AMO-Advanced Modeling and Optimization, Volume 15, Number 2, 2013

Pupil detection and feature extraction algorithm for Iris recognition

Vanaja Roselin.E.C[1]
Research scholar,
JNTUH, Kukatpally, Hyderabad - 500085(India)

Dr.L.M.Waghmare[2]
Director,
SGGS, Institute of Engineering and Technology,
Vishnupuri, Nanded (MS) –India.

***ABSTRACT*:** For fast, secure and reliable authentication process as compared to other security systems such as password or any other biometric systems. To get efficiency in terms of cost of computation and execution our proposed method proposes scanning method for pupil detection and five level decomposition techniques for feature extraction. Implementation using haar wavelet and daubechies wavelet (db2, db4), Feature vector (FV) are clear and useful after decomposing up to five-level using 2D haar wavelet transform algorithms(HWT) than daubechies wavelet and Hamming distance classifier is used for matching the patterns efficiently with stored database and latter perform the comparison on the bases of performance evaluation parameters. Experimental results are conducted using CASIA iris database which shows that the proposed method is efficient and reliable.

***Keywords*:** Biometrics, iris recognition, Pupil detection, Feature extraction, False Acceptance Rate (FAR), False Rejection Rate (FRR).

1. INTRODUCTION

Biometrics, which refers to authentication based on his or her physiological or behavioral characteristics, its capability to distinguish authorized person and an unauthorized. Since biometric characteristics are distinctive as it cannot be forgotten or it cannot be lost, for identification, person has to be present physically. Biometric is more reliable and capable than traditional knowledge based and token-based techniques. Biometric has also drawback i.e., if it is compromised then it is difficult to replace. Among all biometrics such as fingerprint, facial thermogram, hand geometry, face, hand thermogram, iris, retina, voice, signature etc.,

Iris-based Recognition is one of the most mature and proven technique. Iris is colored part of eye as in Figure1. A person's two eye iris has different iris pattern, two identical twins also has different in iris patterns because iris has many feature which distinguish one iris from other, primary visible characteristic is the trabecular meshwork, a tissue which gives the appearance of dividing the iris in a radial fashion that is permanently formed by the eighth month of gestation [27] and iris is protected by eyelid and cornea as shown in Figure1 therefore it increases security of the systems. Spoofing is very difficult with iris patterns as compare to other biometrics. In practical situation it is observed that iris part is occluded by interference of eyelids and eyelashes, improper eye opening, light reflection and image quality is degraded because of low contrast image and other artifact [14]. Advantages of Iris is that it is not subject to the effects of aging which means it remains in a stable form from about age of one until death . The use of glasses or contact lenses has little effect on the representation of the iris and hence does not interfere with the recognition technology [27].

Pupil is surround by colored part called Iris as in Figure1, which is unwanted part for our experiment, so pupil extraction is performed using scanning method which is simple in terms of computational complexity cost and thus reduces mathematical burden on the system, achieves high accuracy, increased correct recognition rate and reduced time for overall system performance. Once pupil is extracted, iris is located and iris texture is considered as iris feature which are then analyzed for person identification.

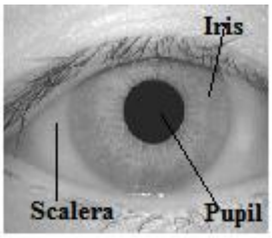


Figure1: Structure of Iris

Feature extraction is performed using five level decomposition technique using haar wavelet and daubechies wavelet. And perform comparision between wavelets and results are better with haar wavelet than daubechies (db2 and db4). Hence consider haar wavelet and image is passed with low pass filter and high pass filter with down sample factors and thus decompose up to five levels, thus decomposed image has 90 feature vector elements which are clear and sufficient to perform person identification efficiently.

Experiment results are evaluated based on parameters such as False Acceptance Rate (FAR), False rejection rate(FRR), Equal Error rate(EER) and Correct recognition rate(CRR). Number of times an unauthenticated person accepted by system is FAR; number of time an authentic person is rejected by the system is FRR. The point where FAR and FRR meets is EER, smaller the EER more accurate system performance i.e. CRR. Our results are very encouraging in terms of reduced EER and Increased CRR using scanning method and five levels decomposition technique.

2. OUTLINE OF THE PAPER

The paper is organized in the following manner; section (1) Introduction of the iris, in section (3) related work of different researcher who worked on iris recognition with feature extraction and with classifier listed in tabular form, in section (4) proposed research work with preprocessing i.e., image acquisition, iris localization & normalization, feature extraction with section (5), section (6), section(7) and section (8).In section (9) Matching and in section (10) experimental results and discussion, finally conclusion in section (11).

3. RELATED WORKS

Various approaches exist in the past for iris recognition for person identification which includes John Daugman's Iriscode [4]. However proposed work uses scanning method for pupil detection and iris localization and five level decomposition techniques for haar wavelet for iris feature extraction to get 90 feature vector elements for effective iris recognition. Advantages of proposed methods are its computational simplicity and speed. This method is less likely to be affected by environmental factors as compared to Gabor wavelet The Iris Recognition system's main work role is to provide compact and significant feature extraction algorithm for iris images with reduced false rejection rate. The extracted feature should have high discriminating capability and the segmented iris image should be free from artifacts [1]. Daugman [5] used Integro-differential operator for pupil detection and a multiscale quadrature two-dimentional (2-D) Gabor filter to demodulate phase information of an iris image to create an Iriscode for authentication by comparing the Iriscode stored in database. Li.Ma et al. [15] used Hough transformation and extracted features using spatial filter, this technique first converts the round image of the iris into rectangular pattern by unwrapping the circular image. Wildes et al. [21] uses Hough transform and gradient edge detection for pupil detection and Laplacian pyramid for analysis of the Irisimages. Boles and Boashash [29] uses zero-crossing method with dissimilarity functions of matching. Lim et.al.,[25] 2D Haar Transform for feature extraction and classifier used are initialization method of the weight vectors and a new winner selection method designed for iris recognition. A. Poursaberi and H. N. Araabi [1, 2] use wavelet Daubechies2 for feature extraction and two classifiers such as Minimum Hamming Distance and Harmonic mean. Li. Ma et al., [14] class of 1-D wavelet i.e., 1-D Intensity signals for feature extraction and for feature matching they have used expanded binary feature vector with exclusive OR operations. Md. Rabiul Islam et al., [19] used 4-level db8 wavelet transform for feature extraction and hamming distance with XOR for pattern matching. In our proposed research work will be using wavelets such as Haar, db2, and db4 for feature extraction and perform comparison on the basis of their performance evaluation. Use Hamming Distance classifier to matching binary strings with enrolled entity in the database. To fasten the matching speed, a lower number of bits i.e., 348 bits is used in composing the iris code, as compared with other methods such as 2048 bits in [4,5]. Comparision of iris feature extraction and classifier algorithm are as shown in Table 1.

4. PROPOSED RESEARCH MODEL

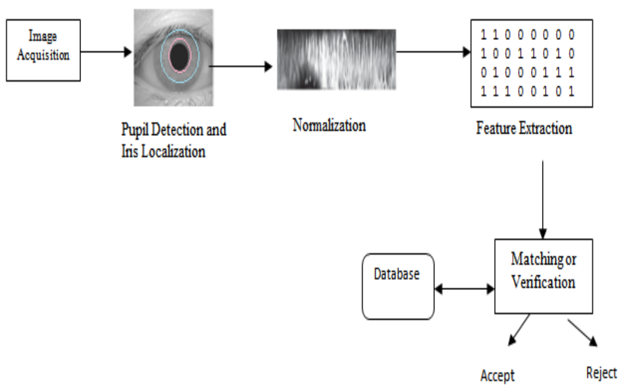


Figure2: step by step process for the proposed system

This section gives details of the proposed system as in Figure2. The system is consisting of 5 steps process to achieve the results. Therefore proposed systems steps are as follows:

Step1: **Image Acquisition**: It is the process of acquiring image, which is done using CCD camera.

Step2: **Iris localization**: when eye is captured in CCD camera, next need to acquire only iris pattern, extracting pupil part.

Step3: **Iris Normalization:** After extracting pupil achieve circular iris, which is to be converted to rectangular form.

Step 4: **Feature Extraction:** Decomposing and formation of iris pattern into iris codes.

Step 5: **Matching or Verification:** accept or reject by comparing stored enrolled pattern of database with submitted pattern.

5. IMAGE ACQUISITION

To capture high quality images for automated iris recognition systems is a major challenge. As given that the iris is a relatively small typically about 1 c.m. in diameter, and pupil is dark object, human are sensitive about their eyes [27], this matter requires careful engineering. Acquiring images of Iris is major aspect of the research work with good resolution and sharpness for recognition system need to maintain adequate intensity of source. Image acquisition is considered the most critical and important step to accomplish this used a CCD camera. Furthermore, took the eye pictures while trying to maintain appropriate settings such as lighting and distance to camera. In our research work, publicly available database i.e., Institute of Automation, Chinese Academy of science (CASIA) [30] is used which contains 756 grayscale images of eye with 108 unique eyes or classes and seven different images of each eye are considered for our work.

6. IRIS LOCALIZATION

6.1 Pupil Detection using Scanning method

In our proposed method scanning method for detection of pupil, this method has reduced computation complexity with reduced mathematical burden to our system. Daugman [6] uses Integro differential operator which has mathematical burden to system, Wildes et.al[10] uses gradient based edge detection, Poursaberi and Araabi [1] uses image morphological operator and suitable threshold and Li Ma [14] uses canny edge detector. Our proposed algorithm is as follows:

Step1: Read the original image from database as shown in Figure1.

Step2: Draw Histogram of original image and calculate threshold value of pixel intensity for pupil is darker. As shown in Figure 3.

Step3: Mark and fix LF(left) pixel point as start point on x-axis and begin scanning on x-axis, as pupil is dark part of the eye, so dark pixel is assigned with value as 0 and for grey pixel that is end of the dark pixel mark and fix it as RT(Right) pixel point and assign value as 1.

Step4: Similarly Mark and Fix UT (UpperTop) pixel point and scan on y-axis, dark pixel assign value as 0 and where the dark ends mark and fix it to LB (LowerBottom) pixel assign the value as 1.

Step5: To locate center C of pupil compute as in Figure5,

$$C= [(LF+RT)/2, (UT+LB)/2]$$

Step 6: Determining pupil radius (PR)

$$PR1= abs (RT-C)$$
$$PR2= abs (C-LF)$$
$$PR3= abs (UB-C)$$
$$PR4= abs(C-UT)$$
$$Pradius\_array [PR1, PR2, PR3, PR4]$$
$$PR=max [Pradius\_array]$$

Now locate four points on the circumference of the pupil with LF(Left), RT(Right), UT(UpperTop), and LB(LowerBottom) as shown in Figure 5.Using region of interest based on color, pupil is detected but must know the threshold value based on pupil intensity. To find the threshold value of pupil intensity, draw the histogram of original image, which gives graphical representation between numbers of pixels v/s pixel intensity. As the pupil is black in color, the pupil pixel intensity lies closer to zero. Pupil has moderate size. Determine maximum number of pixels for intensity value, which is closer to zero. That value is threshold value of pupil intensity. If some noise occurs with pupil image, due to eye lids or eyelashes remove it. This means that there are certain pixels which lies near the pupil are of part of the iris section but having gray levels in the range of 0 to 5O. For pixels used a standard library function bwareaopen() which removes pixels having less number of count than a certain threshold. The formula for threshold (T) is as in eq1.

$$g (m, n) =1 \text{ if } (m, n) \leq T \qquad (1)$$

Figure1 shows the original image from database, Figure3 shows histogram of the original image, Figure4 shows image with only pupil constructed using thresholding. Results are quite encouraging in terms of computational complexity in seconds and improved accuracy as shown in table2 and graph Figure6.

Therefore our method is simple with less mathematical burden to system and efficiency is achieved.

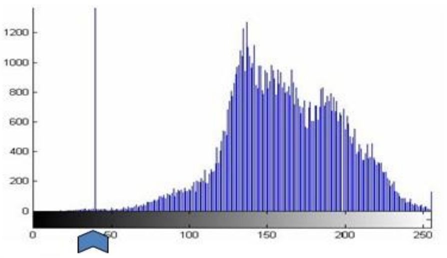


Figure 3: Histogram of original image

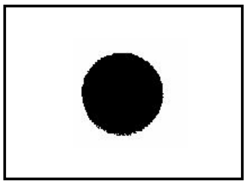


Figure 4: Image with only pupil

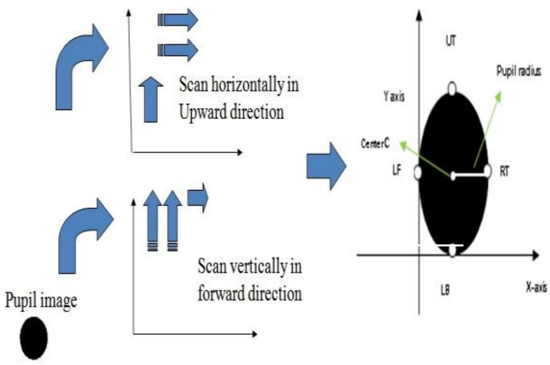


Figure 5: Four coordinate points (UpperTop(UT), LowerBottom(LB), left(LF), and right(RT))

Table 2: Computational complexity cost for pupil detection

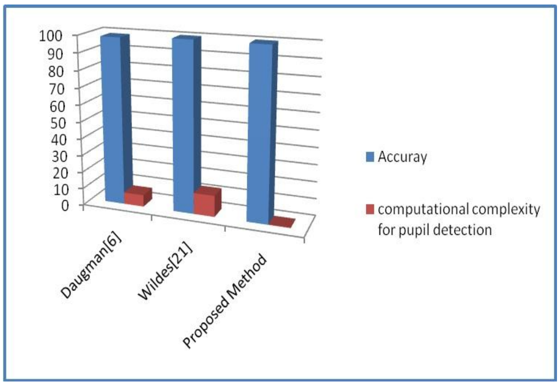
Methods	Accuracy (%)	Computation complexity(Secs)
Daugman[6]	98.6	6.99
Wildes[21]	99.9	12.54
Proposed Method	99.97	0.32

6.2 Iris radius

In our research work consider the iris radius (as in eq2) [1].

Iris_ radius = pupil_radius + 38 (2)

Where 38 pixel elements are defined in [1], add this to pupil radius to obtain Iris radius. Thus pupil is extracted



Fgure6: comparision of proposed method with others

from input image and iris is located, which is used for further processing.

7. IRIS NORMALIZATION

Steps for normalizing Iris image.

- Use of Daugman's rubber sheet model.
- Representing Cartesian to polar coordinates.
- Output normalized iris image.

Detection of pupil is once completed then iris section can be extracted easily. In our proposed system consider small part of iris section for further processing, so consider lower half part of iris section because most of the time upper iris section is densely covered by the eyelashes which can affect and decreases the accuracy of the system. In our proposed work consider CASIA database. As iris should be isolated and stored as separate image because of its limits such as occluded iris part or iris covered with eyelashes and also observe that possibility of pupil dilating and appearing in terms of different size of pupil for different images. So, need to change the coordinate system by unwrap the lower part of the iris i.e., lower 180 degree and mapping all the points within the boundary of the iris into their polar equivalent using Daugman's rubber sheet model as shown in Figure7. The size of the mapped image is fixed which means that taking an equal amount of points at every angle. In our proposed research work consider region of interest which is then isolated and transformed to a dimensionless polar system. The process is achieved to be a standard form irrespective of iris size, pupil diameter or resolution. Algorithm is based on Daugman's stretched polar coordinate system. Working idea of the dimensionless polar system is to assign 32 pixels along r and 180 pixels along ϴ value to each coordinate in the iris that will remain invariant to the possible stretching and skewing of the image and results with unwrapped strip of 32 X 180 sizes. Thus the process gives us the normalized image as in figure8.

Remapped image is called normalized image, which is remapped for lower 180 degrees and following figures shows the results, Figure9 (a) shows original image Figure9 (b) shows localized iris and Figure9(c) and (d) shows iris normalization (isolated image for lower half), Figure9 (e) Enhanced iris image and Figure9(f) region of interest if iris is occluded. The remapping of the iris image $I(x, y)$ from raw Cartesian coordinate to polar coordinates $I(r, \theta)$ can be represented as in eq 3.

$$I(x(r, \theta), y(r, \theta)) \longrightarrow I(r, \theta) \quad (3)$$

Where r radius lies in the unit interval (0, 1) and θ is the angle between (0, 2π).

The eq. 3 yields from eq. 4 and eq.5 and they are

$$x(r, \theta) = (1-r)*x_p(\theta) + r*x_i(\theta) \quad (4)$$

$$y(r, \theta) = (1-r)*y_p(\theta) + r*y_i(\theta) \quad (5)$$

Where $(x_p(\theta)), y_p(\theta))$ and $(x_i(\theta), y_i(\theta))$ are the coordinates of pupil and iris boundary points respectively.

The normalization step not only reduces exactly the distortion of the iris caused by pupil movement and also simplifies subsequent processing [22].

After normalization, results are not appropriate to quality of iris image due to light sources and other reasons which later affect to performance of feature extraction and matching process.

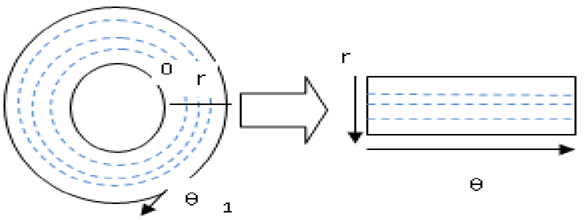


Figure 7: Daugman's Rubber sheet model with annular iris zone is stretched to a rectangular block and dashed lines are sampling circles.

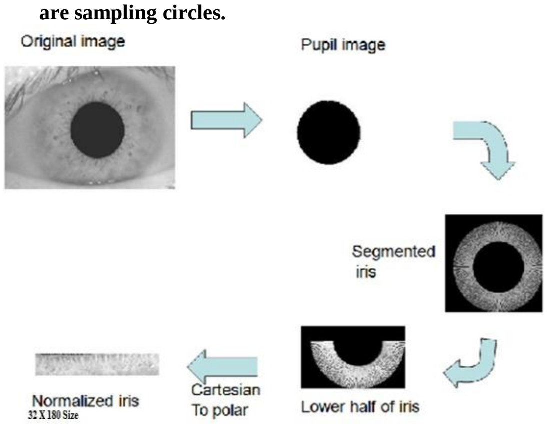


Figure 8: The process of Cartesian to polar coordinate system

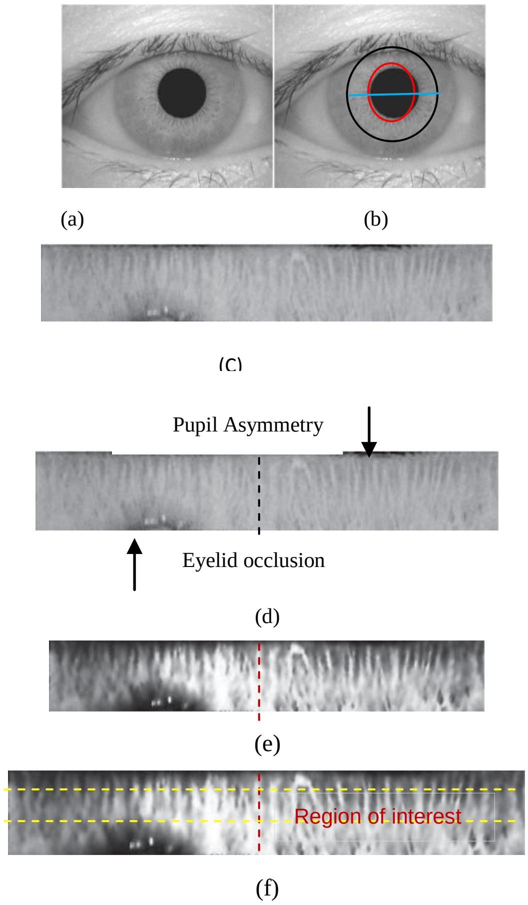


Figure 9: (a) Original Image (b) localized iris (c) & (d)Normalization of original image(Iris isolated image of lower half) (e) Enhanced iris (f) Region of interest

8. FEATURE EXTRACTION

The iris has abundant texture information, so to provide accurate recognition of individual extract the pattern of the iris image with out noise so that quality of matching will be enhanced. In our proposed system Haar wavelet and daubenchies wavelet(db2 and db4) are used for extracting feature. The following steps for feature extraction.

1. Apply 2D DWT with Haar and Daubenchies(db2 and db4) up to 5-level decomposition.
2. Using 4^{th} level, 5^{th} level decomposition details constructed the feature vectors.
3. Feature vectors are in the form of bianaries.
4. Store these feature vectors.

In the research work of M. Nabti et. al.,[8] proposed the feature extraction using wavelet maxima components first and then applying Gabor filter bank to extract all features. The decomposition level considered by Shimaa M. Elserief et. al.,[11] are four level using 2D discrete wavelet transform(DWT) with four sub bands at each stage. Gabor and Wavelet transform are typically used for analyzing the persons iris patterns and extraction of features from them[2,5,16,17,22,26]. In our proposed work, five level decomposition technique which is considered with 2D(DWT) as in Figure10 (a). Performance evaluation is done for differnet wavelet such as Haar wavelet, Daubenchies wavelet(db2 and db4). Wavelet algorithms have the advantage of better resolution for smoothly changing time series. But they have the disadvantage of being more expensive to calculate than the Haar wavelets. The higher resolution provided by these wavelets is not worth the cost for financial time series, which are characterized by jagged transitions. Haar wavelet is defined by a function ψ(t) which is described as in eq6.

$$\psi(t) = \begin{cases} 1 & 0 \le t \le 1/2 \\ -1 & \frac{1}{2} \le t \le 1 \\ 0 & otherwise \end{cases} \quad (6)$$

and scaling function φ(t) can be described as in eq8

$$\varphi(t) = \begin{cases} 1 & 0 \le t \le 1 \\ 0 & otherwise \end{cases} \quad (7)$$

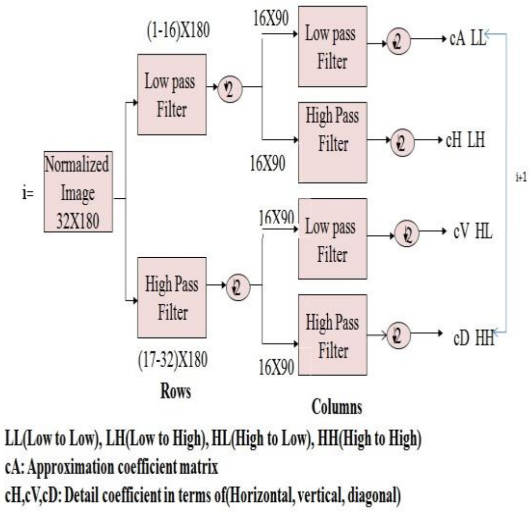
Feature extraction carried by [2,5,19] uses Gabor wavelets to extract patterns but they lack with less computational time, if implemented using artificial neural network for feature extraction[20] it is time consuming i.e. lack with less efficiency and computational complex. So, proposed system uses five-level decomposition technique with haar wavelet (as in Figure10(c), decomposed diagram is as shown Figure10(a) and conceptual diagram in Figure 10(b). Why five level decomposition Technique? Because decomposing images with a wavelet transform yields a multi-resolution from detailed image to approximation image in each levels considering image of size N X M (320 X 280) and decompose up to K^{th} level where K=1,2,3,4,5. The quadrants (sub images) with in images as the LH(Low pass filter to High pass filter), HL(High pass filter to Low pass filter) and HH(High pass filter to High pass filter) represents detailed i.e. images for horizontal, vertical and diagonal orientation in the first level. The sub images LL (Low pass filter to Low pass filter) corresponds to an approximation image that is further decomposed, resulting in further decomposed image which level two. Obtain 5^{th} level wavelet tree showing all detail and approximation coefficients these levels are CV_1 to CV_5 (vertical coefficient), CH_1 to CH_5 (horizontal coefficient), CD_1 to CD_5 (diagonal coefficient). After 5^{th} level, combine vertical, Horizontal and Diagonal coefficients of 4^{th} level and 5^{th} level i.e., LH4, HH4, HL4, LH5, HH5, HL5 obtains feature vector of 90 elements which are sufficient for person identification efficiently. Figure12 shows the conceptual diagram for organizing feature vector by five level decomposition of normalized image and decomposition steps are as follows:

- **Step 1**: Input normalized image, i.
- **Step 2**: Consider rows blocks, call Low Pass Filter (LPF ()) and High Pass Filter (HPF ()) functions.
- **Step 3**: Down sample columns by 2 and Keep even index columns.
- **Step 4**: Consider column blocks, call LPF() and HPF() functions.
- **Step 5**: Down sample Rows by 2 and keep even index rows.
- **Step 6**: Convolve Rows and Columns of filter entries.
- **Step 7**: store in Approximation matrix coefficient and Detail matrix coefficient in term of Low to Low(LL) for approximation, Low to High(LH) for Horizontal, High to Low(HL) for vertical and High to High(HH) for Diagonal.
- **Step 8:** Output Decomposed image for level 1.
- **Step 9:**Repeat step 2 to step 7 for i+1 image and decompose image for Level 2, level 3, level 4, level 5.

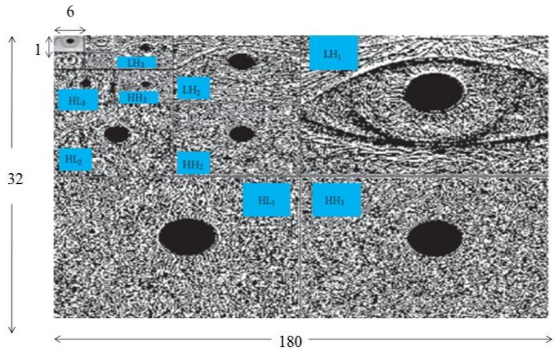
Figure11 shows the results of first level decomposed image with coefficient such as approximation coefficient, first horizontal coefficient, vertical coefficient and diagonal coefficient, size of the first decomposed images are 16 X 90 pixels. Similarly obtain second level decomposition approximation, horizontal, vertical, diagonal details has the size 8 X 45. In third level decomposition approximation, horizontal, vertical, diagonal details have size 4 X 23. In forth level decomposition approximation, horizontal, vertical, diagonal details have size 2 X 12. In fifth level decomposition approximation, horizontal, vertical, diagonal details have size 1 X 6. Now pick up the coefficients that represent the core of the iris pattern. Therefore those that reveal redundant information should be eliminated. In fact, it is obvious that the patterns in the cD_1^h, cD_2^h, cD_3^h, cD_4^h, are almost the same and only one can be chosen to reduce redundancy. Since cD_4^h repeats the same patterns as the previous horizontal detail levels and it is the smallest in size, then take it as a representative of all the information the four levels carry. The fifth level does not contain the same textures and should be selected as a whole. In a similar fashion, only the fourth and fifth vertical and diagonal coefficients can be taken to express the characteristic patterns in the iris-mapped image. Thus represents each image applied to the Haar wavelet as the combination of six matrices i.e. cD_4^h, cD_5^h, cD_4^v, cD_5^v, cD_4^d and cD_5^d. These matrices are combined to build one single vector characterizing the iris patterns. Such vector is called Feature vector. Since all mapped images have a fixed size of 320 X 280 then all images will have a fixed feature vector. In our proposed work consider the vector size of 90 elements. This shows that feature vector have successfully reduced as compared to Daugman[4,5,6] uses a vector of 1024 elements as he always maps the whole iris even if some part is occluded by the eyelashes, while map only the lower part of the iris obtaining almost half the feature vector's size. After achieving feature vector, need to represent it in a binary code as it is easy to make the difference between two binary code words than between two number vectors. Thus Boolean vectors are always easier to compare and easier to manipulate. After observing characteristic, code the feature vector by considering the condition (as in eq. 8) results the vectors have maximum value greater than 0 and a minimum value that is less than 0 i.e. if Coef is the feature vector of an image than the following quantization scheme converts it to its equivalent code word

$$\text{If Coef (i)} \geq 0 \text{ then Coef (i)} = 1$$
$$\text{If Coef} < 0 \text{ then Coef (i)} = 0 \quad (8)$$

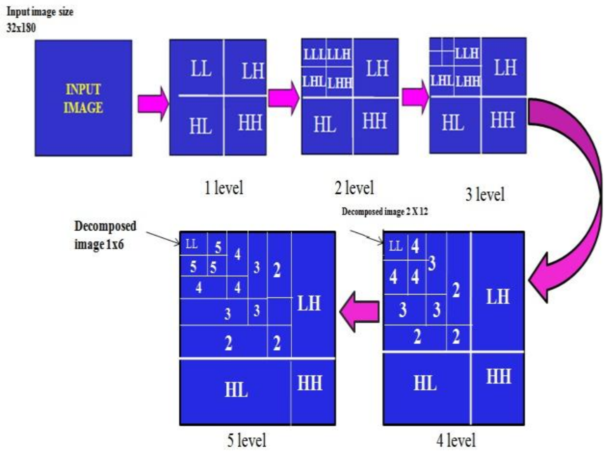
After representing in binary coding scheme, need to match the two codes to check whether it belongs to same person or not. The cost for computational complexity in milliseconds is best achieved with decomposition technique of image up to five levels using 2D Haar wavelet and it is fast as compared to other methods for feature extraction. Our method takes 78.0(ms) which is best as compared to Daugman [6] method takes 682.5(ms) and method proposed by Li ma et.al [16] takes 720.3(ms) as shown in table3 and comparative graph in Figure 12.



(a)



(b)



(c)

Figure10 (a), (b) and (c) 5- level decomposition technique

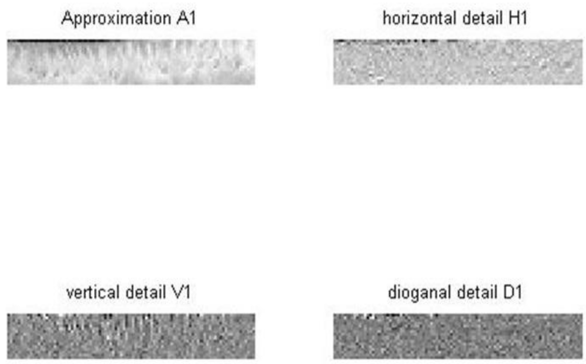


Figure 11: First level decomposed image with coefficient matrix

Table 3: Computational complexity cost for feature extraction

Methods	Feature Extraction (in ms)
Daugman[7]	682.5
Wildes et al.[22]	210.0
Boles et al.[29]	170.3
Li Ma et al.[16]	260.2
Proposed Method	78.0

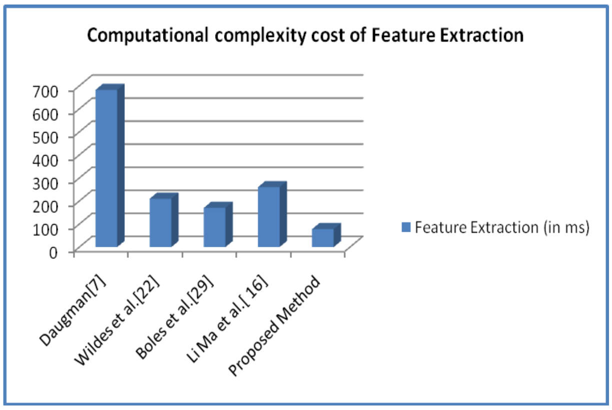


Figure 12: Comparative graph for feature extraction

9. MATCHING

Calculate two irises from the same class and compare between two feature vectors. Conceptualizing using Daugman's [4, 5, 6, 7, 9], develop step by step pseudocode approach which is proposed to perform matching process using Hamming Distance. Hamming distance is beneficiary as it performs XOR operation on Boolean vectors.

Step 1: Compare Query image feature vector with stored image feature vector of database.

Step 2: Hamming Distance is calculated for each image feature vector.

Step 3: Finally Calculate minimum Hamming Distance.

If Hamming Distance between two feature vectors is greater, difference between them is also greater. Two similar irises will fail the test since the difference between them will be small. The Hamming Distance (HD) between two Boolean vectors is defined (as in eq (9)).

$$HD=\frac{1}{N}\sum_{j=1}^{N} C_A(j) \oplus C_B(i) \quad (9)$$

Where C_A and C_B are the coefficients of two iris images, N is the size of the feature vector, Ex-OR is the Boolean operator that gives a binary 1 if the bits at the position j in C_A, C_B are different and 0 if they are similar. Daugman [9] conducted tests on very large number of iris patterns i.e. up to 200 Billion irises images and resulted that the maximum Hamming distance that exists between two irises belonging to the same person is 0.32.

- If HD<= Threshold then Match successful.
- If HD> Threshold then Match unsuccessful i.e. different person or left and right eye iris of the same person.

10. EXPERIMENTAL RESULTS AND DISCUSSION

10.1 Data set

In our proposed system experimental results are concluded in two modes i.e., identification or training the images to perform 1: m matching in the set and verification is the process of testing the images enrolled during training which is consider to perform 1:1. our system has 756 trained images as using Institute of automation Chinese academy of science(CASIA) database with 108 unique eyes or classes and 7 different images of each unique eye in BMP format with resolution of 320*280 [16,24]. Evaluation is performed using Hamming Distance between two irises with MATLAB7.0 software. Hence consider lower 180 degree portion of iris as it is sufficient for recognition of the person. The implementation process is done by using wavelets such as Haar, db2, db4 algorithms and the frequency distribution for HD is calculated which is as shown in figure13, score distribution of intraclass and interclass hamming distance for imposter and genuine of the system is calculated and graph as shown in Figure14.

10.2 Results

Calculate and plot score distribution for system's Intra class i.e., testing the image with in the class and inter class i.e., testing image with other class, achieve false match rate and false non match rate as show in Figure15, our system results are quite encouraging with false Non match rate of 0.025% and False match rate of 0.033% for Haar wavelet with different hamming distance. HD distribution for intra class and interclass overlap each other to get the separation between them requires FAR and FRR, if smaller HD then FAR reduces and FRR increase and if HD increases then FAR increases and FRR decreases as illustrated in Figure14. Also compute ROC as in Figure15 with EER of 0.03, FRR of 0.025, FAR of 0.033% and compute Correct Recognition Rate (CRR) is the ratio of the no. of samples being correctly classified to total number of test samples and results with CRR of 99.97%. False Rejection Ratio (FRR) is the ratio of number of times person rejected to number of comparision between same person and if the hamming distance is greater than threshold value then the image is rejected, the graph and results are as shown in (table 4 and Figure16).The FAR and FRR is calculated for the system for different HD using the formula as in eq 11 and eq 12

$$FAR=\frac{No.of\ times\ different\ persons\ match}{No.of\ comparissions\ between\ different\ persons} * 100 \quad (11)$$

$$FRR = \frac{No.of\ times\ persons\ rejected}{No.of\ comparissions\ between\ same\ persons} * 100 \quad (12)$$

Statistical analysis is performed based on parameters such as computational Time, Feature vector size, FAR, FRR, Accuracy and Match Ration. Calculate computational time for system with testing dataset of images and different wavelet transforms are used to find feature vector. Considering threshold value 0.32 which is maximum hamming distance that exists between two irises belonging to the same person tested by Daugman on up to 3 million iris images [15]. In all wavelet such as Haar, db2 and db4, system performance results are encouraging with haar wavelet as its system accuracy is improved with reduced EER of 0.03% and increased CRR of 99.97% and computation time of 16.79(Secs).

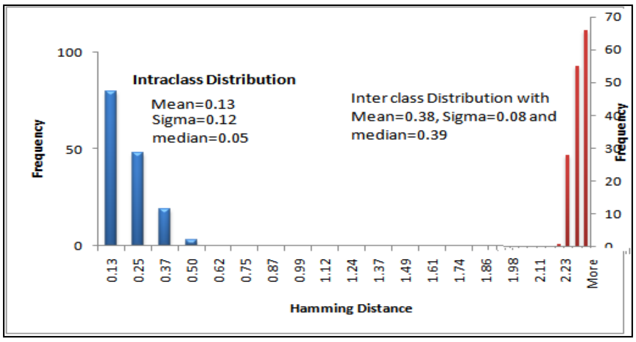


Figure13: frequency distribution of HD for intraclass and interclass

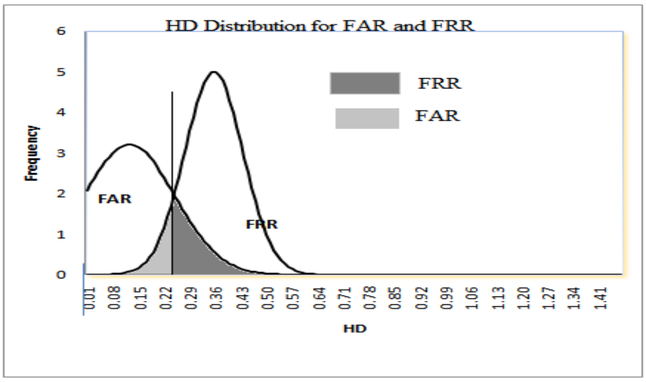


Figure14: score distribution for imposter and genuine for different hamming distance

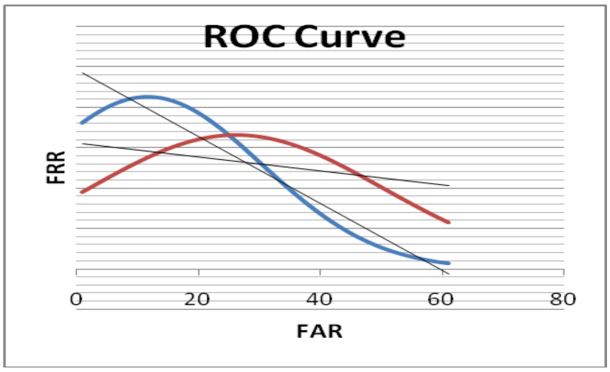


Figure 15: ROC curve for the system for different HD

10.3 Comparision and Discussion

The previous existing proposed methods for iris recognition by Daugman [4, 5], Wildes [22], Boles et al. [29], and Li Ma et al. [16] are the best know. Moreover they explain and present different way of details for iris recognition in identification and verification modes. Poursaberi [1] works on wavelet for partially occluded iris texture image, Li Ma[3,16] also works on iris texture analysis and give encouraging results as comparing other methods Daugman results are quite encouraging in terms of accuracy and efficiency. Therefore, analyze and compare our proposed work with exiting methods. Our method uses CASIA Iris database for verification and identification modes and found that our results are also encouraging in terms of accuracy, efficiency and reduced computational complexity. Make comparison of our results with methods [1, 4, 5, 16, 22, 29] of their published results. Table 4 and Figure17 gives the comparison in terms of CRR and EER.Table4 shows Daugman [7] method is the best as it achieves 100% CRR and EER is of 0.08, our proposed system shows encouraging results with reduced EER of 0.03 and recognition rate of CRR is 99.97 and EER achieved by our system is less than methods proposed by [1, 7, 16, 22, 29]. Figure16 also depict comparision graph for the table4, Daugman [7] reached high accuracy with recognition rate of 100% and next our method is reaching 100. Boles [29] method has increased EER than other methods.

The experimental results depicts that our proposed method is much better than Wildes et al. [22], Boles et al. [29], Li Ma [16] and Poursaberi and Araabi [1]. Achieve high accuracy with decomposed image (five levels) using Haar wavelet.

Lim et al. [25] uses four level high frequency information of an iris image's 2-D Haar wavelet decomposition for feature extraction which results with very less accuracy, so their does not provide quality of feature vector . Our method and Daugman's algorithm achieve good quality of feature vector so accuracy is also impressive as our method is little lesser than Daugman's method in terms of identification and verifications which is as shown in Table4 and Figure17. As know Daugman uses demodulated phase information instead of decomposition and achieve small local region using multi-scale quadrature wavelets and then quantized the resulting phasor denoted by a complex-valued coefficient to one of the four quadrants in the complex plane. This results in high accuracy. This makes Daugman method is slightly better than our method. Also make comparison based on computational cost for the methods of Daugman [7], Wildes [22], Boles et al. [29], Li Ma [16] and our proposed algorithm on the bases of Feature Extraction from preprocessing image to form feature vector and Matching from feature vector generated for images to query image using XOR operation to match bit by bit and calculating Processing time in milliseconds. Table3 illustrates comparision of computational complexity cost for feature extraction in terms of milliseconds. Since Boles et al. [29] shows less cost time as it is takes 170.3(ms), as it is based on 1-D signal analysis. The method proposed by Wildes[22] also shows the encouraging results in terms of cost in time for feature extraction as it takes 210.0(ms) as to build a four-level Laplacian pyramid representation of an images. Daugman's method has highest encouraging results for matching as it has very less cost of time i.e. 4.3(ms) which is the fastest among other methods, as this method uses XOR operation to compute the distance between a pair of feature vectors in C/C++. Our proposed method also uses XOR operation to compute the distance between pair of feature vectors in Matlab7.0 on 32bit machine as matching time is better than methods proposed by [7, 16, 29] but less than method proposed by Wildes et al. [22].

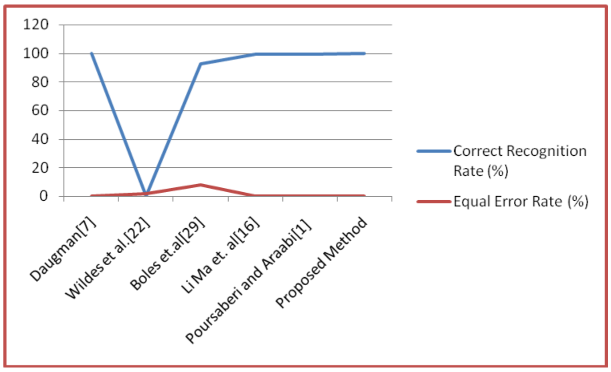


Figure 16: Comparision of CRR and EER

Table4: Comparision of CRR and EER

Methods	Correct Recognition Rate (%)	Equal Error Rate (%)
Daugman[7]	100	0.08
Wildes et al.[22]	-	1.76
Boles et.al[29]	92.64	8.13
Li Ma et. al[16]	99.60	0.29
Poursaberi and Araabi[1]	99.31	0.2687
Proposed Method	99.97	0.03

10.4 Future work

Our experimental results demonstrates that enhance method for pupil extraction and five level decomposition for iris image has significantly encouraging and promising results in terms of EER and CRR. Our Feature work will include:

- Improving effectiveness in matching in terms of computational cost time.
- We are also currently working on global textural analysis with more levels of decomposition with accurate feature
- Extraction for larger database similar to Daugman's methods.

11. CONCLUSION

In this paper, enhancing iris recognition algorithm based on Haar wavelet with quality texture features of iris within feature vector, even though obstruction of eyelashes and eyelids and our proposed method also works perfect for narrowed eyelid as proposed method consider small part of the iris even though it is occluded. So, it increases the overall accuracy of the system with less computational cost in terms of time as compared with methods of Daugman[7] and Li Ma[16] and high recognition rate with reduced EER,FAR,FRR. The results also show the performance evaluation with different parameters with different class of variations i.e., Inter class hamming distance variation and Intra class hamming distance variation.

REFERENCES

[1] A. Poursaberi and H. N. Araabi, Iris Recognition for Partially Occluded Methodology and Sensitivity Analysis, *EURASIP journal on "Advances in Signal* processing, Vol. 2007, Article ID 36751, (2005).

[2] A.Poursaberi and B.N.Araabi, A Half Eye Wavelet Based for Iris Recognition *proceeding of the 2005,5th International*

Conference on Intelligent Systems Design and Applications (ISDA'05, (2005).

[3] Amol D. Rahulkar, R.S. Holambe, "Half-Iris Feature Extraction and Recognition using a New Class of Biorthogonal triplet Half-Band Filter Bank and Flexible k-out-of-n: A postclassifier", IEEE Transactions on Information Forensics and Security, Vol. 7, No.1, Feb 2012.

[4] J.Daugman, How Iris Recognition works, proceedings of 2002 International conference on Image processing, vol.1, (2002).

[5] J.Daugman, High confidence visual recognition of persons by a Test of statistical Independence, IEEE Transactions on pattern analysis and machine intelligence, vol.15, no.11, (1993) ,pp1148-1161.

[6] J.Daugman, How Iris Recognition works, IEEE Transactions on Circuits and systems for video Technology, Vol. 14, No. 1, Jan 2004.

[7] J.Daugman , Statistical Richness of Visual Phase Information: Update on recognizing persons by Iris patterns, International Journal of computer vision, Vol.45, No.1, (2001), pp.25-38.

[8] Jafar M. H. Ali, Aboul Ella Hassanien , An Iris Recognition System to Enhance E-security Environment Based on Wavelet Theory, AMO-Advance Modeling and Optimization, vol. 5, No. 2, (2003).

[9] John Daugman, Probing the Uniqueness and Randomness of IrisCodes: Results from 200 Billion Iris Pair Comparisons, Proceedings of the IEEE, Vol. 94, Issue: 11, (Nov 2006), pages: 1927-1935.

[10] Karu K, Anil Jain K, and Bolle R M, Is there any texture in the Image?, IEEE Transactions on Pattern Recognition, Vol. 29, No. 9, (1996), pp.1437-1446.

[11] Kevin W.Bowyer, Karen Hollingsworth, Patrick J. Flynn, Image understanding for iris biometrics: A survey, Elsevier computer vision and Image Understanding 110, (2008), pg no. 281-307.

[12] L.Ma, Y.wang, T.Tan , Iris recognition Based on multichannel Gabor Filtering, Proc. of the 5th Asian conference on computer vision, vol.I, (2002), pp.279-283.

[13] L.Ma, Y.wang, T.Tan, Iris Recognition using Circular Symmetric Filters, proc. of the 16th International Conference on pattern recognition, vol.II, (2002), pp.414-417.

[14] Li Ma, T. Yunhong Wang, and D. Zhang ,Personal identification based on iris texture analysis, IEEE Transactions on Pattern Analysis and machine Intelligence, vol.25, (2003), no.12.

[15] Li Ma, Tieniu Tan, Yunhong Wang and Dexin Zhang, Efficient Iris Recognition by Characterizing Key Local Variations, IEEE Transactions on Image processing, Vol. 13, No.6, (June 2004).

[16] Li. Ma, et al., Local Intensity Variation Analysis for Iris Recognition, Elsevier- Pattern Recognition, vol.37, No.6, (2004) , pp.1287-1298.

[17] Makram Nabti, Lahouari Ghouti and Ahmed Bouridane , An effective and fast iris recognition system based on a combined multiscale feature extraction technique, Elsevier-Pattern Recognition 41, (2008), pg no. 868-879.

[18] Mayank vatsa, Richa singh, Afzel Noore, Improving Iris recognition performance using segmentation, Quality Enhancement, Match Score Fusion, and Indexing, IEEE Transactions on Systems, Man, and Cybernetics B, Cybern., vol. 38, no. 4, (Aug. 2008), pp.1021-1034.

[19] Md. Rabiul Islam, Dr. Wang Yin Chai, Asma Khatun, Partial Iris Image Recognition Using Wavelet Based Texture Features, International Conference on Intelligent and Advance Systems (ICIAS), (2010) .

[20] Mao, Jianchang, Jain, Anil K, "Artificial neural network for feature extraction and multivariate data projection", IEEE Transactions on neural network, Vol. 6, issue 2, Mar 1995, pages: 296-317.

[21] R.P.wildes, Iris Recognition: An Emerging Biometric Technology, Proceeding of the IEEE, vol. 85, (1999), pp 1348-1363.

[22] R.Wildes, J.Asmuth, G. Green,S. Hsu, R. Kolczynski, J. Matey and S.McBride , A machine-vision system for Iris Recognition, Machine vision and Applications, vol.9, (1996), pp1-8.

[23] R.Wildes et al., Machine Vision System for Iris Recognition, Machine Vision and Applications, Vol.9, (1996), pp. 1-8.

[24] Richard Yew Fatt Ng, Yong Hour Tay, Kai Ming Mok, A Review if Iris Recognition Algorithm, IEEE Transaction, DOI 978-1-4244-2328-6/08, 2007.

[25] Robert W. Ives, Anthony J. Guidry and Delores M Etter ,Iris Recognition using Histogram Analysis, *IEEE conference on signal*, system and computer, (2004) , pp. 562-566.

[26] S.Lim, K. Lee, O. Byeon, T. Kim, Efficient Iris Recognition through Improvement of Feature Vector and Classifier, ETRI Journal, Vol. 23, No. 2, (June 2001),pp. 61-70.

[27] S. Mallat, W. Hwang, singularity detection and processing with wavelet, IEEE Transaction on information Theory, 38(2):617-643,(1992).

[28] Shimaa M.Elsherief, Mahmoud E. Allam, Mohamed W. Fakhr, Biometric Personal identification Based on Iris Recogition, International conference on computer Engineering and Systems, on (Nov 2006),page 208-213, 5-7.

[29] W.Boles and B.Boashash, A Human Identification Technique using Images of the Iris and wavelet transform", IEEE Transactions on signal processing, Vol. 46, No. 4, (April 1998).

[30] http://www.sinobiometrics.com/resources.htm.

Table1: List of iris feature extraction and Matching Algorithm of different researcher's.

Sl. No.	Researcher's methods	Feature Extraction	Matching Process	Feature vector	Results
1	Daugman[2]	2D Gabor	Hamming Distance with XOR	Binary i.e., 2048 bit phase vector	300 MHZ CPU, search are performed at the rate of about 100,000 iris per second.
2	Wildes [6]	Laplacian pyramid & Gaussian Filters	Normalized Hamming Distance with exclusive OR operator	256 bytes	-
3	A.Poursaberi & H.N. Araabi[11][12]	Wavelet Based Feature extraction	Minimum Hamming Distance(MHD) & Harmonic mean	408(544) binary feature vector	CRR is 99.31% & ERR is 0.2687%
4	Vatsa et al.,[18]	1-D log polar Gabor Transform & Topological feature extraction using Euler No.	2v-SVM method for matching the texture & topological features	-	Performance in terms of accuracy is 97.21%
5	Makram Nabti et al.,[19]	Wavelet maxima component as multiresolution technique & special Gabor filter bank	Hamming Distance with XOR	Statistical feature with 480 vector elements & moments invariants using 1680 vector elements	Feature extraction computational complexity (ms), statistical feature: 74 Moment invariants: 81
6.	Amol D. Rahulkar et al.,[13]	Biorthogonal Triplet Half Band Filter Bank(THFB)	Flexible k-out-of-n: postclassifier	7 integer values per region	Low computational complexity with significant reduced FRR.
7	Lim et al.,[3]	Haar wavelet Transform	LVQ neural network	87 dimensions (1bit/dimension) i.e.,87bits	Recognition performance is 98.4%
8	L. Ma et al.,[14]	Class of 1-D Wavelets i.e., 1-D Intensity signals	Expanded binary Feature vector & Exclusive OR operations	Vector consists of 660 components & represented in byte.	CRR is 100 % & EER is 0.07% & computational complexity is 250.7(ms)
9	Md. Rabiul Islam et al.,[16]	4-level db8 wavelet transform	Hamming Distance with XOR	Binary codes of 510 bits	CRR is 98.14% & ERR is 0.21%
10	Proposed Method	5-level Wavelet transformation method such as Haar,db2,db4	Hamming Distance with XOR	FV of 90 bits	EER=0.03% CRR=99.97%