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Efficient Iris Recognition by Fusion of Matching Scores obtained by Lifting DWT and Log-Gabor methods of Feature Extraction

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Abstract
Iris Recognition technology is gaining wide range of applications day by day because of its accuracy and reliability. The main reason for this is the varying iris texture of every individual. However, iris images are usually distorted by various sources of noise such as occlusions by eyelashes and eyelids, error during iris localization, iris deformation. etc. Therefore, development of accurate iris recognition techniques which can be more tolerant to noise is highly desirable. In this paper, an efficient algorithm is proposed to increase the accuracy of Iris recognition which is more than that of existing methods of iris recognition. In addition, since two methods of feature extraction i.e. Lifting DWT and Log Gabor have been used and also the matching scores i.e. TSR (Total Successive Rate) of these two methods are fused in the proposed algorithm, the experimental results shows that the iris recognition rate will be more accurate compared to other Iris Recognition system.

General Terms
Image processing, Iris recognition, Lifting DWT, Log Gabor Filter.

Keywords: FAR, FRR, EER, TSR, Fusion, Normalization.

1. Introduction

The word Biometrics is obtained from Greek, meaning of ‘bios’ is life and ‘metrikos’ is to measure. Personal recognition of an individual can be done by using a wide range of pattern recognition systems, there by identity of an individual who is requesting their services can be viewed. The main responsibility of these schemes is to ensure that the services are accessed only by a valid user. Biometrics cannot be forgotten, stolen, borrowed and forging can never be done. Applications of biometrics include secure access to laptops, entry to premises, ATM, Cell phones, banking transactions. Biometrics refers to the recognition of individuals depending on their behavioral or physiological characteristics such as fingerprint, face, retina, DNA, palm print, iris, gait etc., Among all the above features, recognition done using iris pattern of an individual will be very accurate [1].

Iris Recognition is a Biometric Technology which deals with identification of an individual based on the pattern of human Iris. It is the most accurate biometric technology which is available today. The iris is differentiated by several characteristics including ligaments, furrows, ridges, crypts, rings, and corona. In iris recognition process we use high-resolution cameras to capture a black and white photograph of iris. Once the black and white image of iris is captured, the elastic connective tissue called the trabecular meshwork is analyzed and then processed into an “optical fingerprint,” and later it is translated into a digital form using a computer algorithm. This binary code will be compared to all others binary codes that are stored in the database for identification or verification. This process takes only one to two seconds and provide the details of the iris that are mapped, recorded and stored for future matching/verification. Given the stable physical traits of the iris, this technology is considered as one of the safest, fastest and most accurate noninvasive biometric technology. Based on the body characteristics such as face, eye, voice etc, human recognizes each other. Human behavior and physical characteristics can be used as basis of biometrics, further each should fulfill the following conditions*(1)Universality*-every individual should have these characteristic *(2)Uniqueness*-the characteristic should vary from person to person *(3)Performance*-the characteristic should be such that the speed as well as recognition accuracy should be high *(4)Permanence*- this human characteristic should not vary with time *(5)Acceptance*-the characteristic should be such that the extent to which the people are willing to accept the use of a particular biometric identifier (characteristic) in their daily lives must be high [1].

There are many chances of eye images to get distorted by various noises due to error in acquisition and the size of iris of the same subject may vary due to varying distance between camera and person. So, these errors can be eliminated by performing many pre-processing techniques such as Gaussian smoothing, Edge Detection, Gamma adjustment, Non maximum Suppression, Hysteresis thresholding.

The initial process in any iris recognition system is to extract the iris i.e. ROI in this case. For this to happen, firstly we need to define the concentric circles i.e. the circular boundary between iris and sclera and also the boundary between pupil and iris has to be defined. This can be done by using Circular Hough transform. Before segmentation, the noise has to be removed by applying smoothing filters

The iris size of a person in an iris image may vary due to many factors like variation in imaging. Normalization is usually done in order to extract the iris region to perform matching in spite of pupil enlargement which is caused by varying illumination and variation in iris size caused by the difference of distance between camera and the person. After normalization, any two images which are captured under different conditions will have same dimensions and the spatial location where the characteristic features are present will be same for both the images.

Motivation: Iris images are usually distorted by various sources of noise such as occlusions by eyelashes and eyelids, error during iris localization, iris deformation.etc. Therefore, development of accurate iris recognition techniques which can be more tolerant to noise is highly desirable.

Contribution: The Lifting Scheme DWT algorithm is used for extraction of minute details of iris texture. The feature extraction using this particular method is faster as compared to other algorithms. We've also used Log Gabor Filter for accurate feature extraction. Using Log Gabor approach we can eliminate DC components present. Then, the matching scores i.e. TSR will be fused using appropriate fusion technique. Now the decision on matching will be based on the TSR values obtained from both the feature extraction methods. Hence the accuracy rate of recognition will be increased greatly.

Related Work

Zhonghua *et al*. [2] proposed "A Novel Iris Recognition Method based on the Natural-Open Eyes". Due to the non-intrusive characteristic of iris recognition, the images of natural-open eyes faces many problems, thereby accuracy is decreased. To avoid this problem, natural-open eyes method is employed. Initially the iris image is preprocessed and the effective iris is ensured adaptively. Secondly, the feature points of iris are found by directional information, width information, length information of the texture, the grey information of the neighboring area of the iris is found. Thirdly the codes are obtained from the feature points and the iris pattern is figured out. Finally, the obtained iris pattern is compared to the database of iris patterns using pattern matching method and then recognition result is obtained. Hence the recognition rate by this method is 99.68% and thus the iris recognition demands are fulfilled. The correct recognition rate (CRR) is lower than the Daugman's algorithm. In this paper, a method is proposed where the time required to find iris characteristic point is reduced, and we can obtain guaranteed recognition speed.

Musab A. M. Ali *et al.* [3] proposed a paper on the fact that iris as biometrics is the accurate method for recognition because it contains very unique patterns. Hence they used Gabor filter as feature extraction to analyze the possibility of obtaining half iris for recognition with Support Vector Machine used as classifier. Experimental analysis conducted depicted that the proposed method is best suitable with half iris as input based on performance attained specifically FAR and FRR of 0.21% and ERR of 99.56%. Thus, this technique could be used to prevent occlusion due to eyelids and eyelashes during segmentation

Fabian Rolando Jimenez Lopez *et al.* [4] proposed a paper which describes the segmentation and normalization process for automatic biometric iris recognition system, it is implemented in MATLAB. For this work we use the images database digitized in grayscale CASIA v. 2.0, where coding and processing through segmentation algorithms was implemented using Gabor filters and Hough Transform, finally a new segmentation algorithm was designed and implemented by the authors, but its performance was evaluated with satisfactory result.

Walid Aydi *et al*. [5] proposed a robust feature extraction method based on monogenic filter for iris recognition system. This method works on the fact that the features of iris varies from person to person. Each iris recognition system have four stages: segmentation, normalization, encoding and matching. In this paper the iris signature will be first extracted by using monogenic filter and 1D log Gabor filter. Further two types of distances measures are used as metric for recognition. Based on the results of the experiments, this method provides high speed and accuracy in terms of performance when demonstrated on CASIA iris database V3.0.m

Sepideh *et al.*, [6] proposed a prototype of field-programmable gate array (FPGA) for iris recognition that performs parallel computing, thereby increasing the performance. This prototype completes the time consuming iris recognition sub-processes in parallel, hence optimum performance will be achieved. The pupil and iris boundaries will be localized and then the features of the iris image will be extracted by unwrapping the same, and this will be done while capturing was in progress. Thus the iris recognition process can be accelerated due to parallel operations that are performed on FPGA prototype.

There may exist many iris recognition systems, but each of them has many major flaws. Hence here is a need of accurate iris recognition system which produces less FAR and FRR.

Proposed Model

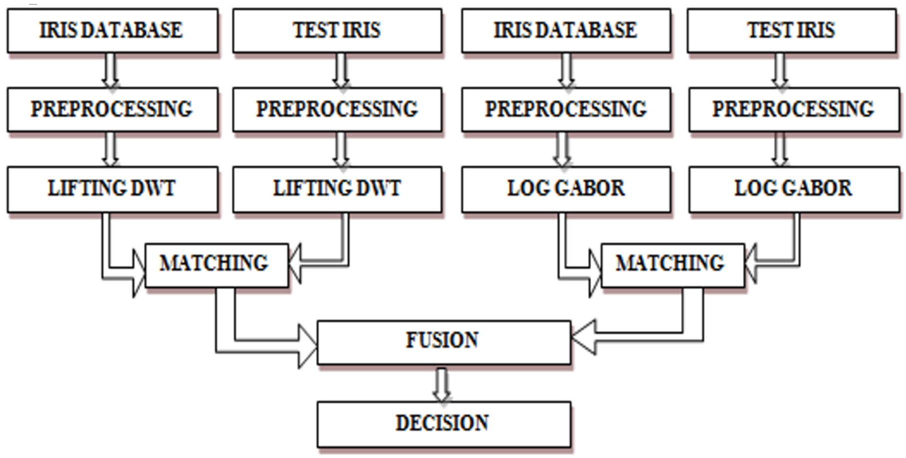

Fig 1: Block Diagram of Proposed Model

Image Acquisition: The eye images have to be acquired under constrained environment i.e. under good illumination and appropriate distance, in order to avoid the noise that may cause the errors in further recognition process. Here in this project we've mainly used the eye images which are made available publically by CASIA, a Chinese institute of automation and science. This database is mainly provided for research as well as implementation. There is no chance of specular reflections, since Infrared Light (IR) is used for illumination.

Preprocessing: There are many chances of eye images to get distorted by various noises due to error in acquisition and also the size of iris of the same subject may vary due varying distance between camera and person. So, these errors can be eliminated by performing many pre-processing techniques before feature extraction. The main preprocessing techniques are Gaussian Smoothing, Edge Detection, Gamma adjustment, Non maximum Suppression, Hysteresis thresholding.

Iris Localization and iris segmentation: The eye image not only consists of Iris, but also Pupil, Sclera, Eyelid, Eyelashes region. But for any iris recognition process, the Region of Interest (ROI) is the Iris part and this ROI can be extracted by localization and segmentation.

Normalization: The iris size of a person in an iris image may vary due to many factors like variation in imaging. Normalization is usually done in order to extract the iris region to perform matching in spite of pupil enlargement which is caused by varying illumination and variation in iris size caused by the difference of distance between camera and the person. After normalization, any two images which are captured under different conditions will have same dimensions and the spatial location where the characteristic features are present will be same for both the images.

Lifting scheme: Lifting Scheme can be used in construction of bi-orthogonal wavelets. The lifting scheme doesn't use Fourier transform for construction, so it can be used in the situation where Fourier transform is not available. This process begins with a trivial wavelet (Lazy wavelet), a function which do not perform anything, but has the properties of a wavelet. Hence the name "Lifting Scheme". This scheme can be used in designing of wavelets as well as in performing DWT. In Lifting Scheme; the signal is divided into odd and even signals. Later, a sequence of convolution and accumulation techniques is applied [7].

Steps involved in Lifting Scheme are:
1. Split
2. Predict
3. Update

1. **Split:** This step is performed in order to split the data into two smaller subsets i.e. even and odd
2. **Predict:** Here, we make use of the even samples that are multiplied by the prediction operator to predict the odd samples. Then the detail coefficient is obtained by taking the difference between the odd sample and the prediction value.
3. **Update:** In this phase, the even samples are updated with detail to get smooth coefficient

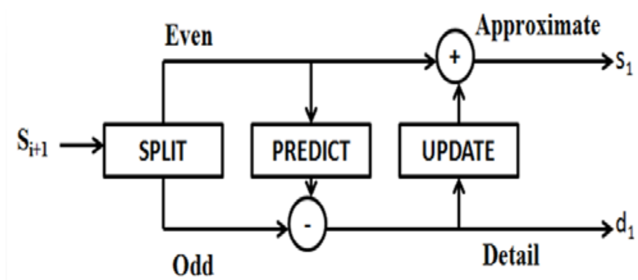

Fig 2: Wavelet Transform: Lifting- based implementation

Log Gabor Filter: Iris texture is very complex and it is very difficult to analyze and extract the features from it. By decomposing this image we can obtain phase information which is complex in nature and these can be used to obtain feature details. By applying "1D log Gabor filter" to each row of normalized template of iris we can obtain accurate feature info. The obtained phase information is quantized to obtain "Binary representation of iris pattern". Thus an accurate representation of features of iris can be obtained. The accuracy rate of recognition using these filters is very good. DC component is removed by the Log Gabor function.1D approach of this filter captures only horizontal components and 2D approach can be captured by 2D Log Gabor Filter [8]

The one-dimensional Gabor filter defined as the multiplication of a cosine/sine (even/odd) wave with a Gaussian window as follows,

$$g_e(x) = 1/\sqrt{2\pi\sigma}\ \ e^{-x2/2\sigma2}\ \mathrm{Cos}\ (2\pi\omega_o X) \qquad (1)$$

$$g_o(x) = 1/\sqrt{2\pi\sigma}\ \ e^{-x2/2\sigma2}\ \mathrm{Sin}\ (2\pi\omega_o X) \qquad (2)$$

ω_o- Centre frequency
σ-the spread of Gaussian window
Daugman extended the Gabor filter to two dimensions
The expression for 2D Log-Gabor is given by

$$g_e(x) = 1/\ (2\pi\sigma_x\,\sigma_y)e^{-1/2[(\frac{x2}{\sigma x})+(\frac{y2}{\sigma y})]}\ \cos\ (2\pi\omega_o x + 2\pi\omega_o y) \qquad (3)$$

$$g_0(x) = 1/\ (2\pi\sigma_x\,\sigma_y)\ e^{-1/2[(\frac{x2}{\sigma x})+(\frac{y2}{\sigma y})]}\ \cos\ (2\pi\omega_o x + 2\pi\omega_o y) \qquad (4)$$

$$\mathrm{1D\_Log\_gabor} = \exp\left(\frac{\left(\log\left(\sqrt{\frac{\omega_x^2+\omega_y^2}{\omega_0}}\right)\right)^2}{2\left(\log\left(\frac{\sigma}{\omega_0}\right)\right)^2}\right) \qquad (5)$$

Where, ω_x and ω_y are horizontal and vertical frequencies.
ω_0 -indicates the center frequency of the filter
σ - Scaling factor of the bandwidth
The ID log Gabor filter possesses crucial advantages such as-

- DC component can be eliminated compared to the Gabor filter
- Limitation of bandwidth that was present in Gabor filters can be overcome
- Log-Gabor has a response of Gaussian shaped along logarithmic frequency

Matching: A threshold value is required in matching process to decide whether the iris pattern belongs to an imposter or an authenticated user. The selection of threshold value should be such that the FAR and FRR should be reduced. The decision is made depending on the threshold value.
"Distance < Threshold", Match between two iris template is said to be found
"Distance>Threshold", No match between two iris template is found
The pairwise distance formula is given by

$$d(p,q) = \sqrt{(p_1 - q_1)^2 + (p_2 - q_2)^2\ + \cdots + (p_n - q_n)^2} \qquad (6)$$

Fusion: We fuse the matching score i.e. TSR obtained from Lifting DWT features with the matching score obtained from Log Gabor features by using the following formula [9].
Final score F= X * C + (1-X) * D (7)
Where, X is improved factor that ranges from 0 to 1

4. Proposed Algorithm

Problem definition: Iris images are usually distorted by various sources of noise such as occlusions by eyelashes and eyelids, error during iris localization, iris deformation. etc. Therefore, development of accurate iris recognition technique

Objectives
1) To increase TSR
2) To reduce FAR, FRR, EER

Table 1: Proposed Algorithm: Iris Recognition using Lifting DWT and Log Gabor

Input: Eye image
Output: Person Recognition

Step 1: Using a camera having resolution of 280*320, the database image which has very clear iris details is captured.

Step 2: The original image size will be 280*320. This image has to be resized, since it occupies more memory space in database. The resizing should be done so as to avoid loss of useful iris texture details.

Step 3: Smoothing of the iris image has to be done because many kind of noise will be added to the images during acquisition

Step 4: Using standard Canny Edge Detection method, the edges of Eye images are found

Step 5: Now the iris, as well as pupil boundaries are localized

Step 6: Using thresholding method eyelid and eyelash are removed

Step 7: Now the circular co-ordinates of iris region will be converted into Cartesian co-ordinates using Daugman's Model

Step 8: Feature extraction is done using Lifting scheme

Step 9: Now repeat the above steps from 2 to 8 by taking the test image.

Step 10: Data base image and test image are compared and then the minimum distance will be calculated using Euclidean distance

Step 11: Matching Score is obtained using TSR (Total Successive Rate).

Step 12: Feature extraction is done using Log- Gabor filter

Step 13: Now repeat the above steps from 2 to 8 by taking the test image

Step 14: Data base image and test image are compared and then the minimum distance will be calculated using Euclidean distance

Step 15: Matching Score, that is TSR (Total Successive Rate) is obtained

Step 16: Now the matching scores are fused, this increases the accuracy of iris recognition system

5. Performance Analysis and Results

The performance parameters and performance analysis are discussed below

5.1. Performance parameters definition:

5.1.1. False Acceptance Rates (FAR) –the probability that a system predicts that there is a complete match between test input template and the database template even though there is no match. This depicts the rate of invalid matches.

$$\%FAR = \frac{Number\ of\ authorised\ persons\ accepted\ X100}{Total\ number\ of\ of\ persons\ outside\ database}$$

5.1.2. False Rejection Rate (FRR) – the probability that a system predicts that there is a mismatch between test input template and the database template even though there is a match. This gives the rate of invalid mismatches.

$$\%FAR = \frac{Number\ of\ authorised\ persons\ rejected\ X100}{Total\ number\ of\ of\ persons\ in\ database}$$

5.1.3.Total Success Rate (TSR) **-**is the numbers of authorized persons matched successfully in the database

$$\%TSR = \frac{No\ of\ authorised\ persons\ correctly\ matchedX100}{Total\ number\ of\ of\ persons\ in\ database}$$

5.1.4. Equal error rate or crossover error rate (EER or CER) –EER is the point where FAR & FRR are equal. We can easily find this in FAR/FRR versus Threshold graph by identifying the point where FAR and FRR curves are intersecting. Lower the EER, higher will be the performance.

5.2. Performance Analysis

The performance parameters TSR and EER are computed for both Lifting DWT and Log Gabor techniques with the help of simulations obtained. The improvement in performance after fusing the matching scores of both the techniques is depicted in the following graphs.

5.2.1. Lifting DWT Algorithm

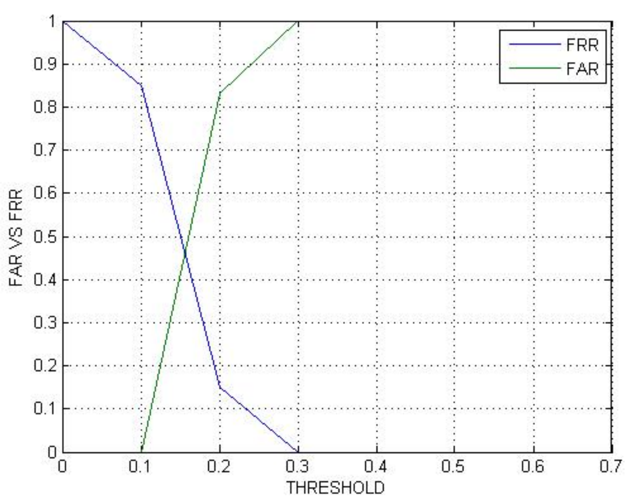

Fig 3: FAR/FRR versus Threshold graph of Lifting DWT

EER is the point where FAR & FRR are equal. We can easily find this in the above graph. It is the point where FAR and FRR curves are intersecting. Here in this case, the value of EER is 0.45

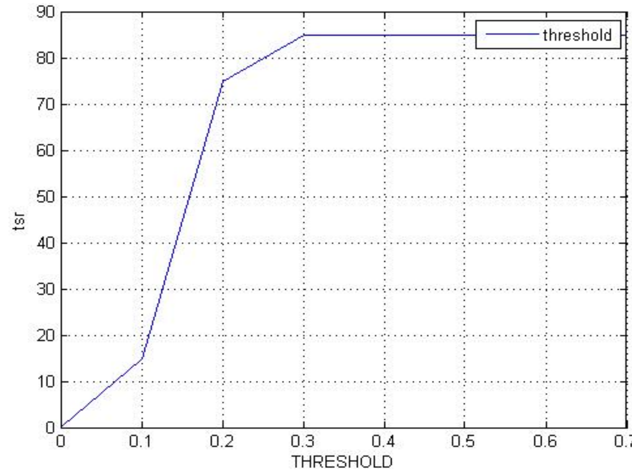

Fig 4: TSR versus Threshold graph of Lifting DWT

The TSR obtained using Lifting scheme is 85 % at threshold 0.3.

5.2.2. Log Gabor Algorithm

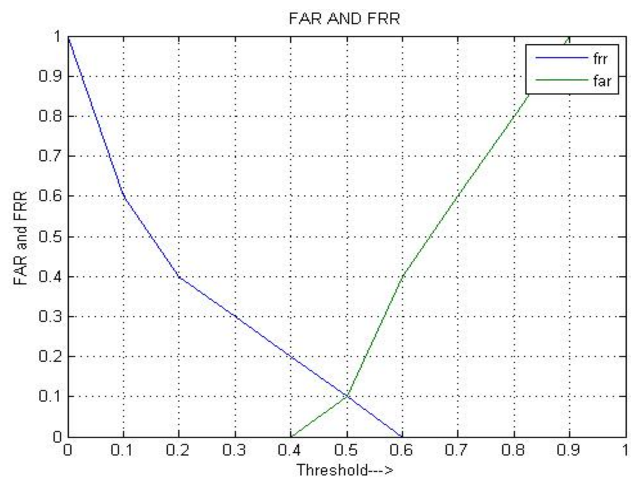

Fig 5: FAR/FRR Versus Threshold graph of Log Gabor

Here in this case, the value of EER is 0.1. Lower the EER, higher the performance

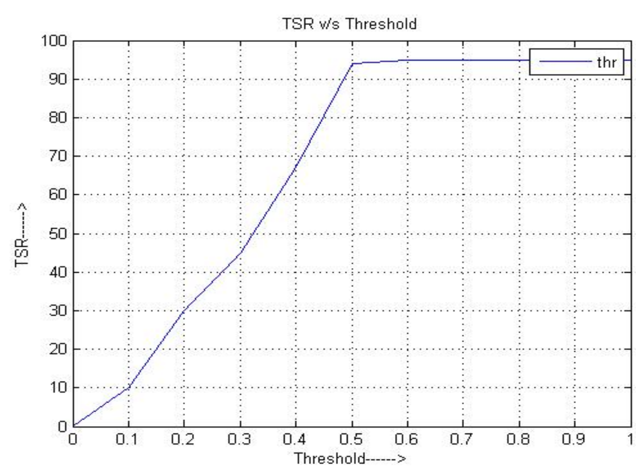

Fig 6: TSR versus Threshold graph of Log Gabor

The TSR obtained using Lifting scheme is 95% at threshold value 0.5.

5.2.3. Proposed method

The following graphs shows the increase in TSR after fusing the matching scores obtained from Lifting DWT and Log Gabor

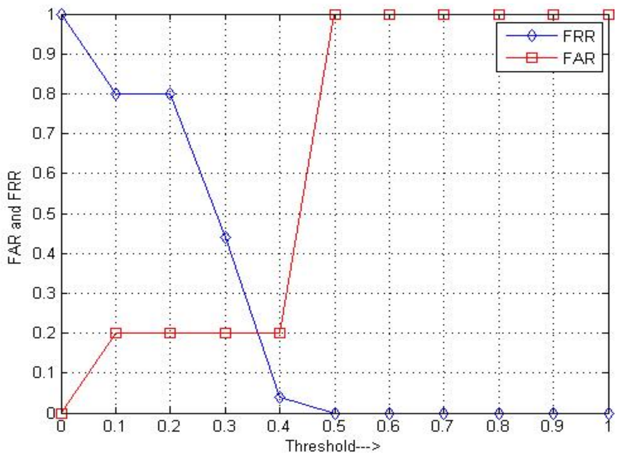

Fig 7: FAR/FRR Versus Threshold graph of proposed method

After fusing the matching scores, the value of EER that we obtain is 0.2.

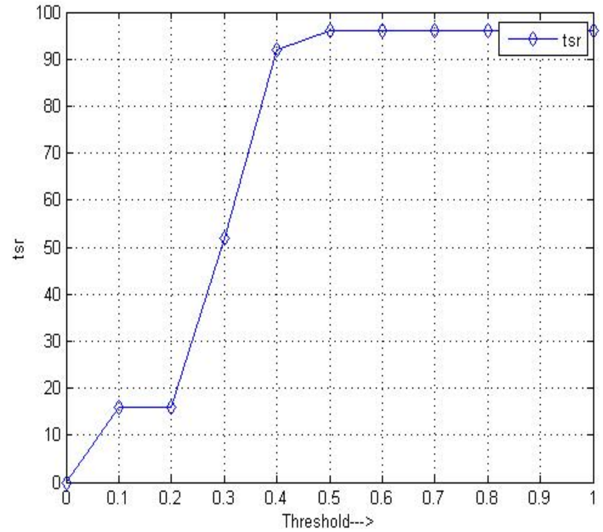

Fig 8: TSR Versus Threshold graph of proposed method

The percentage of TSR that we obtain after fusion is 98.This is better than all other existing methods.

Table 2: EER AND TSR values for different recognition Methods

Lifting DWT			Log Gabor			Proposed Method		
EER	Opt TSR (%)	Max TSR (%)	EER	Opt TSR (%)	Max TSR (%)	EER	Opt TSR (%)	Max TSR (%)
0.45	65	85	0.1	94	95	0.2	80	98

Opt TSR-Optimum TSR
Max TSR- Maximum TSR

Table 1 gives the values of EER, Optimized TSR and Maximum TSR of LWT, Log Gabor and the proposed method. We can observe from the table that the TSR in proposed method has been increased greatly after fusing the matching scores obtained from the former two methods.

Table 3: Comparison of TSR with proposed method and existing Algorithms

Sl. no	Author	Techniques	TSR (%)
1	Chun and Ajay [10]	Geo Key +Log Gabor	92.90
2	Dong *et al*. [11]	Weight map Feature	95.22
3	Khary.*et al.* [12]	HT+MLBP	96.00
4	Proposed	LWT+Gabor	98.00

The algorithm which we've proposed is very simple and gives high TSR than the existing algorithm that are complex. Also the EER has been reduced to great extent. The proposed model can even be implemented on FGPA because of its simplicity.

6. Conclusion

In the proposed algorithm, the eye image is preprocessed to obtain ROI i.e. iris part. The Lifting DWT and Log-Gabor Filter are applied on ROI to extract features individually. The matching scores i.e. TSR (Total Successive Rate) is used to generate final features from individual features. The test iris features are compared with database iris features using Hamming distance and Euclidian Distance respectively. The proposed algorithm gives better TSR and EER values compared to existing algorithms. In future the algorithm may be tested with different transformations and fusion techniques.

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