Biometric Personal Identification Based on Iris Patterns+

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Abstract

A new system for personal identification based on iris patterns is presented in this paper. It is composed of iris image acquisition, image preprocessing, feature extraction and classifier design. The algorithm for iris feature extraction is based on texture analysis using multi-channel Gabor filtering and wavelet transform. Compared with existing methods, our method employs the rich 2-D information of the iris and is translation, rotation, and scale invariant.

1. Introduction

Traditional methods for personal identification are based on what a person possesses (a physical key, ID card, etc.) or what a person knows (a secret password, etc.). These methods have some problems. Keys may be lost, ID cards may be forged, and passwords may be forgotten. In recent years, biometric personal identification is receiving growing interests from both academia and industry [1]. There are two types of biometric features: physiological (e.g. iris, face, fingerprint) and behavioral (e.g. voice and handwriting).

Iris, as showed in Figure 1, is a kind of physiological biometric feature. It contains unique texture and is complex enough to be used as a biometric signature [2]. Compared with other biometric features such as face and fingerprint, iris patterns are more stable and reliable. It is unique to people and stable with age [3-4]. Furthermore, iris recognition systems can be non-invasive to their users [3-4].

A general iris recognition system is composed of four steps. Firstly, an image containing the user's eye is captured by the system. Then, the image is preprocessed to normalize the scale and illumination of the iris and localize the iris in the image. Thirdly, features representing the iris patterns are extracted. Finally, decision is made by means of matching. There are four key parts in the iris recognition system: iris image acquisition, preprocessing, feature extraction, and classifier design.

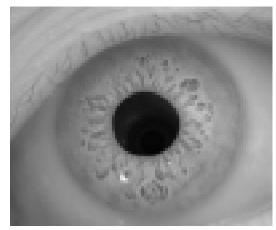

Figure 1. Iris image

In Section 2, we will introduce the iris acquisition device. Section 3 will discuss the preprocessing. Section 4 is about iris feature extraction. Section 5 will discuss the classifier. Experiments and results will be presented in Section 6. Conclusions will be drawn in Section 7.

2. Iris image acquisition

An important and difficult step of an iris recognition system is image acquisition. Since iris is small in size and dark in color (especially for Asian people), it is difficult to acquire good images for analysis using the standard CCD camera and ordinary lighting. We have designed our own device for iris image acquisition [5], which can deliver iris image of sufficiently high quality (e.g. Figure. 1).

3. Preprocessing

The acquired image always contains not only the 'useful' parts (iris) but also some 'irrelevant' parts (e.g. eyelid, pupil etc.). Under some conditions, the brightness is not uniformly distributed. In addition, different eye-to-camera distance may result in different image sizes of the same eye. For the purpose of analysis, the original image needs to be preprocessed. The preprocessing is composed of three steps.

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3.1. Iris localization

Both the inner boundary and the outer boundary of a typical iris can be taken as circles. But the two circles are usually not co-centric. Compared with the other part of the eye, the pupil is much darker. We detect the inner boundary between the pupil and the iris by means of thresholding. The outer boundary of the iris is more difficult to detect because of the low contrast between the two sides of the boundary. We detect the outer boundary by maximizing changes of the perimeter-normalized sum of gray level values along the circle. The technique is found to be efficient and effective (see Figure. 2b).

3.2. Iris normalization

The size of the pupil may change due to the variation of the illumination and the *hippus*, and the associated elastic deformations in the iris texture may interfere with the results of pattern matching. For the purpose of accurate texture analysis, it is necessary to compensate this deformation. Since both the inner and outer boundaries of the iris have been detected, it is easy to map the iris ring to a rectangular block of texture of a fixed size.

3.3. Image enhancement

The original iris image has low contrast and may have non-uniform illumination caused by the position of the light source. These may impair the result of the texture analysis. We enhance the iris image and reduce the effect of non-uniform illumination by means of local histogram equalization. Figure 2 shows the preprocessing result of the iris image.

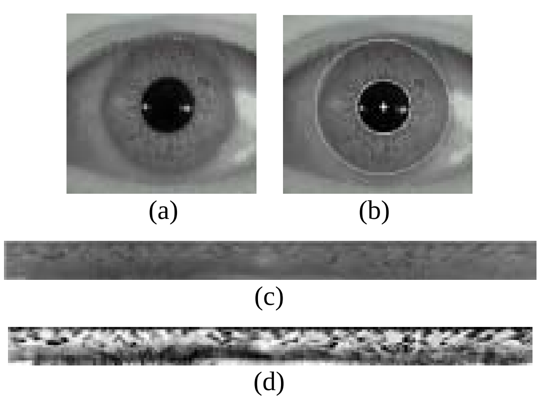

Figure 2. Image Preprocessing: (a) Original iris image (b) Image after iris localization (c) unwrapped texture image (d) texture image after enhancement.

4. Iris feature extraction

We implement two well-established texture analysis methods to extract features from the normalized block of texture image, namely the multi-channel Gabor filter and the wavelet transform.

4.1. Multi-channel Gabor filtering

The multi-channel Gabor filtering technique is inspired by the psychophysical findings that the processing of pictorial information in the human visual cortex involves a set of parallel and quasi-independent mechanisms or cortical channels which can be modeled by bandpass filters.

A simple computational model for the cortical channels is described in [6]. Briefly stated, each cortical channels is modeled by a pair of Gabor filters $h_e(x, y; f, \theta)$ and $h_o(x, y; f, \theta)$. The two Gabor filters are of opposite symmetry and are given by

$$\begin{aligned} h_e(x, y) &= g(x, y) \cdot \cos[2\pi f (x\cos\theta + y\sin\theta)] \\ h_o(x, y) &= g(x, y) \cdot \sin[2\pi f (x\cos\theta + y\sin\theta)] \end{aligned} \qquad (1)$$

where $g(x, y)$ is a 2-D Guassian function, f and θ are the central frequency and orientation which define the location of the channel in the frequency plane. Commonly used frequencies are of power 2. The central frequencies used in this paper are 2,4,8,16,32 and 64 cycles/degree.

For each central frequency f, filtering is performed at $\theta = 0^\circ, 45^\circ, 90^\circ$ and 135°. This leads to a lot of 24 output images (4 for each frequency), from which the iris features are extracted. These features are the mean and the standard deviation of each output image. Therefore, 48 features per input image are calculated. Testing was performed by using all 48 features or its various subsets.

4.2. 2-D wavelet transform

Wavelet transform is a good scale analysis tool and has been used for texture discrimination [7]. A 2-D wavelet transform can be treated as two separate 1-D wavelet transforms. After applying wavelet transform on an original image, a set of sub-images are obtained at different resolution levels. The mean and variance of each wavelet sub-image are extracted as texture features. We applied wavelet transform whose wavelet basis is DAUB4. The information at the finer resolution level is strongly affected by noise. In order to reduce this effect on the extracted features, only five low resolution levels, excluding the coarsest level, are used. For each resolution level, means and standard deviations are extracted as features. This makes the 26 extracted features robust in a noisy environment.

4.2. Comparison with existing methods

Several methods have been proposed for iris recognition. Daugman [3] presented a system for iris recognition and reported that it has excellent performance on a diverse database of many images. Wildes [4] described a system for personal verification based on automatic iris recognition. Boles *et al.* [8] proposed an algorithm for iris feature extraction using zero-crossing representation of 1-D wavelet transform.

Both systems of Daugman and Wildes employed carefully designed devices for image acquisition to ensure that the iris is located at the same location within the image, and the images have the same resolution and are glare free under fixed illuminations. However, these requirements are not always easy to be satisfied especially in practical applications. In our method, the irises are localized and unwrapped to form a block of texture. Features are extracted using multi-scale global texture analysis. This makes our method translation and rotation invariant as well as tolerant to illumination variations. Compared with zero-crossing representations of 1-D wavelet transform [8], which employed only the information along the circle, our methods use 2-D texture analysis because the iris patterns also exist along the radius.

5. Iris Identification

Iris recognition based on given feature vectors is a typical pattern recognition problem. In principle, we can use any type of classifiers here. Particularly, we use Weighted Euclidean Distance classifier to identify the iris.

Features of an unknown testing iris are compared with those of a set of known irises. It is identified as iris k *iff* the following Weighted Euclidean Distance is a minimum at k:

$$WED(k) = \sum_{i=1}^{N} \frac{(f_i - f_i^{(k)})^2}{(\delta_i^{(k)})^2} \qquad (2)$$

where f_i denotes the i th feature of the unknown iris, $f_i^{(k)}$ and δ_i^k denotes the i th feature and its standard deviation of iris k, N denotes the total number of features extracted from a single iris.

6. Experimental Results

A number of experiments using real iris images were carried out to show the effectiveness of the proposed algorithms. A total of 16 different iris classes (i.e. 16 different eyes) were tested. For each iris pattern, 10 images were acquired under different conditions. This makes up a total of 160 experimental iris samples. The original data was collected as grey-level images. Some of the original iris images are shown in Figure 3.

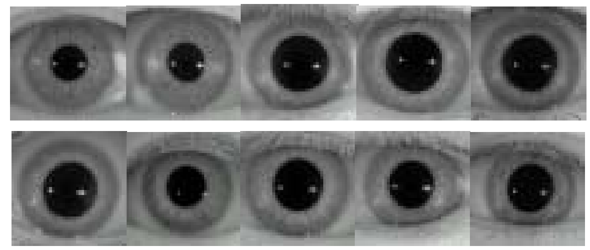

Figure 3. Example images of 10 different irises.

Each original image is preprocessed to form a block of texture. The size of the extracted block is 64×512 pixels. We organized the iris samples into two sets. Set A: for each iris pattern, the first 5 samples for training and the last 5 samples for testing. Set B: for each iris pattern, the last 5 samples for training and the first 5 samples for testing. Testing was conducted using different combinations of features. Identification results are summarized in Table 1.

Table 1. Identification accuracy of the Gabor filtering Technique and Wavelet Transform under WED

Features	Set A	Set B
All	93.8	92.5
Mean	90.0	90.6
Std	91.3	91.9
All at f=2,4,8,16,32	93.8	92.5
All at f=2	62.5	67.5
All at f=4	76.3	82.5
All at f=8	76.3	81.3
All at f=16	76.6	82.5
All at f=32	70.0	67.5
All at f=64	65.6	60.0
Wavelet Transform	73.1	82.5

In Table 1, features were extracted using the channels at f=2,4,8,16,32,64 and $\theta = 0^\circ, 45^\circ, 90^\circ$ and 135°. This led to a total of 24 Gabor channels and 48 features. A classification rate of 93.8% was obtained when either all the 48 features were used or features at f=2,4,8,16,32 were used. The wavelet transform obtained an accuracy of 82.5.1%.

To study the discrimination performance of our new algorithms, inter-class WEDs were calculated and the results are showed in Table 2. Each $[I_i, I_j]$ entry gives the WED between the trained feature vector of iris class I_j and means feature vector of testing samples belonging to iris class I_i. The entries of the table are normalized with respect to the maximum of the weighed Euclidean distance over all the iris classes. As a result, the WEDs between the testing and training features from the same iris class are much smaller than those obtained from different iris classes. This shows that the system is capable of correctly classifying and recognizing the different iris patterns. For easier comparison, Figure 4 shows the histogram of the WEDs between a certain testing iris sample from iris class No.7 and all the 16 iris classes.

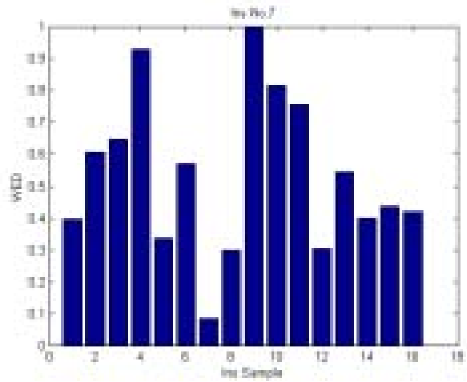

Figure 4. WEDs between a testing iris sample from iris class No.7 and all the 16 iris classes.

6. Conclusions

A system and algorithm for personal identification based on iris patterns have been proposed. The system is composed of iris image acquisition, image preprocessing, iris feature extraction and classifier design. The algorithm is translation, rotation, and scale invariant. The key point of our new algorithm for iris recognition is global texture analysis. It employs multi-channel Gabor filtering and the wavelet transform to extract global texture features. It uses only a few selected resolutions or scales for matching, thus making it computationally efficient and less sensitive to noise.

7. Acknowledgement

Parts of this work have been filed for Chinese Patents[5,9].

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Table 2 Iris discrimination performance of the multi-channel Gabor filter technique

Pattern / Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	5.1	29.3	37.0	43.2	12.0	27.3	28.3	10.7	100.0	72.5	40.0	14.9	41.0	24.4	54.3	48.0
2	33.0	3.1	17.4	16.9	38.1	28.2	50.1	43.4	100.0	58.5	31.1	43.6	37.6	36.8	65.2	48.5
3	34.0	19.3	4.0	23.1	35.0	34.0	42.9	43.3	100.0	54.7	26.0	44.2	46.2	39.8	59.2	44.8
4	13.0	20.6	26.0	5.9	24.0	35.9	40.8	34.0	100.0	52.4	21.8	47.7	29.9	29.9	76.9	61.0
5	20.3	55.8	69.6	76.4	12.4	32.4	32.9	17.3	100.0	88.2	62.5	22.2	41.3	28.2	52.1	51.7
6	28.2	41.9	55.5	61.4	16.3	4.8	45.9	31.9	100.0	79.7	64.1	31.1	35.5	25.4	59.9	50.6
7	39.7	60.7	64.8	92.8	33.7	57.2	8.6	29.8	100.0	81.4	75.7	30.5	54.7	39.8	43.7	42.0
8	20.3	28.1	28.8	39.7	16.1	27.6	29.4	11.6	100.0	61.9	44.6	31.9	40.4	32.6	62.9	48.0
9	100.0	71.5	62.3	78.0	88.4	88.8	59.5	76.8	5.3	18.5	71.7	77.5	58.2	55.9	23.9	20.4
10	97.0	71.8	58.9	100.0	82.2	97.3	38.7	71.3	52.3	14.4	91.0	75.6	71.1	61.6	29.5	19.2
11	25.4	27.8	41.4	27.1	31.4	41.7	56.6	64.7	100.0	64.0	4.7	52.7	28.1	25.6	71.2	65.9
12	17.9	39.5	44.2	54.6	23.9	45.0	28.7	14.7	100.0	73.4	51.4	6.8	43.9	28.0	48.5	49.2
13	37.8	42.1	58.3	31.2	43.0	45.0	63.4	71.5	100.0	57.4	32.3	70.0	8.8	21.8	86.3	61.3
14	62.0	58.7	75.1	86.8	55.1	52.3	44.0	67.6	100.0	69.9	83.2	58.1	30.5	17.2	74.8	46.4
15	74.8	62.5	62.7	100.0	62.3	72.0	32.8	46.3	43.6	52.8	78.3	38.2	62.8	53.0	9.0	21.6
16	69.3	68.2	65.5	100.0	55.2	61.8	32.5	40.6	38.9	45.6	85.4	37.6	55.4	44.5	18.9	9.5