circ}=\sum_{i=1}^{M\times M}e^i_{45^\circ},\quad e_{90^\circ}=\sum_{i=1}^{M\times M}e^i_{90^\circ},\quad e_{135^\circ}=\sum_{i=1}^{M\times M}e^i_{135^\circ}. \tag{19}$$

GFDEEF is a global feature reflecting the strength of lines in different directions in a whole palmprint image.

4.2. Block Edge Energy Feature (BEEF)

BEEF is a $M \times M$ -dimensional vector, denoted as $V_B = (e^1, e^2, \cdots, e^{M \times M})$, which represents the total energy of all lines in each block:

$$e^i = e^i_{0^\circ} + e^i_{45^\circ} + e^i_{90^\circ} + e^i_{135^\circ}, \quad i = 1, 2, \cdots, M \times M. \qquad (20)$$

5. Experimental Results

In these experiments, 450 palmprint images captured from 50 persons' right palm are used. Each palm is captured 9 times in which four are used to train template and the other five are used to test. The captured palmprints are 320×240 256-grayscale images and the central 128×128 sub-image is cut to compute FDEEF. The images are divided into 4×4 blocks, so the length of GFDEEF, BEEF and FDEEF are 4, 16 and 64, respectively. The variance of Canny algorithm is set to 1.0 and Euclidean distance is used in these experiments.

The templates are formed by averaging the vectors of the training samples. And the label of template nearest to the test vector is the identification result.

The identification rates of GFDEEF, BEEF and FDEEF are 16%, 91.2% and 97.2%, respectively. However, the computation complex increases with the extension of vector in matching stage. Therefore, in order to improve the performance of the system, these three features can be integrated to identify palms in hierarchy (Fig. 2). At the first level, GFDEEF is used to search in the all templates database and get a candidate set A. At the second level, BEEF is used to search in set A and get another candidate set B. And at the third level, FDEEF is used to search in set B and get the identification result. Table 1 lists the accumulated identification rates of different number candidates for each feature. When 32 and 11 candidates are selected at the first and the second level respectively, we can obtain a high identification rate which is same as the one gotten when the FDEEF is used alone, i.e. 97.2%, while the computing time is decrease dramatically.

6. Summary and Future Work

In this paper, we propose originally to modify the methods of handwritten Chinese character recognition for palmprint recognition. FDEEF, a statistical feature containing line structural information of palmprint, is a modification of DEF which is an efficient handwritten Chinese character recognition method. FDEEF can be extracted, represented and compared easily and has a strong ability to distinguish palms. Its rotation and translation robustness will be investigated in our future work.

Table 1. The identification rates of FDEEF, BEEF and GFDEEF with different number of candidates

Rate	1	5	9	11	20	32
GFDEEF	16%	36.8%	49.2%	54.4%	73.6%	100%
BEEF	91.2%	97.6%	99.6%	100%	-	-
FDEEF	97.2%	99.2%	100%	-	-	-

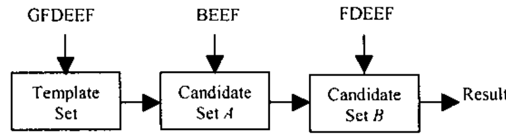

Figure 2. Palmprint Identification in hierarchy

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