A NOVEL PERSONAL BIOMETRIC AUTHENTICATION TECHNIQUE USING HUMAN IRIS BASED ON FRACTAL DIMENSION FEATURES

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ABSTRACT

This paper presents a novel approach mainly based on fractal dimension for recognizing the iris of a human eye. The proposed system consists mainly of four modules: iris image acquisition, iris image preprocessing, iris feature extraction, and iris pattern recognition. Two methods for extracting the iris features based on the fractal dimension are proposed. Recognition performances of 91.18% in accepting authentics and 100% in rejecting fakers are obtained.

1. INTRODUCTION

Biometrics [1], which refers to automatic identity authentication of a person on the basis of his or her unique physiological or behavioral characteristics, is inherently more reliable in and more capable of discriminating between an authorized person and an impostor than traditional methods. Under such circumstances, biometrics offers the most secure means to automatically identify individuals without requiring them to carry ID cards or memorize passwords. In principle as well as in practice, any human physiological and behavioral trait can be employed to develop a personal identification which should satisfy the following seven requirements: high universality, high uniqueness, high permanence, high collectability, high performance, high acceptability, and high circumvention.

A major concern in the development of biometric authentication techniques, however, is how to avoid rejecting valid users (authentics) or approving fakers (imposters). The human iris may provide a solution to personal authentication by offering a much more discriminating biometric feature than some other techniques such as fingerprint or face recognition. Therefore, to design a powerful and high security biometric authentication technique by applying the iris's advantages is a worthwhile research issue. In this paper, we investigate and design an automatic biometric recognition system using the human iris.

2. REVIEW

The iris, a kind of physiological biometric feature with genetic independence, contains an extremely information-rich physical structure and the most unique phenotypic texture pattern visible in a person's face, and thus is complex enough to be used as a biometric signature [1]. The human iris is an enormous complex meshwork of pectinate ligament tissue resulting in patterns of almost infinite variety.

In 1993 Dougman developed a successful system by using the 2-D Gabor wavelet transform [2]. The basic principle of Daugman's approach is that it converts an iris image into a representation invariant to differences in rotation and scale, filters the resulting image with oriented, quadrature pair bandpass filters, and coarsely quantizes the resulting representation for bitwise matching. In this system, the visible texture of a person's iris in a real-time video image is encoded into a compact sequence of multi-scale quadrature 2-D Gabor wavelet coefficients, whose most significant bits consist of a 256-byte "iris code." Daugman claimed that his system has an excellent performance on a diverse database of many iris images. In 1996, Wildes *et al.* developed a prototype system based on an automated iris recognition which uses a very computationally demanding image registration technique [3]. Recently, some approaches have also been conducted, which all are based on multiresolution wavelet analysis. Boles and Boashash [4] proposed an iris identification system in which zero-crossing of the wavelet transform at various resolution levels is calculated over concentric circles on the iris, and the resulting 1-D signals are compared with the model features using different dissimilarity functions. Zhu, Tan, and Wang [5] proposed an algorithm for global iris texture feature extraction using multi-channel Gabor filtering and wavelet transform. The mean and standard deviation of each sub-image at different resolution levels are extracted as the features. Their algorithm uses only a few selected resolutions for matching, thus making it computationally efficient and less sensitive to noise. The work in [6] also uses wavelet multi-resolution analysis based on Gabor filtering for iris feature extraction. In summary, all of the studies discussed previously are based upon the multi-scale analysis technique.

3. THE PROPOSED SYSTEM—AIRS

The human iris possesses very complex texture patterns. In order to use the iris patterns for authentication, it is essential to define a representation that is well adapted for extracting the iris information content from human eye images. In this paper, we propose two novel approaches for extracting unique iris features from iris images by using the fractal dimensions measure. The iris code representing the fractal dimension of the texture of an iris can then be used to recognize individuals.

The entire system diagram of the proposed system, namely Automatic Iris Recognition System (AIRS), is illustrated in Fig. 1. The AIRS system is composed of four main modules: *iris image acquisition (IIA)*, *iris image preprocessing (IIP)*, *iris feature extraction (IFE)*, and *iris pattern recognition (IPR)*. In the IIA module, an image containing the user's eye is captured and a proper red-component image with pure texture information is selected from the captured color image. Next, the IIP module uses segmentation, normalization, and enhancement on the captured iris image to produce a fine-tuned image for the subsequent feature extraction processing. Two examples of normalized iris images are shown in Fig. 2. Fig. 3 shows a series of the images after preprocessing. Then, the IFE module partitions the segmented iris zone into some adequately small blocks, and measures the fractal dimension values for all blocks to generate the corresponding iris feature code. Finally, in the IPR module two pattern matching techniques, including K-means and neural network, are employed on the iris feature code to recognize (or identify) the iris patterns.

4. IRIS FEATURE EXTRACTION (IFE)

Since every human iris to be identified possesses its unique complex texture features, in this module we propose two novel methods both based on fractal dimension measures to extract the features of an iris. The features extracted in method 1 are based on box-counting and correlation dimensions measured in the 2-D spatial domain, while method 2 is based on divider dimension measured in the 1-D wavelet domain. In each method, the iris zone segmented previously is partitioned into some small blocks in which the local fractal dimension features of all blocks are computed as the iris code.

A. Method 1

Two different measures of fractal dimension, including box-counting dimension and correlation dimension, are adopted in this method. Since typical fractal dimension estimate methods are square block-based, we must segment the entire iris zone into some small overlapping blocks in which each is fan-shaped. Overlapped block segmentation reduces the effect of rotation and zoom in/zoom out of the eye in the image acquisition step. An example of the iris block segmentation obtained by using method 1 is shown in Fig. 4. The number of blocks segmented is selected to be 64 in this method. In order to compute the fractal dimension feature values, the fan-shaped iris blocks must be transformed into square blocks by using the polar-rectangular transformation and the bilinear interpolation.

This unit computes the fractal dimension of each of 64 iris sub-image blocks as the iris feature. In this paper, five different estimate algorithms, including the differential box-counting (DBC) algorithm [7], shifting differential box-counting (SDBC) algorithm [7], scanning box-counting (SBC) algorithm [7], correlation dimension (CD) algorithm, and HCALC algorithm, are employed to compute the fractal dimension values. Since these algorithms have their own advantages, the five fractal dimension values expose the different textural characteristics of each iris block. The AIRS system computes five fractal dimension values, each with 8 bits, for each iris block, thus an iris code of $64 \times 5 = 320$ bytes (or $2,560$ bits) in total will be generated for each iris image. The iris code representing the fractal dimension features effectively demonstrates "size," "location," and "distribution" of roughness and feature patterns of texture residing in an iris.

B. Method 2

In method 2, divider dimension concept is adopted to measure each iris block in the 1-D wavelet domain. The flowchart of feature extraction is depicted in Fig. 5. The demarcation of the useful iris zone is the same as in method 1. The segmented zone of the iris is partitioned into four circular ring areas with equal width, as shown in Fig. 6. Then, the system divides each ring area equally into twelve small overlapped fan-shaped blocks, and thus each iris zone will be divided into 48 ($= 12 \times 4$) small iris blocks.

After demarcating and segmenting the iris zone, we convert each small 2-D iris block into a 1-D sequence signal. In the following step, the 1-D Haar wavelet transform is performed on the derived 1-D signal to generate a set of wavelet transform sub-patterns which are non-self-intersecting curves. By the above method, each 1-D signal, which passes through a two-scale relation for the Harr wavelet transform, will generate two waveform patterns in high-frequency and low-frequency bands, respectively, as shown in Fig. 5. Moreover, the information offered by the high-frequency band is strongly affected by high frequency noise. To avoid the interference of noise, the high-frequency band waveform is discarded. Then we compute divider dimensions fd_L corresponding to the low-frequency band waveform. The divider dimension, fd_L, which is the slope of the textural dimension region measured from the Richardson plot corresponding to the low-frequency band waveform, expresses the roughness of the 1-D signal (i.e., the texture information) of the iris block in the wavelet domain. Therefore, 48 features for each input iris image are extracted. We use 48 divider dimension values to construct a feature vector for the original 2-D iris pattern for the following pattern recognition. The value of each of these features is a real number ranging from 1.0000 to 2.0000. In this method, we allocate 14 bits to each feature. Totally, an iris code of 84 bytes (48×14 bits) is generated to represent an iris image.

5. EXPERIMENTAL RESULTS

A prototype of the proposed iris recognition technique, namely the Automatic Iris Recognition System (AIRS) has been designed and implemented. In order to evaluate the performance of the AIRS system, a number of real eye images were captured and tested. In this section, the verification performance results are presented. In the experiment, a total number of 120 iris images captured from the right eye of 40 volunteers were collected. Among them, 80 iris images were stored in the iris image database as the registered patterns and the remaining 40 iris images corresponding to the 40 volunteers, were used as the tested patterns. In addition to the use of ovelapped block segmentation, each image in the iris database was slightly shifted along the radial and tangent directions to generate nine different iris images. These operations make our system more robust on invariance of translation, rotation, and scale. Totally, the iris database contains 720 iris images.

A. Results of Method 1

Fig. 7 demonstrates the recognition results obtained by using the five FD estimate algorithms independently and the hybrid algorithm (i.e., the combination of the five FD estimate algorithms) for feature extraction and the K-means clustering method for recognition. The results show that with the hybrid algorithm the ERR is about 3% (see Fig. 7(f)). Therefore, the proposed AIRS system achieves a good performance. The results show that with the hybrid algorithm the AF (or FAR) is 0%, however, the RA (or FRR) is up to about 35%. We acknowledge that the neural network model we used here does not perform well, especially in accepting authentics. Therefore, our system is suitable for high security applications due to very low FAR, but not good for forensic applications due to high FRR.

B. Results of Method 2

Fig. 8 shows the plot of the variation of two error rates according to the degree of match by selecting a proper distance value as a threshold. By selecting the distance threshold of 0.67, we can obtain the ERR = 5%. A recognition performance of AF (or FAR) = 3.67% and RA (or FRR) = 8.82% are obtained. Compared with method 1, the performance of RA is significantly improved as the feature in wavelet domain is extracted, though AF becomes worse slightly. However, it is worth noting that an iris code size of only 84 bytes is used in method 2 instead of 320 bytes used in method 1. Accordingly, we conclude that extracting the feature in the wavelet domain is superior to extracting it in the original image domain.

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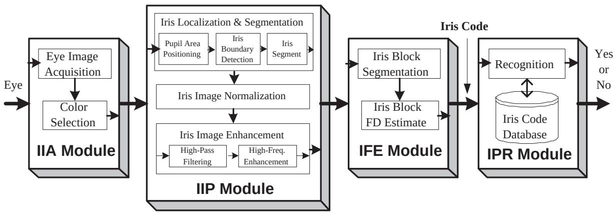

Figure 1: System diagram of the AIRS system.

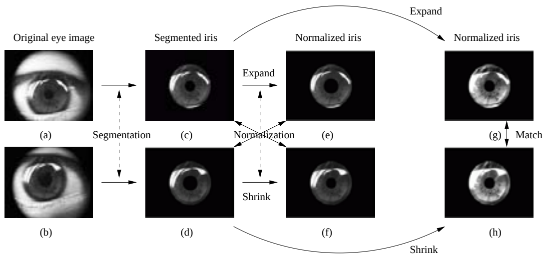

Figure 2: Two examples of normalized iris images. (a) and (b) are two different images of the same person captured in different time.

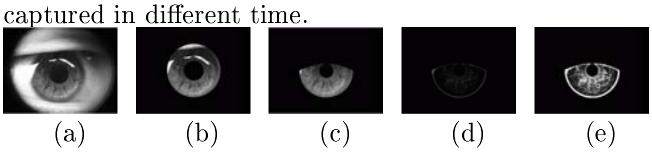

Figure 3: Images after preprocessing.

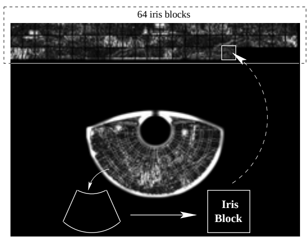

Figure 4: Iris block segmentation used in method 1.

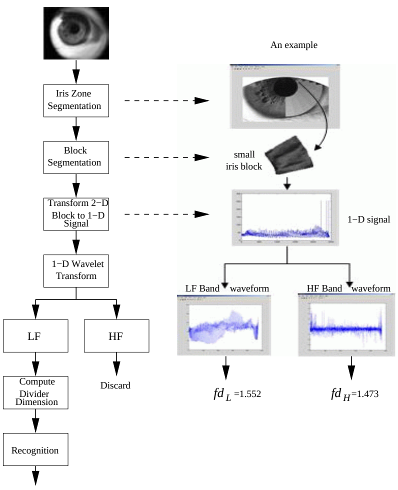

Figure 5: Flowchart of method 2.

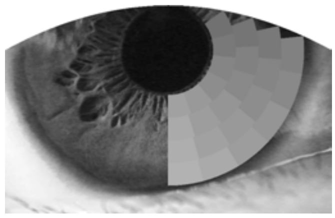

Figure 6: Iris block segmentation used in method 2.

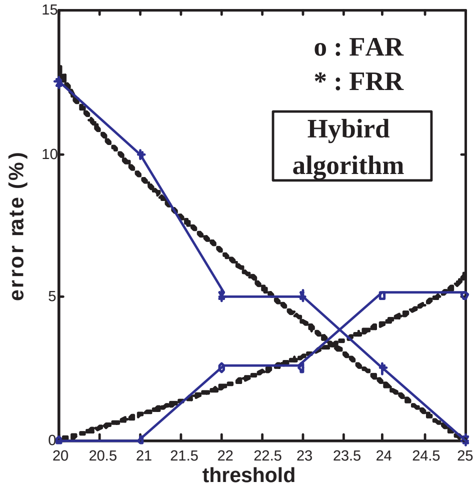

Figure 7: Recognition rates obtained by using Hybrid algorithms. (Method 1)

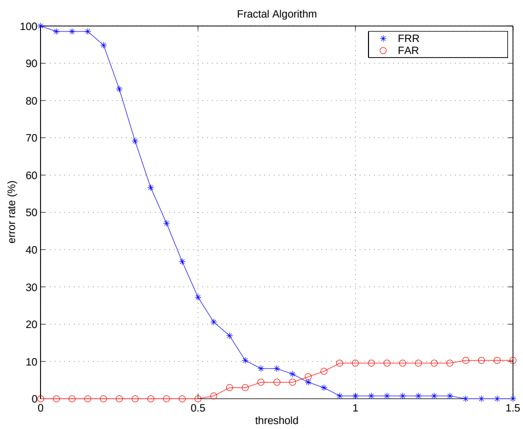

Figure 8: Plot of the variation of two error rates according to the degree of match. (Method 2)