PCA based Iris Recognition using DWT

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Abstract—The Iris pattern is an important biological feature of human body. The recognition of an individual based on iris pattern is gaining more popularity due to the uniqueness of the pattern among the people. In this paper PCA based iris recognition using DWT (PIRDWT) is proposed. The upper and lower portion of the iris which is occluded by the eyelids and eyelashes is removed using morphological process. According to Springer Analysis of CASIA data base, to get better recognition forty five pixels to left and right of the pupil boundary is considered as iris template for the proposed algorithm analysis. The image is enhanced using Histogram Equalization to get high contrast. DWT is applied on histogram equalised iris template to get DWT coefficients. The features are extracted from the approximation band of the DWT coefficients using PCA. Multiple classifiers such as KNN, RF and SVM are used for matching. The proposed algorithm has better performance parameters compared to existing algorithm.

Keywords— Iris, Dilation, Erosion, Biometrics, DWT, PCA, KNN, RF, SVM;

1. Introduction

Identification and authentication of any individual is becoming more important in recent days. In the modern world where computers and electronics devices are more extensively used and the population of the world is increasing, there is a need for highly accurate and secured practical authentication technology. Traditional techniques such as user name, passwords, keys, ID cards, hardware token based systems are not reliable and secure in many of the security zones. Thus there is an increasing need for automatic reliable authentication process in modern society. In the recent few years biometric identification has proven to be more reliable means of verifying the human identity. Biometric refers to a science of analyzing human physiological or behavioral characteristics for security purposes and the word is derived from the Greek words \textit{bios} means \textit{life} and \textit{metrikos} means \textit{measure}. The Biometric \cite{1} characteristics cannot be faked, forged, guessed and stolen easily. One need not remember his/her biometric traits.

Biometric identification techniques use inherent physical or behavioral characteristics which are unique among all individuals. The behavioral biometrics are signature, voice, keystroke, gait tec., and physiological biometrics are fingerprint, face, palm print, iris, retina, ear, DNA etc. Among the physiological biometrics, iris is an important feature of the human body and it has the characters of uniqueness and stability. Iris recognition technology is now a days more advantageous in the field of information security and verification of individuals in the areas such as controlling access to security zones, verification of passengers at airports, stations, computer access at defence establishments, research organization, data base access control in distributed systems etc. Iris recognition systems are currently being deployed in many countries for airline crews, airport staffs, national ID cards, and missing children identification etc.

Iris is the round contractile membrane of the eye suspended between cornea and lens which is perforated by the pupil. Iris begins to form during gestation and by the eighth month of the pregnancy it gets completely formed. The uniqueness of the iris pattern comes from the richness of the texture details in the iris image such as cornea, crypts, filaments, flecks, radial furrows, stripes, arching ligaments etc. These irregularly shaped microstructures are so randomly distributed patterns which make the human iris as one of the most important biometric characteristics. Iris is encircled by two concentric circles. The inner boundary is the junction of the iris and the pupil which is identified by the gray scale change and the border where as the outer boundary is the junction between iris and sclera which is characterized by smooth gray scale change and the little vogue border. The inner and outer boundaries are like circles but they are not concentric and blocked by the upper and lower eyelids and eyelashes.

There are many iris recognition systems and the first automatic system was developed by Daugman \cite{2} using efficient integrodifferential operator, which is still popular in today’s most of the iris recognition systems. In the zero crossings representation method \cite{3} the image is decomposed using wavelet transform and the required features are extracted from the image. Using Gabor filter the coefficients are converted to binary code for matching. Key local variation method \cite{4} proposed by L ma is another technique of iris recognition. The position of the local variations of the normalized image reduced to one dimensional feature vector of 660. This feature vector is
converted to binary code in the matching phase and comparison is computed using Exclusive OR.

Motivation: Traditional methods of identifying a person are PIN, password etc. However these methods can be stolen or faked, but biometric parameters are more secure and reliable in personal identification. Several biometric traits have been used till date for authentication. However most biometric parameters have several drawbacks thus iris is chosen as the best amongst all. Iris pattern has unique, i.e., stable throughout one’s life time and are not similar even for twins.

Organization: The paper is organized into following sections. Section 2 is an overview of related work. The proposed model is described in section 3. Section 4 discusses the algorithm of iris recognition based on DWT and PCA. Performance analysis is discussed in section 5 and Conclusion is given in section 6.

Contribution: In this paper, PIRDWT is proposed. The dilation and erosion operations are used to generate iris template. The DWT and PCA are applied on iris template to derive iris features, and different classifiers are used for matching.

2. Related Work

Benke Xiang and Xiaoping Cheng [5] proposed an improved AD Adaboost algorithm for eye detection in an image. The AD Adaboost is an integration of multiple classifier and all of them work together to train samples. The identification mark was used with suitable positive weight and negative weights. Depending upon the weights the AD Adaboost algorithm produce the results with a spread of degradation Nitin Bhatia and Megha Chhabra [6] proposed the algorithm of improved Hough transform for fast recognition of iris. The iris image of size $A = M \times N$ was divided into 9 equal parts of size M/3 X N/3. The middle part was used to get the centre and the features of the iris. The method was to limit the image space to the valid promising region and applying the transforms like circle Hough transform to detect the iris circles. Hugo Proença [7] proposed the segmentation method for iris recognition from degraded images acquired in the visible wave length. The degraded images provide poor segmentation. In the algorithm the sclera was detected and extracted. The mandatory adjacency between the iris and sclera was calculated for the localization of iris. The constrained polynomial fitting procedure was adopted to get the pupillary and scleric iris border. Liu Yang et al., [8] proposed the iris recognition system based on chaos encryption. After the preprocessing the features of iris were extracted using the multiscale 2D Gabor filter to generate the iris code. The iris code was encrypted using one way coupled map lattice to store into the data base for future protection of data and to reduce the size of the data base.

P Radu et al., [9] proposed the method of combining information from both eyes for iris recognition. The CASIA data base containing the iris images with the motion blur was used for recognition. After the preprocessing, 2D Gabor wavelet was employed for feature extraction. The features from both left and right iris was combined to generate the feature vector for the images distorted by motion blur. Qichuan Tian et al., [10] introduced the zero crossing detection method for iris recognition. The captured iris image was subjected to boundary localization to locate the boundary of iris/pupil and iris/sclera. Then the eye lashes occlusions were detected and eliminated using the segmentation techniques. The circular iris was then unrolled into a horizontal strip for feature extraction. The Zero Crossing detection was performed over the iris to extract sharp local variations as feature vector. The matching was performed using Exclusive OR operation. Mahdi S Hosseini et al., [11] presented the algorithm of extracting the pigment melanin for iris recognition. The iris image acquired in Visible Light (VL) session will be affected by reflections from cornea thus the pattern of melanin pigments and shapes were extracted to get more features. The Near Infrared (NIR) images were also used for feature extraction using the variable technique on image histogram. The features from VL and NIR images were fused to generate the final feature vector.

Chung-Chih Tsai N et al., [12] presented a matching strategy based on possibilistic fuzzy clustering algorithm for iris recognition system. The gradient iris image around the iris boundaries was generated in the radial direction. The Fuzzy gray scale curve tracing method was applied to extract the smooth curve of the inner and outer boundaries. A bank of Gabor filters were used to detect the local feature points to generate the feature vector. The matching was performed using Fuzzy Clustering method. Nathan D Kalka et al.,[13] presented the Dempster-Shafer (DS) algorithm to estimate and fuse quality factors for different iris images. A procedure was presented for estimation of defocus blur, occlusion, lighting, motion blur, specular reflection, off-angle, pixel counts and their features were applied on the images of the data sets CASIA 3.0, WVU and ICE 1.0. Then the features were combined using DS fusion algorithm to assess the unified quality score as a measure of the overall suitability for authenticating the individual. Eri Prasentyo Wibowo and Wisnu Sukma Moulan [14] proposed the real time iris recognition system using fusion of multiple techniques. The dilation and erosion techniques were applied on iris images. The value between dilation and erosion was calculated. Iris localization was done using the skeleton algorithm and pupil edge boundary detection algorithm. Cutting and canny edge detectors were used for feature extraction. Matching was performed using Hamming and Euclidean distance algorithms. Poulami Das et al., [15]...
presented the statistical approach for iris recognition and personal identification. After the preprocessing operations, the pupil area the boundary was located using the edge detection operator. The iris location and boundary detection was performed and then 12 X 8 rectangular area of iris effective region was extracted. The statistical correlation coefficients were calculated using statistical estimation theory for matching and recognition. Kazuyuki Miyazawa et al., [16] proposed an iris recognition system using phase based image matching. In preprocessing iris localization and normalization was performed. The matching was carried using matching techniques of phase only correlation function and band limited phase only correlation function. Popescu – Bodarin and Bolas [17] introduced the family of iris encoders for matching. The circular fuzzy iris segmentation procedure was adopted to get limbic boundary. The features were extracted using Haar-Hilbert based iris encoders. Single level 2 D Discrete Haar Wavelet Transform was used for noise attenuation and Hilbert transform was used to encode. The phase Log–Gabor encoder was employed for feature extraction. Jinyu Zuo and Natalia A Schmid [18] proposed methodology for robust segmentation of non ideal iris images. In preprocessing a sparse PDE based inpainting procedure was applied to refine localized specular reflections. To eliminate the noise 2D adaptive Wiener filter was adopted. An Ellipse based model was used to contour the estimated boundaries for pupil and iris regions. To detect the iris boundary even under uneven illumination, contrast balancing technique was used. The estimation of occlusion was performed by applying adaptive illumination compensation technique and Sobel operator. The segmentation procedure was applied on CASIA3.0, INT, ICE, WVU and WVU-OA data bases.

Mohammed Abdullah et al., [24] presented an algorithm of non ideal iris images. In preprocessing a sparse PDE based inpainting procedure was applied to refine localized specular reflections. To eliminate the noise 2D adaptive Wiener filter was adopted. An Ellipse based model was used to contour the estimated boundaries for pupil and iris regions. To detect the iris boundary even under uneven illumination, contrast balancing technique was used. The estimation of occlusion was performed by applying adaptive illumination compensation technique and Sobel operator. The segmentation procedure was applied on CASIA3.0, INT, ICE, WVU and WVU-OA data bases.

F M Wheeler et al., [19] proposed the stand off iris technique for recognition system. A dual iris approach was described for feature extraction. Hamming distance was used for matching. The user was declared as identified if one of the two irises was recognized. Zhonghua Lin and Bibo Lu [20] suggested the iris recognition method based on the imaginary coefficients of Morlet Wavelet Transform. The one dimensional series of imaginary coefficients at different scales were generated. The distribution map of imaginary coefficients of wavelet transform at different scales was formed. The binary code of the iris image according to the coefficients was created. The matching and classification was performed using the pattern matching method. Dhananjay [21] presented the algorithm using Principal Component Analysis for iris detection. In preprocessing step the iris was localized and centered. The principal component analysis was used to extract the features and computing Eigen irises. The matching was performed using Euclidean distance. Jing Huang et al., [22] proposed iris recognition based on non separable wavelet. Iris image was decomposed into wavelet sub band coefficients using sixteen non separable wavelet filters. The Generalized Gaussian Density (GGD) modeling of each non separable orthogonal wavelet coefficient was treated as means for feature extraction. The Kullback Leiblar distance between GGDs was computed for matching. Zian Osman [23] proposed iris recognition using phase congruency. Before applying phase congruency, the iris was segmented in the image of the eye, then normalized using Hough transform and Daugman’s rubber sheet model. The wavelet transform was applied to obtain the frequency information local to a point. The phase congruency algorithm was applied to normalized iris image at eight different orientations and feature vector matrix was formed. Matching was performed using Euclidean distance.

3. Proposed Model

The definitions and block diagram of PIRDWT are discussed in this section.

3.1. Definitions

3.1.1. False Acceptance Rate (FAR): The probability that a biometric system will incorrectly identify an individual or will fail to reject an imposter using Match Count (MC) and is designed as ratio of Match Count (MC) to the total impostor persons (IP) as given in the Equation 1.

\[
FAR\% = \frac{MC}{IP} \times 100
\]  

(1)

3.1.2. False Rejection Rate (FRR): The probability that a biometric system will fail to identify an enrollee using Miss Match Count (MMC) and Total Number of Persons (NP) as given in the Equation 2.

\[
FRR\% = \frac{MMC}{NP} \times 100
\]  

(2)

3.1.3. Morphology: The technique of analyzing images based on geometrical structures and topology.

3.1.4. Threshold: The acceptance or rejection of biometric data is dependent on the match score falling above or below the threshold. The threshold is adjustable so that the biometric systems can be more or less strict, depending on the requirements of any given biometric application.

3.1.5. Equal Error Rate (EER): The rates at which both accept and reject errors are equal. The smaller the EER, the more precise is the biometric system.
3.2. Block Diagram

The block diagram of the proposed PIRDWT model is shown in Figure 1:

3.2.1. Iris database

The iris is an annular region between the sclera and the pupil which is rich in unique textural information. The image of an eye is captured using the appropriate set up with good contrast and resolution, avoiding aberrations and reflections. The acquired image must initially be converted to grayscale format. The Chinese Academy of Sciences Institute of Automation (CASIA V1.0) [25] iris database is considered to test the algorithm which consists of 756 eye images from 108 persons i.e., 7 eye images per individual. Each eye image is a grayscale image of size 280×320. The database images were collected using close-up iris camera in two sessions i.e., first three images in the first session and the next four images in the second session. The pupil regions of all the iris images in the CASIA V1.0 database were initially detected and replaced by a circular region of constant intensity masking out the reflections. This makes the iris recognition system much simpler and has minimal or no effects on the feature extraction and matching algorithms. The first six out of seven images per person are considered to create the iris database i.e., total number of images in the database is 108×6=648. The seventh image of each person is used as test image to compare with six images in the database. One image sample of CASIA is shown in the Figure 2.

3.2.2. Iris Template

An iris region between the pupil and the sclera from an eye is obtained by iris localization. The iris region can be approximated by two circles viz., one for the iris/sclera boundary and another for the iris/pupil boundary. The upper and lower parts of an iris region nearer to sclera are not considered as it is occupied by eyelids and eyelashes. The initial stage begins with locating the center and radius of the pupil in order to separate the iris image. The estimation efficiency of the pupil depends on computational speed rather than accuracy since it is simple in shape and is the darkest region in an eye image and can be extracted using a suitable threshold. The Morphological process is used to remove the eyelashes and to obtain the center and radius of the pupil and is shown in Figure 3.

The basic morphological operations are dilation and erosion which use the structuring element to process the image. The structuring element with required dimension is used to remove the eyelashes. A structuring element is a matrix consisting of 1’s and 0’s which can have arbitrary shape and size and is typically smaller than the image being processed. The centre pixel of the structuring element is called the origin which identifies the pixel of interest in an image and the neighbouring elements are used to dilate or erode the image. Dilation adds pixels to the boundaries of an object in an image, while erosion removes pixels on object boundaries. The number of pixels added or removed from the objects in an image depends on the size and shape of the structuring element. In dilation and erosion operations, a rule is applied to the pixel of interest and its neighbours in an image. The rules are:
i) The origin of the structuring element identifies the pixel of interest in the input eye image and the minimum value of all the pixels in its neighbourhood is assigned to the corresponding pixel in the output image. In a binary image, if any of the pixels is set to 0, the output pixel is also set to 0 in erosion as shown in Figure 4.

\[
\begin{array}{cccccccc}
0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 \\
0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 \\
0 & 0 & 1 & 1 & 1 & 1 & 1 & 0 .
\end{array}
\]

\[\text{Erosion}\]

\[
\begin{array}{cccccccc}
0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 .
\end{array}
\]

\[\text{Fig.4. Eroded image}\]

ii) The origin of the structuring element identifies the pixel of interest in the input eye image and the maximum value of all the pixels in its neighbourhood is assigned to the corresponding pixel in the output image. In a binary image, if any of the pixels is set to the value 1, the output pixel is also set to 1 in dilation as shown in the Figure 5.

\[
\begin{array}{cccccccc}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 \\
0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 .
\end{array}
\]

\[\text{Dilation}\]

\[
\begin{array}{cccccccc}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 \\
0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 .
\end{array}
\]

\[\text{Fig.5. Dilated image}\]

**Pupil Detection:** Connected components labeling scans an image and groups its pixels into components based on pixel connectivity. All pixels in a connected component share similar pixel intensity values and are in some way connected with each other. Once all groups have been determined, each pixel in that group is labeled. The center and the diameter of all the groups are determined and the one with the largest diameter is the pupil.

Now the upper and lower portions of the iris, occluded by eyelashes and eyelids are removed by setting all the pixels above and below the diameter of the pupil as Not a Number (NaN) as shown in Figure 6.

\[\text{Fig.6. After removing upper and lower iris regions}\]

According to the Springer analysis of the CASIA database [26], the lowest and highest iris radius is found to be 90 and 125. Based on this, 45 pixels to the left and right of the pupil boundary is considered as iris region for the proposed algorithm analysis as shown in Figure 7.

\[\text{Fig.7. Localized image}\]

Conventional iris recognition systems use edge detection techniques for localization like Hough circle for iris and pupil boundary detection and line detecting algorithms for eyelids. These methods involve excessive computation and hence are time consuming. However, we have used morphological processing which reduces the time required for preprocessing to a large extent. Also, conventional methods use Daugman’s rubber sheet model for iris normalization. In the proposed method, iris normalization is avoided. From the localized image, the iris regions to the left and right of the pupil are selected and a template is created by mapping the selected pixels on a 60x80 matrix as shown in Figure 8.

\[\text{Fig.8. Template creation}\]

Histogram equalization is done on each iris template to generate an image whose intensity levels are uniform and it also covers the entire range of intensity levels. The resulting image has high contrast as shown in Figure 9.
3.2.3. **DWT**

Discrete Wavelet Transform (DWT) is applied on the Histogram equalized iris template to determine DWT coefficients by passing the signal through low pass filter to derive approximation coefficients and high pass filter to get detail coefficients. The coiflet wavelet is used to generate four bands of coefficients viz., approximation, horizontal, vertical and diagonal as shown in Figure 10.

3.2.4. **PCA Feature Extraction**

The Principal Component Analysis (PCA), known as Eigen-XY analysis is applied on the approximation band of DWT to reduce the dimensionality of the image data. This technique extracts the main variations in the feature vector and allows an accurate reconstruction of the data to be produced from the extracted feature values and reduces the amount of computation needed. PCA identifies the strength of variations along different directions in the image data which involves computation of Eigen vectors and corresponding Eigen values. The Eigen vectors with largest associated Eigen values are the principal components and correspond to maximum variation in the data set.

Eigen vectors can only be found in square matrices; however every square matrix need not have Eigen vectors. There are \( n \) Eigen vectors for a given \( n \times n \) matrix that has Eigen vectors. The proposed model consists of 648 Eigen vectors. Eigen vectors of a square matrix are the non-zero vectors, which being multiplied by the matrix remains proportional to the original vector. The examples of non Eigen and an Eigen Vector are given in Equations 3 and 4 respectively.

\[
\begin{bmatrix} 2 \\ 2 \\ 1 \\ 1 \end{bmatrix} \times \begin{bmatrix} 1 \\ 3 \end{bmatrix} = \begin{bmatrix} 11 \\ 5 \end{bmatrix} \tag{3}
\]

\[
\begin{bmatrix} 2 \\ 2 \\ 3 \\ 1 \end{bmatrix} \times \begin{bmatrix} 3 \end{bmatrix} = \begin{bmatrix} 12 \\ 8 \end{bmatrix} = 4 \times \begin{bmatrix} 3 \\ 2 \end{bmatrix} \tag{4}
\]

The steps involved in PCA include:

- The DWT coefficients of each iris template, of size 40x32, are converted into a one-dimensional vector. These column vectors of 648 images are stacked to form a matrix \( 'X' \) of size 1280x648.
- The mean of each vector is given in Equation 5.

\[
X_m = \frac{1}{N} \sum_{k=1}^{N} X_k \tag{5}
\]

Where \( N=648 \).
- The mean is subtracted from all of the vectors to produce a set of zero mean vectors given in Equation 6.

\[
X_r = X_i - X_m \tag{6}
\]

Where
- \( X_r \) is the zero mean vector,
- \( X_i \) is each element of the column vector,
- \( X_m \) is the mean of each column vector.
- The Covariance matrix is computed using an Equation 7.

\[
C = [Xz^T \times Xz] \tag{7}
\]

- The Eigen Vectors and Eigen values are computed using Equation 8.

\[
[C - \lambda I]e = 0 \tag{8}
\]

Where
- \( \lambda 's \) are the Eigen value and
- \( e 's \) are the Eigen vectors.

This gives us \( N \) Eigen Vectors \((e1, e2, \ldots , eN)\).
Each of an Eigen vectors is multiplied with zero mean vectors $X_z$ to form the feature vector. The feature vector is given in Equation 9.

$$f_i = [X_z] V_i$$ (9)

The signature of each image is found by multiplying the transpose of zero mean vectors with feature vectors given in Equation 10.

$$S_i = [X_z^T] f_i$$ (10)

3.2.5. Matching

The features of the test image are compared with the features of images in the database for match or non match using classifiers such as:

i) K-Nearest Neighbors (KNN): It involves (a) Training phase in which the feature vectors are stored and the class labels are assigned to the training samples and (b) Classification phase in which the test sample is classified by assigning the label which is most frequently occurring among the $k$ training samples closest to the test sample. Cityblock distance parameter in KNN is used for matching and is given in Equation 11.

$$d(a, b) = \sum_{i=1}^{n} |b_i - a_i|$$ (11)

ii) Random forest (RF): The training set consisting of $N$ cases is sampled at random to form a new training set, which is used for growing the decision trees. If there are $M$ variables, then $m<<M$ variables are selected which are used to split the node. The tree is grown without pruning. For a given input vector each tree gives its classification, this is called as voting. The forest chooses the class which has maximum number of votes. The error is calculated during the training. The feature vectors are sampled and a few vectors are left out and are called OOB (out-of-bag) data. The size of OOB data is about $N/3$. The classification error is estimated by using this OOB data. The classification error is calculated as follows:

- A prediction is obtained for each vector which is OOB relative to the $i^{th}$ tree.
- The class winner (one with majority votes) is found from the vectors which are OOB and compared to ground-truth response.
- The ratio of misclassified OOB vectors to all vectors in the original data is equal to the classification error.

The forest error depends on two things such as:

a) The correlation between any two trees in the forest. Increasing the correlation increases the error.
b) The strength of each individual tree in the forest. Increasing the strength decreases the error.

iii) Support Vector Machine (SVM) classifier: It takes a set of input data and predicts which of the possible classes the input belongs to. The input data is treated as an $x$-dimensional vector. It builds a model by constructing a set of hyper planes in a high dimensional space. For an $x$-dimensional vector, $(x-1)$ hyper planes are created. A good separation is achieved by the hyper plane that has the largest distance to the nearest training data points of any class and is the functional margin. The larger the margin, the better is the classification.

4. Algorithm

Problem Definition: The iris is used to authenticate a person. The objectives are:

i) Reducing the complexity of the algorithm by eliminating edge detection and normalization.
ii) To improve accuracy of recognition

The algorithm of PIRDWT to recognize a person using iris localization DWT, PCA and multiclassifiers is given in Table 1.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Algorithm of PIRDWT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input: Eye image</td>
<td>Output: Recognition of a person</td>
</tr>
<tr>
<td>Step 1: Read the eye image.</td>
<td>Step 2: Iris template creation.</td>
</tr>
<tr>
<td>Step 3: Histogram equalization on the iris template.</td>
<td>Step 4: The coiflet wavelet is applied and the approximation band is considered.</td>
</tr>
<tr>
<td>Step 5: PCA is applied on approximation band to form feature vector.</td>
<td>Step 7: Form the signature of each image.</td>
</tr>
<tr>
<td>Step 8: Perform steps 1 to 7 for test image.</td>
<td>Step 9: Match/Non match decision is obtained using multiclassifiers.</td>
</tr>
</tbody>
</table>

5. Performance Analysis

The CASIA version 1.0 database is used for the performance analysis. The database consists of iris images of 108 individuals. It has seven samples for each person out of which six samples are used to create the database of 648
images and one sample per person is used for the test image. The seven iris samples of a person are shown in Figure 11.

The recognition rate i.e., Success Rate (SR) is determined using an Equation 12.

\[
SR = \frac{\text{Number of persons correctly recognized}}{\text{Total number of persons in the database}} \quad (12)
\]

The SR for different number of features with KNN, RF and SVM are tabulated in the Table 2. It is observed that the SR improves as the number of features increases from 10 to 50. KNN classifier gives better SR compared to RF and SVM for 50 features.

Table 2. Accuracy of recognition for different number of features

<table>
<thead>
<tr>
<th>Number of features per image</th>
<th>Success Rate (%)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>KNN</td>
<td>RF</td>
</tr>
<tr>
<td>50</td>
<td>99.07</td>
<td>98.15</td>
</tr>
<tr>
<td>40</td>
<td>99.07</td>
<td>98.15</td>
</tr>
<tr>
<td>30</td>
<td>94.45</td>
<td>98.15</td>
</tr>
<tr>
<td>20</td>
<td>90.75</td>
<td>97.22</td>
</tr>
<tr>
<td>10</td>
<td>78.70</td>
<td>89.81</td>
</tr>
</tbody>
</table>

The performance parameters such as FAR, FRR and EER are evaluated by splitting total database of 108 persons into 90 and 18 persons. The database is created for 90 persons with 6 images per person i.e., total number of images in the database are 540. FAR is calculated by comparing seventh image of every individual with 540 images in the database of 90 persons. FAR is calculated by considering 18 individuals as imposters and are compared with 540 images in the database. The variations of FAR and FRR with threshold is shown in the Figure 12. It is noticed that for lower values of threshold, there is a possibility of genuine samples being rejected and hence the FRR is high and for higher values of threshold, invalid samples could also be accepted as a valid match, hence the FAR is high. The value of EER is 0.111.

![Figure 11. Iris samples of one person from CASIA V1.0 database](image)

![Figure 12. Plot of FAR and FRR vs. threshold](image)

Table 3. Comparison of efficiency between existing and proposed algorithm

<table>
<thead>
<tr>
<th>Algorithms</th>
<th>Number of features</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing IRDWT [27]</td>
<td>24</td>
<td>98.98</td>
</tr>
<tr>
<td>Proposed PIRDWT</td>
<td>40</td>
<td>99.07</td>
</tr>
</tbody>
</table>

The efficiency of the existing algorithm, Iris Recognition using Discrete Wavelet Transform (IRDWT) [27] is compared with the proposed PIRDWT is given in Table 3. The efficiency of the proposed algorithm is improved by increasing the number of features and using morphological localization with reduced region of interest in the iris portion compared to the existing algorithm.

6. Conclusion

Iris pattern recognition is one of the most reliable, secure and promising approaches for individual authentication. In this paper PIRDWT algorithm based on DWT and PCA is proposed. The basic morphological operations such as dilation and erosion are used to remove the eyelashes and eyelids. Histogram equalization is applied to get the high contrast iris image. As per the Springer Analysis of CASIA data base maximum features will be found in iris image at the radius of 90 to 125 pixels on left and right of the pupil boundary. In our algorithm 45 pixels portions of the iris to the left and right of the pupil is considered to get the template. Using DWT and PCA the feature vector is generated. The matching of test iris and data base iris is performed using KN, RF and SVM Classifiers. It is found that the success rate is better in the case of KNN classifier compared to RF and SVM. In future the features are...
generated by different techniques and are fused with multiple classifiers.

References


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