Int. J. Advance Soft Comput. Appl, Vol. 6, No. 2, July 2014
ISSN 2074-8523; Copyright © SCRG Publication, 2014

An Enhanced Approach for Iris Recognition Using Fusion of FWT with Gabor Wavelet Transform and Daugman Encoding

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This paper discusses iris recognition, which is accepted as one of the best biometric methods for identifying an individual. A comparative analysis is done for eight algorithms, namely DCWT, FWT, SWT, CWT, DB, Complex dual tree, Haar wavelet and Wavelet packet for extracting the feature from iris image. Extracting the iris features of the image is still inconceivable as the existing algorithms fail to deliver the maximum accuracy. Among the eight algorithms, Fast Wavelet Transform (FWT) delivers 72.9 percent accuracy. This paper suggests a better way to enhance the accuracy using the Fast Wavelet Transform with the use of Gabor Wavelet Transform and Daugman algorithm. Gabor Wavelet Transform has multi-resolution and multi-orientation properties, which makes it popular for feature extraction. Daugman algorithm has computational simplicity and speed, which supposes the proposed method. Learning Vector Quantization (LVQ) neural network is used in the authentication unit. Results from confusion matrix and ROC shows that the proposed method produces cent percent accuracy. This implies that the effectiveness in authenticating the right person will be higher.

Keywords-*Biometric,Daugman algorithm, FWT, Gabor Wavelet Transform and LVQ neural network*

1 Introduction

At present, biometric recognition is a reliable method for authenticating the identity of a person. This is done on the basis of behavioral or physiological characteristics. Physiological characteristics correspond to fingerprint, facial attributes, iris pattern, etc. Fingerprint recognition fails when sizes or form/pattern of a person changes with respect to time. In case of face recognition, it is known that face is an organ which displays a variety of expressions. It is also a three-dimensional object, where its image will vary with viewing angle, illumination, pose, age and clothing. Hence iris recognition is far better than the above two methods.

The term iris recognition refers to the identification of an unknown iris image with the aid of computational algorithms. Iris recognition uses pattern recognition techniques based on high-resolution images of the irises in a person’s eye. This operation is performed by comparing the unknown iris and the iris images stored in the database. The features of the iris are obtained from its image using wavelet transforms. Wavelet transform delivers a proper basis for image handling on account of its beneficial features. Wavelet transform compresses the energy of the signal to transformation coefficients. It has the ability to capture and represent the image backgrounds and image edges effectively, which is low and high frequency components respectively. Wavelet transform can receive the image at different qualities because of its progressive transmission property. Wavelets have following applications, which are much useful in iris recognition.

- To detect the signal changes at the exact instance.
- To observe the discontinuities in the signal derivatives.
- Detecting the overall trend of the signal.
- Self similar signal detection.
- In de-noising signals and images
- Image compression.

Wavelet transforms, which are used in iris recognition, deliver less accuracy in authenticating the right persons. The proposed method makes a comparative analysis of eight wavelets transform algorithms such as DCWT (Discrete Continuous Wavelet

Transform), FWT (Fast Wavelet Transform), SWT (Stationary Wavelet Transform), CWT (Complex Wavelet Transform), DB (Daubechies Wavelet), Complex dual tree, Haar wavelet and Wavelet packet. It was found that the FWT produces up to 72 % accuracy, which is the highest among these eight.In order to enhance the accuracy, the FWT (Fast Wavelet Transform) algorithm is used along with Gabor Wavelet Transform and Daugman algorithm. The enrolled image is verified using the above three algorithms and passed through the authentication unit.Authentication unit uses a neural network to carry on its process. Learning Vector Quantization (LVQ) neural network is employed here. LVQ creates prototypes, which can be easily interpreted in the application domain. LVQ is applied for solving multi-class classification problems. Using confusion matrix the performance of the algorithm is visualized. The results show that the proposed method produces cent percent accuracy in authenticating right persons.

The rest of this paper is structured as below: In Section 2, research works related to the iris recognition are discussed. The detailed explanation of the proposed framework is given in Section 3. Empirical study is reported in the Section 4 to prove the efficiency and accuracy of the proposed framework. Finally, Section 5 concludes this paper along with directions for future work.

2 Related Works

There were many proposals and experiments on iris recognition using different methods. Most of the proposals were made to extract the right features of the iris. It will be a tough task to capture an iris image without offset. So it requires taking an account of the off-angle information. So Bi-orthogonal wavelet network (BWN) was designed [1] to carry out non-ideal iris recognition. Repositioning of BWN allows the adjustment of non-ideal factors. The off angle data were collected with less constraints. The drawback of this process was its computational complexity.In order to reduce processing time, [2] proposed a model, which filters out iris image from the eye using different masks. This method avoided the normalization step and the computational time was fairly reduced. In addition, the performance parameters were also increased. In [3] a robust method for generating less constrained iris recognition with the aid of the noisy images in the UBRIS.v2 database was introduced. About 500 images were selected randomly from the UBRIS.v2 database and processed. The accuracy obtained from this method was around 98%. The processing time was also nearing real time.The paper proposed by [4] suggests a non-orthogonal view of iris recognition system. Four-spectral images were taken with the help of dual-charge coupled device camera developed for simplifying the iris segmentation task. For matching the iris images obtained at various off-angles, [4] proposes a circle rectification method. The results showed minimal error rate during iris image recognition within 30 degrees. However, clear four-spectral images can be obtained only with the help of special cameras and additional light sources are needed. The light sources are needed to be placed at the right places. Also high computational time is required. These shortcomings are eliminated in this proposed method and best is obtained with less computational time. The images from ordinary camera are enough for processing. Iris acquisition from the noisy images proposed by [5] produced effective output even with different colors, illumination systems, image sizes and occlusions. The paper by [6] suggests some metrics, which delivers sensible accuracy in iris recognition. However, iris texture enhancement is needed for achieving iris recognition accuracy. As per [7] the application of optimized JPEG XR quantization strategy delivers improved iris recognition. In [8]iris was recognized from the Visible Light imaging (VL) and Near-Infrared (NIR) imaging. The features from these images were fused to increase recognition performance. The presentation by [9] conveys that Haarlets level-5 surpasses the performance of other Haarlets in proving high texture of the images in iris recognition. This method has minimum query execution time and suitable for real time applications. Using circular Hough transform and active contour model [10] developed an efficient iris localization method. This method achieved 99% accuracy and worked 2.5 times faster than Daugman's algorithm. This method was tested only with the database containing iris images of Chinese subjects. The role of iris segmentation in the error rates of different iris recognition methods was analyzed in [11]. It concluded that the rise in error rates would be directly proportional to the inaccuracies in the amplitude of segmentation. The algorithm suggested by [12]will be suitable for producing secure and revocable biometric templates. Bit reliability-driven matching presented in [13], is applied to various iris recognition algorithms, which resulted in good recognition rates. Similarly,[14] deals with time optimization in iris recognition. A new comparison technique was developed by [15] to increase the iris recognition. The use of visual cryptography in iris recognition using iris templates is employed in [16]. The paper [17] uses the Daugman's algorithm segmentation method for Iris recognition. Then the features of the iris are encoded by convolving the normalized iris region with 1D Log-Gabor filter. Histogram of Gabor phase pattern (HGPP) is proposed for robust face recognition in [18]. The quadrant-bit codes are first extracted from the faces based on the Gabor transformation. Global Gabor Phase Pattern (GGPP) and Local Gabor phase pattern (LGPP) are proposed to encode the phase variations. Iris recognition based on the covariance of discrete wavelet using Competitive neural network (LVQ) is proposed in [19]. A set of edge Iris profiles is used to build the covariance matrix by discrete wavelet transform using neural network. In this section, we have analyzed the advancements and shortcomings of the related works. Considering limitations,a new we method for high accuracy iris recognition with less computational time.

3 Proposed Work

The proposed method employs comparative analysis between eight different algorithms (as discussed earlier) for iris feature extraction. The feature extraction is done by all eight algorithms and this proposed scheme include only FWT algorithm for feature extraction due to its high accuracy. The results display that FWT algorithm produces better output than others do. Still, it is not enough for right authentication. So Gabor Wavelet Transform and Daugman algorithm is used with FWT to achieve the most precise authentication. Figure 1 shows the overall proposed schema with the selected FWT algorithm.

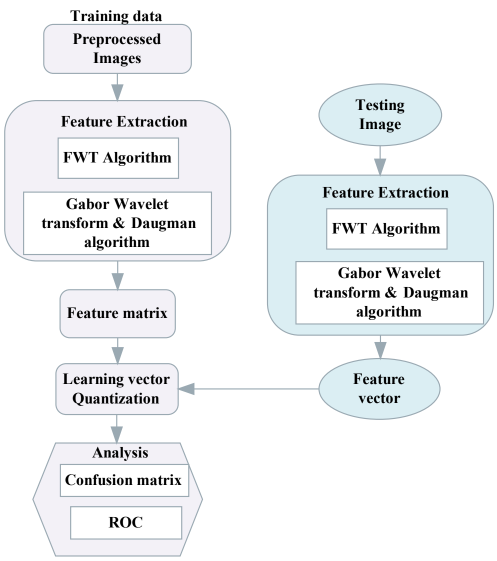

Fig.1 Schema of the proposed method

3.1. Database Collection

To start-off with this method a collection of iris images are needed. Preprocessed iris images are used as input in this method. The dataset contains 48 images. These 48 images are used in training and testing dataset. Out of 48 images, 24 images are of authorized persons and 24 images are of unauthorized persons. Each of these iris images has distinct features and these features are to be extracted precisely and stored. The preprocessed images are taken from the Iris database reference of Michael Dobeš and Libor Machala [20-22]. The image size range is 24 bits (RGB color model) and comprises 576 x 768 pixels with PNG (Portable Network Graphics) file format. The irises are scanned by TOPCON TRC5OIA optical device connected tothe SONY DXC-950P3CCD camera.

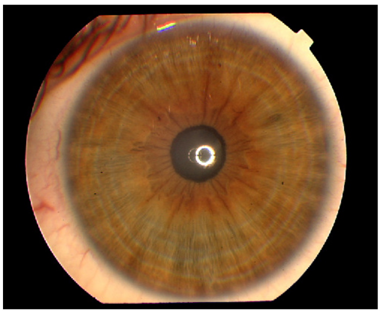

Fig.2 A test iris image

3.2. Feature Extraction

The iris image feature extraction is very substantial in working with image processing techniques, which uses various procedures and techniques to detect and isolate distinctive portions or shapes of an image. Fast Wavelet Transform (FWT) is considered as the highly accurate algorithm for iris recognition among the eight algorithms tested. It is an algorithm designed to convert a signal or waveform in the time domain to a sequence of coefficients based on wavelets. FWT can be extended to images easily, where the time domain replaces the space domain. It will be suitable for non-stationary functions, where its frequency changes in accordance with time. The algorithm is effective in extracting the iris feature. The outcomes from the analysis are presented below in Figure 3 and Figure 4.

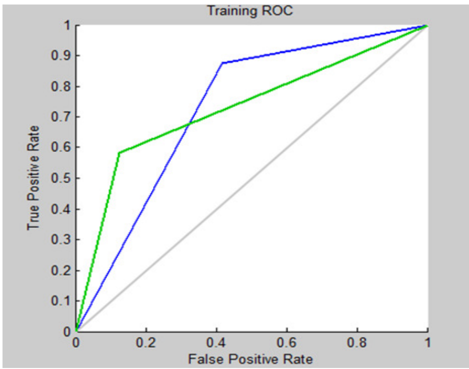

Fig.3 ROC curves for FWT algorithm

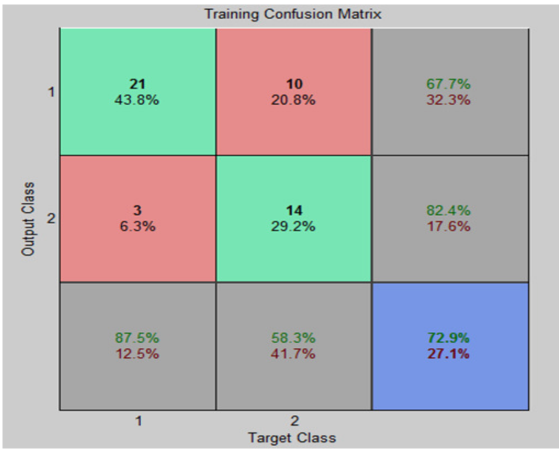

Fig.4 Confusion matrix for FWT algorithm

From the above figures, it is observed that the ROC curves are formed slightly similar to the expected output curve. The confusion matrix also shows good accuracy percentage. Still the possibility of recognizing the correct iris is tentative as the accuracy is not cent percent. Therefore, we decided to utilize the Gabor Wavelet Transform and Daugman algorithm.

3.3. Gabor Wavelet Transform and Daugman algorithm

Gabor wavelet transform is frequently used in image processing researches because of its excellent biological and mathematical properties. Gabor functions deliver optimal resolution in frequency and spatial domain. For the extraction of local features, Gabor wavelet transform will be effective. It has multi-orientation and multi-resolution properties. In pattern recognition tasks, Gabor wavelet transform provides distortion tolerance space. There is no need of considering the non-orthonormal properties in this transform.

A distinctive victorious application of Gabor phase is the phase-Quadrant demodulation coding method proposed by Daugman for iris recognition. The Daugman's algorithm is the most referenced method for iris recognition. This is the first method to be implemented effectively in the operating biometric system. The Daugman's algorithm is based on iris codes. This method is based on the application of integro-differential operator for the detection of iris contour. These operators are used for the detection of the diameter and the center of the iris. Differential operators are also involved in the detection of the pupil. The Daugman's algorithm employs the altered complex 2-D Gabor wavelets. Based on this algorithm, each resultant image is encoded in two bits, $(S_{a,b}^{Re}(X), S_{a,b}^{Im}(X))$ by the following rules:

$$S_{a,b}^{Re}(X) = \begin{cases} 0, & if\ Re\left(G_{a,b}(X)\right) > 0 \\ 1, & if\ Re\left(G_{a,b}(X)\right) <= 0 \end{cases} \quad (1)$$

$$S_{a,b}^{Im}(X) = \begin{cases} 0, & if\ Im\left(G_{a,b}(X)\right) > 0 \\ 1, & if\ Im\left(G_{a,b}(X)\right) <= 0 \end{cases} \quad (2)$$

3.3.1 Global Gabor Phase Patterns (GGPP):

This scheme computes one binary string for each pixel by concatenating the real or imaginary quadrant-bit codes of different orientations. The value of $GGPP_f(X_0)$ with frequency f and at point X_0 is formulated as in equations (3) and (4).

$$GGPP_f^{Re}(X_0) = \left[S_{0,f}^{Re}(X_0), S_{1,f}^{Re}(X_0), \ldots\ldots, S_{k,f}^{Re}(X_0)\right] \quad (3)$$

$$GGPP_f^{Im}(X_0) - \left[S_{0,f}^{Im}(X_0), S_{1,f}^{Im}(X_0), \ldots\ldots, S_{k,f}^{Im}(X_0)\right] \quad (4)$$

Equation (5) and Equation (6) are used to calculate decimal values for the 8-bit binary strings. By using this encoding method, two decimal numbers for each pixel corresponding to real and imaginary GGPPs are obtained.

$$GGPP_f^{Re}(X_0) = \begin{bmatrix} S_{0,f}^{Re}(X_0) * 2^k + S_{1,f}^{Re}(X_0) * 2^{k-1} +, \\ \ldots.. + S_{k,f}^{Re}(X_0) \end{bmatrix} \quad (5)$$

$$GGPP_f^{Im}(X_0) = [S_{0,f}^{Im}(X_0) * 2^k + S_{1,f}^{Im}(X_0) * 2^{k-1} +, \ldots.. + S_{k,f}^{Im}(X_0) \quad (6)$$

The accuracy in this algorithm is nearly equal to 100% and the computation time is very much less. Because of the ideal properties of these algorithms, they are combined with FWT for feature extraction. This process leads to an intrusion of the additional feature extraction stage.

3.4. Learning Vector Quantization (LVQ) Neural Network

A neural network (NN) is a system consisting of numerous processing elements, which operate in parallel. It is a multiprocessor computer system with a high degree of interconnections, scalar messages, and flexible interaction between elements. Its function is determined by its connection strengths and network structure. NN is identical to biological neural networks in executing functions collectively and in parallel by the units. It normally refers to models used in cognitive psychology, statistics, and artificial intelligence. NN provide important speed advantage over other conventional approaches. It is used in character recognition, image compression, stock market prediction, medicine, miscellaneous applications. NNs have following advantages

- It is more similar to the real nervous system
- Parallel organization grants solutions to problems where multiple constraints are simultaneously fulfilled
- Elegant degradation
- The rules are implicit
- The neural network continues to work with their parallel nature when an element of NN fails.
- It needs minimum formal statistical training

- It has the ability to discover all feasible interactions between predictor variables. Complex nonlinear relationships between independent and dependent variables can also be detected.

Neural networks have the following characteristics:

- Contains many weighed connections between the elements.
- Distributed representation over the connections
- Parallelism properties
- Fault tolerance

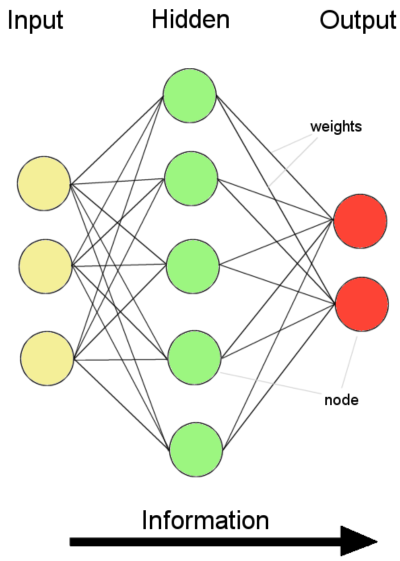

Fig.5 Neural Network (NN)

Figure 5 shows the structure of NN with three layers: input layer, hidden and output layer. Data is presented to the input layer and passed on to hidden and output layer. Information flow is unidirectional. Information is distributed and processed in parallel. The neural network is used for the categorization and recognition of iris patterns. The adaptive learning strategy is used for NN training. NN provides a high accuracy rate for iris recognition when compared to other existing techniques. In iris recognition, the neural networks are used to train the iris images. Here Learning Vector Quantization (LVQ) neural network is used. LVQ is a monitored version of the vector quantization. It is a prototype based classifier algorithm. This algorithm does not approximate the density functions of class samples. It is hybrid networks that form classification through supervised and unsupervised learning. It directly defines the class boundaries based on prototypes. LVQ begins from a trained SOM with input vectors and weights. For each weight, the best classification label is detected from the input labels. The following are the applications of, Learning Vector Quantization.

- Speech recognition
- Multi-class classification
- Image processing
- Text-document classification

These applications of LVQ justify its use in the proposed method. The output of the neural network will be checked for its performance. LVQ network comprises of three layers: Input layer, Competitive layer and Output layer. Figure 6 shows the structure of LVQ network. The number of neurons in each layer depends on the input data and the class of the system. The input neurons are as many as the input iris features of the training pattern, and the number of the output neurons is equal to the number of classes to which iris patterns are classified. The number of hidden neurons is 4. The LVQ algorithm proceeds as follows:

(1) Let us consider that the weight vectorw_v is close to the input vectorz_i. Let μ_{wv}denote the class associated with the weight vector,w_v and μ_{zi}denote the class label of the input vector z_i. The weight vector w_v is adjusted as follows:

a. If $\mu_{wv} = \mu_{zi}$ $then$

$$w_v(n+1) = w_v(n) + \alpha_n[z_i - w_v(n)] \quad (7)$$

b. If $\mu_{wv} \neq \mu_{zi}$ $then$

$$w_v(n+1) = w_v(n) - \alpha_n[z_i - w_v(n)] \quad (8)$$

(2) The other weight vectors are not modified. a_n is a learning constant $(0\langle\alpha_n\langle 1)$.

It is desirable to decrease monotonically with the number of iterations *n*. The above steps are repeated for each input vector in the input space.

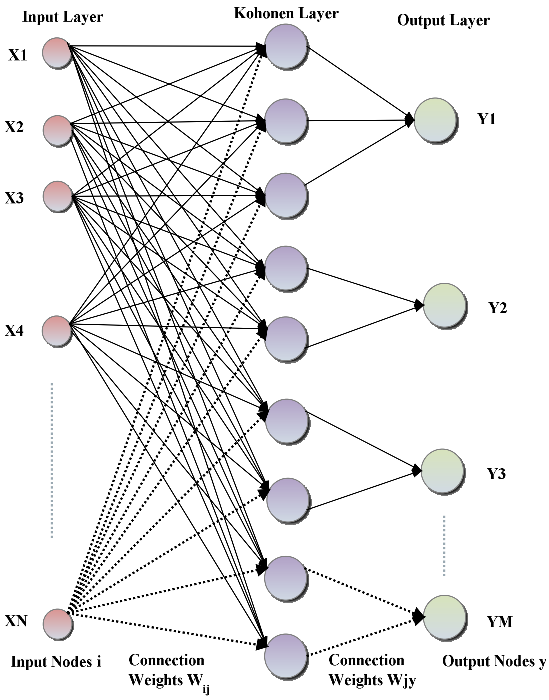

Fig.6 Structure of Learning Vector Quantization (LVQ) network

4 Performance Evaluation

The proposed method has been processed through the various steps for iris recognition. However, its performance is needed to be evaluated. This is carried out in two ways.

i. Confusion matrix

ii. Receiver Operating Characteristic

4.1. Confusion Matrix

Confusion matrix is a table layout, which visualizes the performance of an algorithm. The term confusion matrix defines a table which contains the information regarding the actual and anticipated classifications processed by the classification system. The evaluation is done with the help of the data in the matrix.

4.2. Receiver Operating Characteristic

Receiver Operating Characteristic (ROC) graphs are employed for organizing the classifiers and visualizing their performance. Here, it is used to compute the accuracy of iris recognition graphically. The accuracy rate of classification results is predicted by the formation of inverted L-shaped curve in ROC graph. The curve is plotted between True Positive Rate (TPR) and False Positive Rate (FPR). The performance of the classifier is analyzed with True Positive (TP), True Negative (TN), False Positive (FP) and False Negative (FN) values. Accuracy is measured by the area under the curve (AUC). The area measures descrimination i.e. the ability of the test to correctly classify those with and without error.A perfect model will score AUC of 1. When the ROC curve is closer to the upper left corner, be higher the overall accuracy of the test.

4.3. Experimental Results

The proposed FWT approach is compared with existing algorithms such as DCWT, SWT, CWT, DB, Complex dual tree, Haar wavelet and Wavelet Packet. Table 1 illustrates the comparative analysis performed with eight different algorithms with their accuracy in recognition of iris.

Table 1: Accuracy comparison of eight different algorithms

Algorithm	Accuracy
DCWT	66.7%
SWT	66.7%
CWT	52.1%
DB	60.4%
Complex dual tree	64.6%
Haar wavelet	66.7%
Wavelet Packet	66.7%
FWT	72.9%

It is evident that FWT has the highest accuracy and justifies its use in this method. The use of FWT along with Gabor wavelet transform and Daugman algorithm increases the accuracy. The output from the feature set is trained in the LVQ neural network. The trained images need to be checked for consistency. It is done using the confusion matrix and ROC curves. Figure 7 shows the confusion matrix obtained for the trained images.

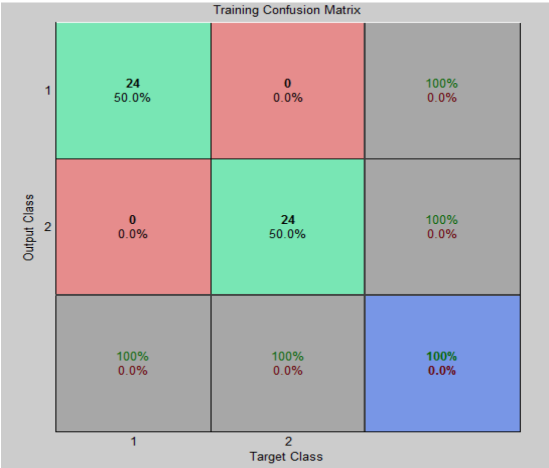

Fig.7 Confusion matrix for the trained images

While comparing the confusion matrix of other algorithms, it is evident that the proposed method is far better and accurate. Out of the 48 persons, half of them were authenticated and the other was unauthenticated as in the table 2. This confusion matrix only produces the true positive and true negative values. Hence, the possibility of wrong recognition is zero.

Table 2: Performance measures of the proposed method

	Authenticated	Un-Authenticated
TP	24	24
FP	0	0
FN	0	0
TN	24	24

Table 3:Analysis table showing the accuracy in authentication

	FRR%	FAR%	GAR%
Authenticated	0	0	100
Un-Authenticated	0	0	100

The performance is also checked with the ROC curves. The graph is plotted between the false positive rate and True positive rate. For best output the curve should be in the structure of inverted 'L' shape.

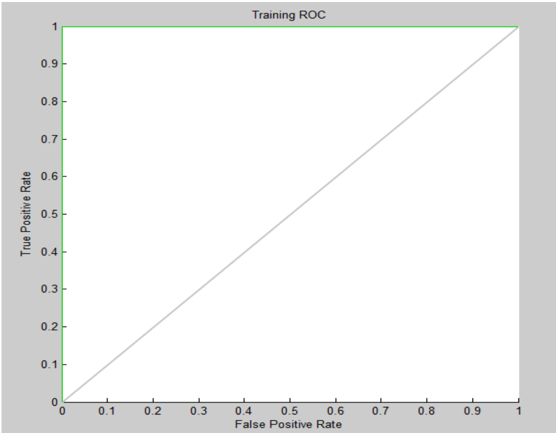

Fig.8 ROC curve

When both the distributions (TPR and FPR) do not overlap it follows the top and left margin, indicating that AUC is 1 as shown in the graph (figure 8). This represents that the accuracy is 100% and discrimination test is ideal. Here, it is evident that the ROC curve is obtained as per the requirement. So both the tests show that the proposed algorithm is effective in iris recognition.

5 Conclusion & Future Work

This paper establishes the analysis work of eight different feature extraction algorithms and the results show that the FWT algorithm affords 72.9% accuracy. To enhance the accuracy further, FWT feature extraction algorithm along with Gabor Wavelet Transform and Daugman's encoding is used in this method. Gabor wavelets transform is used to accurately analyze and extract unique texture of an iris. Daugman encoding is performed in terms of phase structure at multiple scales of analysis. Gabor wavelets provide efficient searches for matches when the representation of pattern information is in terms of phase bit strings. Authentication is handled by learning vector quantization (LVQ) neural network and the final analysis is done with the results of confusion matrix and ROC curves. The area under curve (AUC) is maximum in the ROC curve. The proposed method outperformed all the other algorithms that were tested. The accuracy in the iris recognition was 100%. Therefore, there is no possibility of error. Hence, it is proposed to use genetic algorithm to study the diseases associated with retina as a future work.

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