A fast Iris recognition system through optimum feature extraction

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With an increasing demand for stringent security systems, automated identification of individuals based on biometric methods has been a major focus of research and development over the last decade. Biometric recognition analyses unique physiological traits or behavioral characteristics, such as an iris, face, retina, voice, fingerprint, hand geometry, keystrokes or gait. The iris has a complex and unique structure that remains stable over a person's lifetime, features that have led to its increasing interest in its use for biometric recognition.

In this study, we proposed a technique incorporating Principal Component Analysis (PCA) based on Discrete Wavelet Transformation (DWT) for the extraction of the optimum features of an iris and reducing the runtime needed for iris templates classification. The idea of using DWT behind PCA is to reduce the resolution of the iris template. DWT converts an iris image into four frequency sub-bands. One frequency sub-band instead of four has been used for further feature extraction by using PCA. Our experimental evaluation demonstrates the efficient performance of the proposed technique.

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A Fast Iris Recognition System through Optimum Feature Extraction

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ABSTRACT

With an increasing demand for stringent security systems, automated identification of individuals based on biometric methods has been a major focus of research and development over the last decade. Biometric recognition analyses unique physiological traits or behavioral characteristics, such as an iris, face, retina, voice, fingerprint, hand geometry, keystrokes or gait. The iris has a complex and unique structure that remains stable over a person's lifetime, features that have led to its increasing interest in its use for biometric recognition.
In this study, we proposed a technique incorporating Principal Component Analysis (PCA) based on Discrete Wavelet Transformation (DWT) for the extraction of the optimum features of an iris and reducing the runtime needed for iris templates classification. The idea of using DWT behind PCA is to reduce the resolution of the iris template. DWT converts an iris image into four frequency sub-bands. One frequency sub-band instead of four has been used for further feature extraction by using PCA. Our experimental evaluation demonstrates the efficient performance of the proposed technique.

INTRODUCTION

Biometric recognition refers to the study of identifying persons based on their unique physical traits or behavioral characteristics (12). Physical characteristics commonly include an iris, face, fingerprint, retina, vein, voice or hand geometry, while behavioral characteristics may include handwriting, walking gait, signature, and typing keystrokes. To be useful a biometric requires features that can be accurately analysed to provide unique, and stable information about a person that can be used reliably in authentication applications and many advances have been made in this area (9). The iris has easily accessible and unique features that are stable over the lifetime of an individual. For this reason, iris recognition technology has been widely studied in the field of information security. Iris recognition systems can already be applied to identify individuals in controlled access and security zones, and could feasibly be used for verification of passengers at immigration, airports, stations, computer access at research organization, database access control in distributed systems etc. (4). Iris recognition systems can also be applied in the field of financial services such as banking services and credit card use, and such as system would not have the same vulnerabilities as passwords and numbers. Iris recognition systems are being trialled in many countries for national ID cards, immigration, national border control, airline crews, airport staffs, and missing children identification etc. (4). While there are still some concerns about using iris-based recognition in mass consumer applications due to iris data capturing issues, it is widely believed that, in

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time, the technology is likely to find its way into common use (8).

An iris is a round contractile membrane of the eye, between sclera and pupil. It begins to form during embryo gestation, being fully formed at around eight months. The uniqueness of the iris patterns comes from the richness of the texture details arising from the crypts, radial furrows, filaments, pigment frills, flecks, stripes and arching ligaments. These give rise to complex and irregular textures that are so randomly distributed as to make the human iris one of the most reliable biometric characteristics. The iris is bounded by the pupil at the inner boundary and the sclera at its outer boundary. These inner and outer boundaries are circular in shape and easily accessible but can be partially blocked by the upper and lower eyelids and eyelashes (4). Fig. 1 shows a view of a typical human Iris.

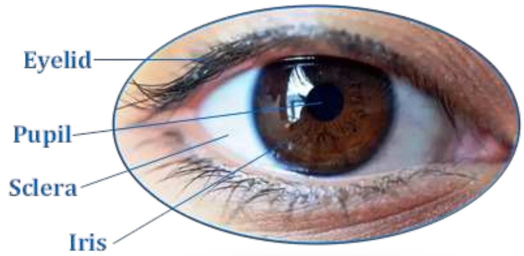

Figure 1. The Outer Look of Human Iris.

In this paper, feature extraction techniques are the main focus. Indeed, the selection of optimal feature subsets has become a crucial issue in the field of iris recognition. To improve feature extraction, we propose that an approach combining Principal Component Analysis (PCA) and Discrete Wavelet Transformation (DWT) will extract the key features of an iris and thereby reduce image resolution and in turn the runtime of the classification or analysis that is required for the resulting iris templates.

METHODOLOGY

Iris recognition processing generally consists of the following steps: (i) Image acquisition (ii) Iris segmentation (iii) Normalization (iv) Feature extraction and (v) Classification. In our approach presented here, segmentation was achieved using the Hough transform for localizing the iris and pupil regions. The segmented iris region was normalized to a rectangular block with fixed polar dimensions using Daugman's rubber sheet model. A combined PCA and DWT were applied on a fixed size normalized iris for feature extraction. The Euclidean distance was used for classification the similarity between the iris templates. Fig. 2 shows the system processes that we used for iris recognition.

Image Acquisition

The first step in iris recognition is image acquisition, i.e., the capture of a sequence of high-quality iris images from the subject. These images should clearly show the entire eye, but particularly the iris and pupil. Preprocessing operations may be applied to the captured images in order to enhance their quality and provide sufficient resolution and sharpness (3). In this work, the CASIA-Iris V4 database has been used instead of actual captured eye images (11). CASIA-IrisV4 is an extension of CASIA-IrisV3, and contains six subsets that including three subsets (from CASIA-IrisV3), namely CASIA-Iris-Interval, CASIA-Iris-Lamp, and CASIA-Iris-Twins. The three new subsets added to CASIA-IrisV4 are CASIA-Iris-Thousand, CASIA-Iris-Syn and CASIA-Iris-Distance respectively. CASIA-IrisV4 contains a total 54,601 iris images. This includes samples from more than 1,800 genuine subjects and 1,000 virtual subjects. All iris images are 8 bit grey-level and the file format is JPEG. CASIA-IrisV4 iris images are collected under near infrared illumination or synthesized. The six datasets were collected or synthesized at different times and CASIA-Iris-Interval, CASIA-Iris-Lamp, CASIA-Iris-Distance; CASIA-Iris-Thousand may have a small inter-subset overlap in subjects (11).

Iris Segmentation

Iris segmentation was used to isolate the actual iris region from a digital eye image. The iris region, (Fig. 1) can be bounded by two circles pertaining to the pupil (inner boundary) and sclera (outer boundary). Hough Transformation was employed to locate the circular iris region.

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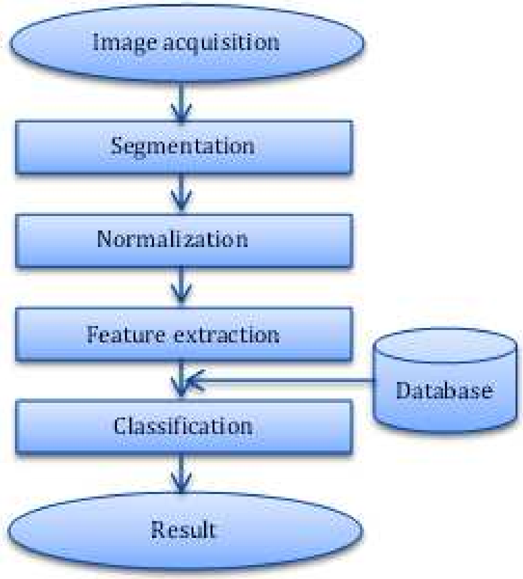

Figure 2. Diagram of Iris Recognition System.

Hough Transformation

The Hough transformation is a procedure generally used to compute the parameters of the geometric objects such as lines and circles in an image. For detecting the center coordinates and radius of the iris and pupil regions, the circular Hough transform can be used. This technique generally uses a voting procedure to find shapes of the objects within the classes available. The Hough segmentation algorithm firstly creates an edge map by computing the gradients or first derivatives of intensity values in an eye image. For each edge pixel in the edge map, the surrounding points on the circle at different radii are taken, and votes are cast for finding the maximum values that constitute the parameters of circles in the Hough space (13). The center coordinates and the radius can be found using the following equation:

$$x_c^2 + y_c^2 - r^2 = 0 \tag{1}$$

In the Hough space, the maximum point corresponds to the center coordinates (x_c, y_c) and the radius 'r' of the circle is given by the edge points.

When performing the edge detection, we have considered derivatives/gradients in the vertical direction to detect the iris-sclera boundary to decrease the effect of the eyelids which are horizontally aligned (13). The vertical gradients are taken for locating the iris boundary and to reduce the influence of the eyelids. When performing circular Hough transform, all of the edge pixels that define the circle are not required for successful localization. Not only does this make circle localization more accurate, but it also makes it more efficient, since there are fewer edge points to cast votes in the Hough space (13).

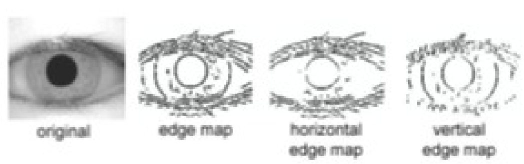

Figure 3. Segmentation Using Hough Transformation.

Normalization

Once the circular iris region is successfully segmented from an eye image, normalization is applied on it to transform the segmented circular iris region into a fixed size rectangular shape. The normalization process produces an iris region that has fixed dimensions so that two photographs of the same iris taken

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under the different capturing environment will have the same characteristic features (14). In this work, Daugman's rubber-sheet model has been used to normalize iris image.

Daugman's rubber-sheet model

Daugman's rubber-sheet model is the most widely used method for iris normalization (2) which converts the circular iris region into a fixed sized rectangular block. Using equation 2, the model transforms every pixel in the circular iris into an equivalent position on the polar axes (r, θ) where r is the radial distance and θ is the rotated angle at the corresponding radius. The radial resolution describes the number of radial lines generated around the iris region while the angular resolution is the number of data points in the radial direction.

$$I[x(r,\theta), y(r,\theta)] \rightarrow I(r,\theta) \tag{2}$$

The iris region is converted to a two-dimensional array. Horizontal dimension represents the angular resolution, and the vertical dimension represents radial resolution, as shown in Fig. 4.

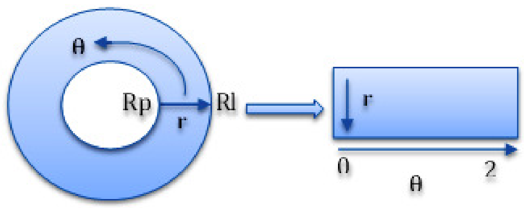

Figure 4. Daugman's Rubber-sheet Model.

Where $I(x,y)$ corresponds to the iris region, (x,y) and (r,θ) are the Cartesian and normalized polar coordinates, respectively. Ranges of θ from 0 to 2π and r from Rp to Rl. $x(r,\theta)$ and $y(r,\theta)$ are defined as linear combinations of pupil boundary points (2).

Feature Extraction

Feature extraction is the most important and critical part of the iris recognition system. Feature extraction is a process of reducing the amount of data required to describe a large set of information present in an iris pattern. The successful recognition rate and reduction of classification time of two iris templates mostly depend on efficient feature extraction technique.

Proposed Technique for Feature Extraction

In this section, the proposed technique produces an iris template with reduced resolution and runtime for classifying the iris templates. To produce the template, firstly DWT has been applied to the normalized iris image. DWT transforms normalized iris image into four-frequency sub-bands, namely LL, LH, HL and HH, as shown in Fig. 5. The frequency range can be represented as LL $<$ LH $<$ HL $<$ HH (6; Yu-Hsiang). The LL sub-band represents the feature or characteristics of the iris (1; 7), so that this sub-band can be considered for further processing (1; 16). Fig. 6 shows that the resolution of the original normalized iris image is (60×300). After applying DWT on normalized iris image the resolution of LL sub-band is (30×150). LL sub-band represents the lower resolution approximation iris with required feature or characteristics, as this sub-band has been used instead of the original normalized iris data for further feature extraction using PCA. As the resolution of the iris template has been reduced, so the runtime of the classification will be similarly reduced.

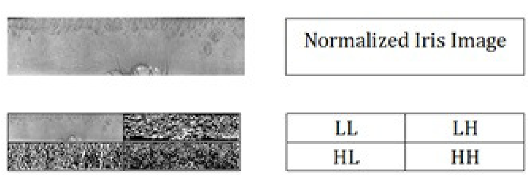

Figure 5. Iris Template Using One Level DWT.

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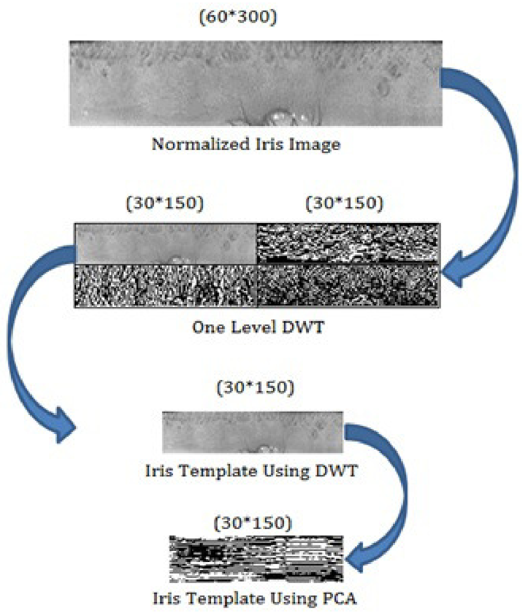

Figure 6. Iris Template Using PCA based on the DWT.

PCA has found the most discriminating information presented in LL sub-band to form feature matrix shown in fig. 6, and the resultant feature matrix has been passed into the classifier for recognition.

The mathematical analysis of PCA includes:

1. The mean of each vector is given in the equation:

$$x_m = \frac{1}{N}\sum_{k=1}^{N} xk \tag{3}$$

2. The mean is subtracted from all of the vectors to produce a set of zero mean vectors is given in the equation:

$$x_z = x_i - x_m \tag{4}$$

where x_z is the zero mean vectors, x_i is each element of the column vector, x_m is the mean of each column vector.

3. The Covariance matrix is computed using the equation:

$$c = [x_z T * x_z] \tag{5}$$

4. The Eigenvectors and Eigenvalues are computed using the equation:

$$[c - \gamma i]e = 0 \tag{6}$$

where γ's are the Eigenvalue and e's are the Eigenvectors.

5. Each of an Eigenvectors is multiplied with zero mean vectors x_z to form the feature vector. The feature vector is given by the equation:

$$f_i = [x_z]e \tag{7}$$

Classification

Classification is a process of measuring the similarity between two iris templates that have been generated in the feature extraction stage. This process gives a range of values during comparison of same iris templates and another range of values during the comparison of different iris templates generated from a different person's eye. This training can ultimately enable us to determine whether the two iris templates belong to the same or different persons.

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Table 1. Algorithm of Iris Recognition System.

Input: Eye image Output: Recognition of a person a) Read the eye image. b) Iris segmentation using Hough Transformation. c) Iris normalization using Daugman's model. d) The DWT is applied, and the approximation band is considered. e) PCA is applied on approximation band to form a feature vector. f) Form the signature vector of each image. g) Match/Non-match decision is obtained using Euclidean Distance Classifier. h) Classification time is measured by using a clock function.

Table 2. Results and Comparison with other Techniques.

Sl.	Methods	Avg. Runtime of 30 iris templates in Second
1.	PCA based feature extraction	2.0485
2.	Gabor filter based feature extraction	2.4777
3.	Gabor filter + PCA based feature extraction	2.3837
4.	Proposed Feature extraction technique	1.7985

K-Nearest Neighbor Classifier

K-Nearest Neighbor is a simple type of classifier, classifying objects based on the Euclidean distance in the feature space of training data. This classifier can be used to compare two templates, especially if the template is composed of integer values. An object is classified based on the majority number of its neighbors and is assigned to the class that is most common among its k-Nearest neighbors. If 1-nearest neighbor is considered, then the object is assigned to the class of its first nearest neighbor; generally larger values of k are considered to reduce the effect of noise on the classification. We considered Euclidean distance for finding the distances between the test metrics and all of the training metrics. The difference d, between the enrolled iris template s and matching iris template k, is given as (5):

$$d = \sqrt{\sum_{i=0}^{i=m} (s(i) - k(i))^2} \tag{8}$$

ALGORITHM

Problem Definition: The iris is a biometric characteristic that can be used to authenticate persons. This algorithm finds whether a person is authenticated or not using iris.

The objectives are: This algorithm recognizes a person using iris segmentation, normalization, DWT, PCA and Euclidean Distance Classifier is given in Table 1.

EXPERIMENTAL RESULTS AND DISCUSSION

In this section, the proposed technique has been evaluated in the CASIA iris database, and the results have been reported in table 2. 30 iris images of 30 individuals were enrolled in our system database for assessing the performance and Intel Core-i5 3.30GH processor, 4GB RAM, Windows-7 operating system and MATLAB2017a tools used as an experimental platform. DWT behind PCA has been used to reduce the resolution of the iris template as well as runtime of classification. 92.6% accuracy of the proposed feature extraction technique has been found by Rana HK et al. (10). We have mainly evaluated the runtime of classification of several feature extraction techniques, and have found runtime of our proposed technique is better than others compared to others available. The experimental results are shown in Table 2.

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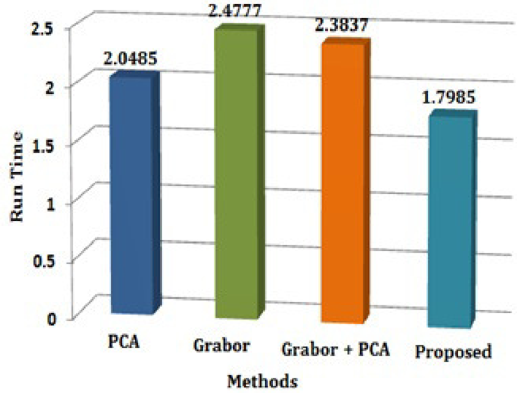

Figure 7. Comparison of Runtime of Several Feature Extraction Techniques.

CONCLUSION

In this paper, we proposed a technique that used Principal Component Analysis (PCA) based on Discrete Wavelet Transformation (DWT) for extracting the optimum features of iris images and reducing the runtime of classification of these iris templates. The point of using DWT behind PCA is to reduce the iris template resolution. DWT converts the iris image into four frequency bands, and One frequency band instead of four has been used for further feature extraction by using PCA. As the resolution of iris template has been reduced by DWT, so the runtime of classification will be reduced. Experimental evaluation using the CASIA iris image database (ver. 4) clearly demonstrated the proposed technique performs in a very efficient manner.

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