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A Dimensionality Reduced Iris Recognition System with Aid of AI Techniques

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Abstract- Technologies that exploit biometrics have the potential for the identification and verification of individuals designed for controlling access to secured areas or materials. One of the biometrics used for the identification is iris. Many techniques have been developed for iris recognition so far. Here we propose a new iris recognition system utilizing unbalanced wavelet packets and FFBNN-ABC. In our proposed system, the eye images obtained from the iris database are preprocessed using the adaptive median filter to remove the noise. After removing the noise, iris part is localized by using contrast adjustment and active contour technique. Then unbalanced wavelet packets coefficients and Modified Multi Text on Histogram (MMTH) features are extracted from the localized iris image. Then MMTH features extracted are clustered by using the MFCM technique. After clustering, the dimensionality of the features is reduced by using PCA. Then the dimensionality reduced features & unbalanced wavelet packet coefficients are given to FFBNN to complete the training process. During the training, the parameters of the FFBNN are optimized using ABC Algorithm. The performance of our proposed iris recognition system is validated by using CASIA database and compared with the existing systems. Our proposed iris recognition system is implemented in the working platform of MATLAB.

Keywords: feed forward back propagation neural network (FFBNN), adaptive median filter, unbalanced haar wavelet, modified multi text on histogram (MMTH), iris recognition, artificial bee colony algorithm (ABC), principle component analysis (PCA), modified fuzzy c-means (MFCM).

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N. Murali Krishna α & P. Chandra Sekhar Reddy σ

Abstract- Technologies that exploit biometrics have the potential for the identification and verification of individuals designed for controlling access to secured areas or materials. One of the biometrics used for the identification is iris. Many techniques have been developed for iris recognition so far. Here we propose a new iris recognition system utilizing unbalanced wavelet packets and FFBNN-ABC. In our proposed system, the eye images obtained from the iris database are preprocessed using the adaptive median filter to remove the noise. After removing the noise, iris part is localized by using contrast adjustment and active contour technique. Then unbalanced wavelet packets coefficients and Modified Multi Text on Histogram (MMTH) features are extracted from the localized iris image. Then MMTH features extracted are clustered by using the MFCM technique. After clustering, the dimensionality of the features is reduced by using PCA. Then the dimensionality reduced features & unbalanced wavelet packet coefficients are given to FFBNN to complete the training process. During the training, the parameters of the FFBNN are optimized using ABC Algorithm. The performance of our proposed iris recognition system is validated by using CASIA database and compared with the existing systems. Our proposed iris recognition system is implemented in the working platform of MATLAB.

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I. Introduction

Today, many countries are considering or even announced procurement of bio-metrically enabled national identity (ID) card schemes, one of whose purposes will be to detect and prevent multiple IDs [1]. Applications such as passenger control in airports, access control in restricted areas, border control, database access and financial services are some of the examples where the biometric technology has been applied for more reliable identification and verification [6]. Biometric is unique to each individual and is reliable [16]. Iris recognition is the most reliable biometric system available because of iris uniqueness [19], stability, permanency and easily taking [3]. Iris based recognition has been gaining popularity in recent years, and it has several advantages compared to other traditional biometrics such as finger prints and facial features [13]. Also, the probability of finding two people with identical iris pattern is almost zero [7]. That's why iris recognition technology is becoming an important biometric solution for people identification in access control [14].

More technically, the iris is part of the unveil, or middle, coat of the eye. It is a thin diaphragm stretching across the interior portion of the eye and supported by the lens [4]. Iris recognition is a method of biometric authentication that uses pattern-recognition techniques based on high-resolution images of the irises of an individual's eyes [2]. There are four main techniques in Iris Recognition System Namely: Segmentation, Normalization, Feature Extraction And Matching [12]. Iris recognition begins with finding an iris in an image, demarcating its inner and outer boundaries at the pupil and sclera, detecting the upper and lower eyelid boundaries if they occlude and detecting and excluding any superimposed eyelashes or reflections from the cornea or eyeglasses. These processes may collectively be called segmentation [1]. Iris normalization mainly involves two basic operations, one is to detect eye lids and the other is boundary detection. The first step involves extraction of circular shaped iris rim by removing the noisy regions. The second step is to detect the inner and outer boundaries of iris. [5]. The matching module generates a match score by comparing the feature sets of two iris images [11].

The great advantage of the authentication using iris recognition is the irreplaceable nature. It has various applications to high-security facilities, but it is now being widespread developed in information systems such as network, e-commerce, and retail applications [3]. Although, a number of iris recognition methods have been proposed, it has been found that several accurate iris recognition algorithms use multiscale techniques, which provide well-suited representation for iris recognition [10]. The main difficulty of human iris recognition is that it is hard to find the apparent feature points in the image and to keep their represent ability high in an efficient way [17]. The data are unique to the individual and remain so throughout one's life [8]. The performance of iris recognition systems highly depends on the segmentation process [9] which is a challenging problem [20].

The rest of the paper is organized as follows: Section 2 reviews the related works with respect to the

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proposed method. Section 3 discusses about the proposed technique. Section 4 shows the experimental result of the proposed technique and section 5 concludes the paper.

II. Related Works

Fernando *et al.* [21] have used a modular neural network architectures as systems for recognizing persons based on the iris biometric measurement of humans. In that system, the human iris database was enhanced with image processing methods, and the coordinates of the center and radius of the iris were obtained to make a cut of the area of interest by removing the noise around the iris. The input to the modular neural networks was the processed iris images and the output was the number of the person identified. The integration of the modules was done with a gating network method results demonstrate that the use of the human iris biometric measurement worked with modular artificial neural networks and favorable results of person identification were obtained.

Kodituwakku *et al.* [22] have attempted to develop an algorithm for iris recognition based on Fuzzy logic incorporated with the visible properties of the human iris function. They were considered the visible features of the human iris such as pigment related features, features controlling the size of the pupil, visible rare anomalies and pigment frill. First they extracted the important and essential feature of a human iris image. Secondly, as an AI technique, Fuzzy logic was applied for iris recognition and person identification. The final system was a very successful at a rate of 98.6% accuracy in recognition with small mistakes.

Hariprasath *et al.* [23] have presented an iris recognition system based on Wavelet Packet Analysis. With an adaptive threshold, WPT sub images coefficients were quantized into 1, 0 as iris signature. Those signatures presented the local information of different irises. By using wavelet packets, the size of the iris signature of code attained was 1280 bits. The signature of the iris pattern was compared against the stored pattern after computing the signature of iris pattern Identification was performed by computing the hamming distance. The accuracy of the proposed system varied when different feature vector was chosen.

Naresh Babu *et al.* [24] have proposed an efficient Fuzzy based Iris Recognition Scheme (FIRS). That scheme has four stages namely Segmentation, Normalization, Feature extraction and classification using fuzzy logic. Hough transforms used for detection of Region of Interest (ROI), and combination of Discrete Wavelet Transform (DWT) and Independent Component Analysis (ICA) was used for feature extraction. Using mean and standard deviation as parameters a fuzzy classifier was used to classify the IRIS images. The results were quite convincing and encouraging.

Pushpalatha *et al.* [25] have proposed an iris recognition system with iris localization to segment and recognize cooler iris with highest speed and accuracy. Frequency domain magnitude and phase features were used for image feature representation. For classification process, support vector machines with "winner takes it all" configuration were used. Tests have shown 97% accuracy with average time of 31 milliseconds seconds for classifying each test image. They developed the iris recognition system using C#.Net (.Net 3.5).

III. Proposed Iris Recognition System using AI Techniques

In the proposed methodology, the given input image is preprocessed using adaptive median filter for removing salt and pepper noise at the first stage. Following that, by adjusting the contrast and applying active contour technique on the preprocessed eye image, iris is localized. Then Unbalanced Wavelet Packet coefficients and MMTH features are extracted from the localized iris image and the extracted features are clustered using MFCM. Following that the dimension of the features are condensed using PCA. The Unbalanced Wavelet Packet coefficients and the dimension reduced MMTH features are given to train FFBNN. While training the parameters of the FFBNN are optimized using ABC. During the testing process the same procedure is done here till the feature extraction process. Then the output obtained from the feature extraction process is given to well-trained FFBNN-ABC to validate whether the given input iris image is recognized or not. The architecture diagram of the proposed Iris Recognition System is shown in Fig.1.

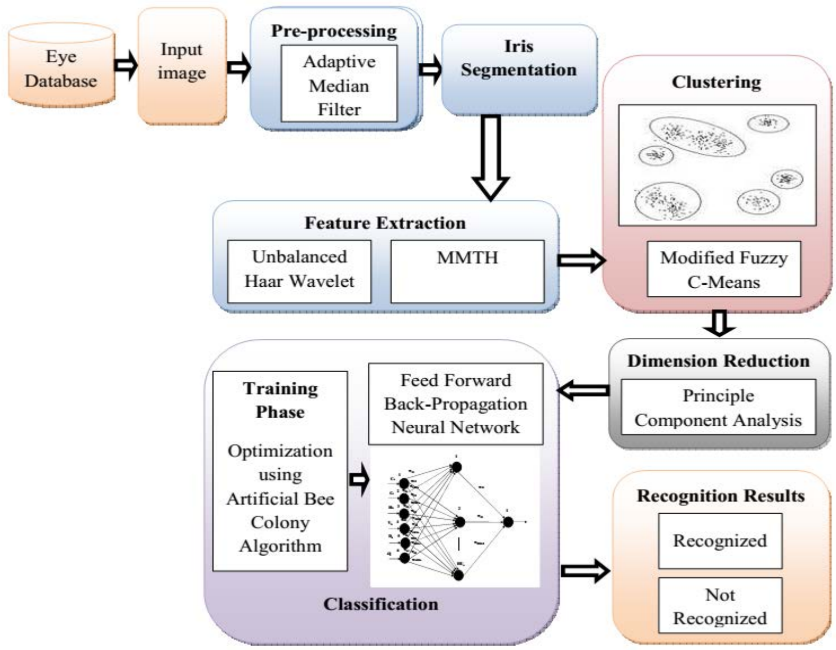


Figure 1 : Architecture of Our proposed Iris Recognition System

a) Preprocessing

The input eye image is initially changed into grey level format. After that using Adaptive median filter, the grey level eye image is preprocessed to take away salt and pepper noise. The input image may have noises which destroy the good pixels in the image. The noise must be eradicated from the input image in order to attain good precision. We are applying adaptive median filter to salt and pepper noise in our suggested work. It identifies the impulse by calculating the difference between the standard deviation of the pixels inside the filter window and the concerned current pixel. Let the iris database (I) contains many eye images and let $x_{i,j}$ be one of the grey level images taken from the database. The lower and upper bounds x are $s_{\min}, s_{\max}$ correspondingly. The grey level of image x is specified by probability

$$y_{i,j} = \begin{cases} s_{\min}, \; probability \; p \\ s_{\max}, \; probability \; q \\ x_{i,j}, \; 1-a-b \end{cases} \quad (1)$$

The noise level is described as $ns = a + b$.

The functioning procedure of Adaptive median filtering is explained below,

- Initialize the window size ws = 3.
- Work out maximum $\left(S_{i,j}^{\min,ws}\right)$, minimum $\left(S_{i,j}^{\max,ws}\right)$ and median $\left(S_{i,j}^{med,ws}\right)$ of the pixel values in $S_{i,j}^{ws}$.
- If $S_{i,j}^{\min,ws} < S_{i,j}^{med,ws} < S_{i,j}^{\max,ws}$, then go to step 5. Or else increase the window size ws by 2.
- If $ws \le ws_{\max}$ go to 2. Or else substitute $y_{i,j}$ by $S_{i,j}^{med,ws_{\max}}$.
- If $S_{i,j}^{\min,ws} < y_{i,j} < S_{i,j}^{\max,ws}$, then $y_{i,j}$ is not a noise candidate or else substitute $y_{i,j}$ by $S_{i,j}^{med,ws}$.

$$S_{i,j}^{w} = \{(k,l): |k-i| \le ws \; and \; |j-l| \le ws .$$

At this point $S_{i,j}^{ws}$ is window of size $ws \times ws$ centered at (i,j). $ws_{\max} \times ws_{\max}$ Be the maximum window size.

$s_{\min}, s_{\max}$ are computed as follow:

$$su(i,j) = \sum_{m=i-k}^{i+k} \sum_{n=i-k}^{j+k} S_{m,n} \quad (2)$$

$$WS(i,j) = (2l+1)^2 \quad (3)$$

Using equiv. (4) and (5), Local mean value $\mu(i,j)$ and local standard deviation $\sigma(i,j)$ are computed as below.

$$\mu(i,j) = \frac{su(i,j)}{WS(i,j)} \quad (4)$$

$$\sigma(i,j)=\sqrt{\frac{\left(\sum_{m=i-k}^{i+k}\sum_{n=i-k}^{i+k}\left(S_{i,j}-\mu(i,j)\right)\right)}{WS(i,j)}} \quad (5)$$

Next by means of these local mean, standard deviation and as well a user defined multiplier upper and lower bounds are computed.

Lower bound $(s_{\min})$ and upper bound $(s_{\max})$ are computed as

$$s_{\min}=\mu 1(i,j)-m\times\sigma(i,j) \quad (6)$$

$$s_{\max}=\mu 1(i,j)+m\times\sigma(i,j) \quad (7)$$

The noise candidates only substituted by the median $S_{i,j}^{med,ws}$ in the above adaptive median filter algorithm, while staying behind are unaltered. By means of the above adaptive median filter algorithm the salt and pepper noise is eliminated from the specified input eye image and the preprocessed eye image is indicated as x'. This preprocessed eye image (x') is subsequently subjected to iris localization process.

b) Iris Segmentation and Normalization

Iris segmentation is the main part in the process of iris recognition. In order to segment the iris from the eye image, here enhanced iris segmentation technique by considering the adaptive thresholding is utilized. The proposed iris segmentation technique has four phases namely,

- Removing Holes
- Pupil Detection
- Iris Detection
- Adaptive Normalization

i. *Hole Filling*

The eye image has holes in the pupil region which is the darkest region in the eye with nearly circular shape. In order to remove the holes from the pupil, binarized image is obtained by applying adaptive thresholding technique. The range of the threshold value (ς) is between 0.1to 0.5. The binary images are obtained by adaptive thresholding technique. The maximum pixel value in the preprocessed image (x') is multiplied with the threshold value (ς). Then by considering the value obtained after the multiplication, the preprocessed image (x') is binarized. The process of removing the hole from the pupil is detailed in the below steps:

Step 1: Set the threshold value (ς) as 0.1.

Step 2: Obtain the binary image (Bx').

Step 3: Take the complement image (Cx') of the binarized image (Bx').

Step 4: Take the binary image (Bx') with all zeros and consider it as hole.

Hx'_q , where $q=0$

Step 5: Catch a point (*po*) inside the hole.

Step 6: Check whether $Bx'_q \neq Bx'_{q-1}$ then go to step 7

Step 7: $B_q=(Bx'_{q-1}\oplus\Gamma)\cap Cx'$ where Γ is the structuring element defined as $\begin{bmatrix}010\\111\\010\end{bmatrix}$

Step 8: If $Bx'_q = Bx'_{q-1}$,then discover the hole filled image (Hx') where $Hx' = Bx'_k \cup Bx'$

Step 9: Find the number of connected components ($\hbar$) from the hole filled image (Hx').

Step 10: Increment the threshold value (ς) as $\varsigma += 0.05$ and go to step 2, Repeat the same until $\varsigma = 0.5$.

Step 12: Find the index of minimum non zero (A) for each threshold (ς).

Step 13: If the index of minimum non zero occurs for more than one threshold (ς) value, select the highest threshold value (ς) among them.

By doing the above steps, the largest filled circle (L_c) which indicates the pupil (Ppl) without having the hole is obtained. Then the radius of the pupil ($RPpl$) and the centre of the pupil ($CPpl$) are obtained from the largest filled circle (L_c).

ii. *Pupil detection*

In order to detect the center of the pupil ($CPpl$) and radius of the pupil ($RPpl$), maximum distance ($md(L_c)$) in the largest filled circle (L_c) is computed by traversing both horizontally and vertically. Following that, center ($CPpl$) and radius of the pupil ($RPpl$) is identified by dividing the maximum distance ($md(L_c)$) by 2. By using the obtained center ($CPpl$) and the radius ($RPpl$), pupil (Ppl) is detected.

iii. *Iris detection*

For iris identification, the preprocessed iris image is upgraded to have sharp variety at the image limits utilizing histogram evening out. This difference upgraded image is utilized for discovering the external iris range by drawing concentric loops of diverse radii from the understudy focus and the intensities lying over the border of the loop are summed up. Among the applicant iris loops, the loop having most extreme change in power as for the long ago drawn round is the iris external limit. The sweep of the iris location steps is itemized in the accompanying steps.

Input: radius of the pupil ($RPpl$), center of the pupil ($CPpl$), preprocessed image (x')

Output: Radius of the iris (*IR*)

Step 1: Obtain the preprocessed image (x').

Step 2: Find the histogram equalized image $HE(x')$

Step 3: Compute the size of the preprocessed image $(x' \in R \times C)$

Step 4: Calculate the radius of the iris as $IR = Rppl \times 1.5$

Step 5: Check whether, $IR \le R/2$, then go to step 6. Otherwise go to step 10

Step 6: Set the angle $\vartheta = 0$, and set the summation of the radius of the Iris as $Sum(I_r) = 0$

Step 7: Find the coordinates (i, j) of the image

$$i = (Rpp\ l_i) + IR \times \cos(\vartheta)$$

$$j = Rppl_j + IR \times \sin(\vartheta)$$

$$Sum(IR) += HE(x')$$

Step 8: Increment the angle (ϑ) by 10

Step 9: If $\varphi \le 360$ go to step 7 otherwise go to step 5

Step 10: Change the intensity over circumference

Step 11: For i=1 to IR, do the following,

$differnce_i = |S_i - S_{i+1}|$

Step 12: Find the maximum change in the intensity

Step 13: Obtain the radius of the iris (IR)

From the radius (IR) which is obtained in the above process is used to segment the iris from the eye image. Thus finally we obtained the iris (I) separately and the obtained iris part (I) passed to the normalization process.

iv. *Adaptive Normalization*

Here, scale based normalization approach [29] is utilized to normalize the iris image (I) in order to preserve the texture property of the features in the iris region (I). In the normalization process, the obtained iris part (I) is converted into Cartesian space to non-uniform polar space. After that, the points lying on the perimeter of the iris $(P(I))$ and pupil circle $(P(ppl))$ are obtained. Subsequently, the range of radius between the pupil and iris boundaries is obtained and it is mapped to a rectangle by considering the distance between the pupil and iris boundaries [29]. Finally, the obtained normalized iris image $(N(I))$ is subjected to feature extraction.

c) *Feature Extraction*

i. *Applying Unbalanced Haar Wavelet*

By passing the localized iris image through the uneven haar wavelet filter coefficients are computed and are applied as attributes. The separate uneven haar wavelet is a decay of one dimensional data concerning an orthonormal haar like basis where jumps vectors do not essentially happen in the middle of their support. At this point, we employ the UH wavelets to incarcerate the texture attributes from the preprocessed image. Not like the traditional wavelet transform, the uneven haar wavelet works as follows:

- ❖ Take the transform of the data with respect to an uneven haar basis
- ❖ Threshold the coefficients
- ❖ Take the opposite transform

We acquire three texture attributes such as starting point ((s)), ending point ((e)), and break point ((b)) which is detailed in by employing the UH wavelet [28]. A fundamental problem in non-parametric regression is the estimation of a one dimensional function $f : [0,1 \to R]$ from noisy measurements X_i observed on an equispaced grid:

$$X_i = f(i/n) + \varepsilon_{i,} i = 1,\dots,n, \qquad (8)$$

Where ε_i's are random variables with $E(\varepsilon_i) = 0$. We first give a description of the construction of the UH vectors. Suppose that our domain is indexed by $i = 1,\dots,n,$ as is the case in (8), and that $n \ge 2$. We first construct a vector $\psi^{0,1}$, which is constant and positive for $i = 1,\dots,b^{0,1}$, and constant and negative for $i = b^{0,1} + {}^{-}1,..,n.$ The breakpoint $b^{0,1} < n$ is to be chosen by the analyst. The positive and negative values taken by $\psi^{0,1}$ are chosen in such a way that (a) the elements of $\psi^{0,1}$ sum to zero, and (b) the squared elements of $\psi^{0,1}$ sum to one.

We then recursively repeat this construction on the two parts of the domain determined by $\psi^{0,1}$: that is provided that $b^{0,1} \ge 2$, we construct (in a similar fashion) a vector $\psi^{1,1}$ supported on $i = 1,\dots,b^{0,1}$, with a breakpoint $b^{1,1}$. Also, provided that $n - b^{0,1} \ge 2$, we construct a vector $\psi^{1,2}$ supported on $i = b^{0,1} + 1, \ldots n$ with a breakpoint $b^{1,2}$. The recursion then continues in the same manner for as long as feasible, with each vector $\psi^{j,k}$ having at most two "children" vectors $\psi^{j+1,2k-1}$ and $\psi^{j+1,2k}$. For each vector $\psi^{j,k}$,their start, breakpoint and end indices are denoted by $s^{j,k}, b^{j,k}$ and $e^{j,k}$, respectively. Additionally, we define a vector $\psi^{-1,1}$ with elements $\psi^{-1,1}(l) = n^{-1/2} \mathrm{I}(1 \le l \le n)$, where $\mathrm{I}(.)$ is the indicator function. Note that to shorten notation, we do not explicitly emphasis the dependence of $\psi^{j,k}$ on $\left(s^{j,k}, b^{j,k}, e^{j,k}\right)$. The indices j,k are scale and location parameters, respectively.

Steps in DUHT

- Take the input domain $X_i, i = 1, \ldots n, n \ge 2.$
- Fix p_o between the range of $\frac{1}{2}$, 1 which is independent of n.
- Define the unbalanced Haar Mother Vector $\psi_{s,b,e}$ where the s,b and c are the start, breakpoint and end with elements

$$= \left\{ \frac{1}{b-s+1} - \frac{1}{e-s+1} \right\}^{\frac{1}{2}} \Pi(s \le l < b) - \left\{ \frac{1}{e-b} - \frac{1}{e-s+1} \right\}^{\frac{1}{2}} \Pi(b+1 \le l < e). \tag{9}$$

The inner product between X and $\psi 1, b^{0,1}, n$ is maximized in absolute value. More formally, $b^{0,1} = \arg\max \left| < X, \psi, B, n > \right|$, the range of b is such that assumption 3.1 holds with $p = p_o$ choose $b^{j+1,l} = \arg\max \left| < X, \Psi_{s^{j+1,l}}, b, e^{j+1,l>} \right|$, where $l = 2k-1, 2k$ again the range of b is such that assumption 3.1 holds with $p = p_o.$

a. *Assumption*

Let $\left|\psi^{j,k}\right|, \left|\psi^{j,k}\right|^{+} and \left|\psi^{j,k}\right|^{-}$ denote the number of non-zero, positive and negative components of the vector $\psi_{j,k,}$ respectively. There exists a fixed constant $p \in [1/2, 1]$ such that for all n, we have

$$\max\left\{ \frac{\left|\psi^{j,k}\right|^{+}}{\left|\psi^{j,k}\right|}, \frac{\left|\psi^{j,k}\right|^{-}}{\left|\psi^{j,k}\right|} \right\} \le p, \tag{10}$$

Uniformly over $j \ge 0$ and k .The condition that both rations should both be bounded away from 1 can be interpreted as the requirement that the UH basis should not be "too unbalanced".

b. *Assumption*

Let $b = \left\{ b^{j,k} \right\}_{j,k}$ be a set of breakpoints which determines a UH basis defined on $\{1, \ldots, n\}$. Let the total numbers of scales j and b be denoted by $J(n)$. If Assumption 3.1 holds, then

$$J(n) \le \left[\log_{1/p} n \right]. \tag{11}$$

Let the i^{th} component of the vector $\psi_{j,k,}$ The inverse DUHT is performed via direct multiplication and addition, using the Parseval identity

$$X_i = \sum_{j,k} DUHT(X)^{J,K} \psi^{J,K}(i). \tag{12}$$

1. Perform Discreet Unbalanced Haar Wavelet Transform of the vector $X = \left\{ X_i \right\}_{i=1}^{n}$ with respect to the basis b. Let $Y_{j,k} = DUHT(X)^{J,K}$. After the transformation the regression problem (8) can be written as,

$$Y_{j,k} = d_{j,k} + \varepsilon_{j,k}. \tag{13}$$

Where $d_{j,k} = DUHT(f)^{j,k}$ with $f = \left\{ f\left(i/n \right) \right\}_{i=1}^{n}$ and $\varepsilon_{j,k} = DUHT(\varepsilon)^{J,K}$ with $\varepsilon = \{\varepsilon_i\}_{i=1}^{n}$. The $d_{j,k}$'s are the true UH coefficients of f which are known and need to be estimated.

- Estimate each $d_{j,k}$ by means of a suitable "universal" shrinkage rule $d_{j,k} = h(Y_{j,k}, \lambda)$, where the function h has the property that $h(y, \lambda) = 0$ if and only if $|y| \le \lambda$, and the "threshold" parameter λ is set equal to $\sigma(2 \log n)^{\frac{1}{2}}.$

The localized iris image is subjected to attain modified multi text on histogram feature after finding the UH wavelet features.

ii. *Modified Multi Text on Histogram Feature Extraction* $(H(V_2))$

To remove the attributes from the images, MTH (Liu, *et al.*, 2010) [26] is a dominant device which extorts the feature from the iris image by combining the benefits of co-occurrence matrix and histogram. Besides with these benefits, mean and variance measures are applied to develop the feature extraction process.

By using the sobel operator on the iris image along both the horizontal and the vertical directions, the gradient images $(gx'x, gx'y)$ is computed in order to locate the modified multi Texton histogram feature

(MMTH). After that, gradient map $(gx'(x,y))$ is erected by means of the gradient magnitude (mag) and the orientation (ori). The gradient magnitude (mag) and the orientation (ori) are worked out as give

$$mag = \sqrt{(gx'x^2 + gx'y^2)} \tag{14}$$

$$ori = \tan^{-1}\left(gx'y \big/ gx'x \right) \tag{15}$$

The MMTH feature extraction process consists of following three steps:

- Computing Original Image Feature ($H(V_1)$)
- Computing Orientation Image Feature ($H(V_2)$)
- Modified Histogram Features ($H(V)$)

a. Computing Original Image Feature ($H(V_1)$)

Initially, the unique iris image is fragmented in to a number of grids where the grid may have the size of 3x3, 5x5 and so on. Subsequently for every grid, mean (m) and variance (v) are computed and by means of those calculated mean ($mean$) and variance (var), threshold value (t_v) is calculated.

$$t_v = \{ mean + \mathrm{var}, mean - \mathrm{var} \} \tag{16}$$

Then for each grid, the center pixel value is compared with the threshold value (t_v).

$$C_p(i) = \begin{cases} mean & ,t_v = \{(mean(i) + \mathrm{var}(i)) \geq t_v \geq (mean(i) - \mathrm{var}(i)\} \\ Unchanged, & otherwise \end{cases} \tag{17}$$

But the center pixel value lies in between the threshold value (t_v), it is substituted with the mean value of the grid or else not as shown in equiv. (11). The grids are partly covered and this process is used for all the grids. The histogram vector ($H(V_1)$) is attained after completing the interchanging process, by finding the frequency of grids (not pixels) based on every grey levels only from the recognized areas.

b. Computing Orientation Image Feature (c)

After obtaining the orientation image i.e. the gradient image as mentioned above using equiv. (8) & (9), the same process done for the original image as explained in section 3.2.1. is repeated for the orientation image. Finally, the histogram vector is obtained, denoted as $H(V_2)$ only from the identified regions.

c. Modified Histogram Features ($H(V)$)

The determined vectors achieved such as ($H(V_1)$) and ($H(V_2)$) are concatenated to acquire the MMTH feature ($H(V)$). The attained MMTH features are subsequently focused to clustering process.

d) Modified Fuzzy C means Algorithm

To attain the cluster, the resultant MMTH features are subsequently passed to the MFCM. Fuzzy c-means (FCM) is a technique of clustering which permits one piece of data to belong to two or more clusters. This technique is often applied in pattern recognition. To develop the clustering result adapted FCM is applied based on minimization of the objective function specified in equiv. (12): In our suggested method, the texture attributes computed are clustered in to 2 clusters by means of MFCM.

$$O = \sum_{r=1}^{N}\sum_{j=1}^{c}\left[(1-\alpha)\mu^{m}{}_{ij}(x_i - c_j)^2\right] \tag{18}$$

Where, m is any real number greater than 1, u_{ij} is the degree of membership of x_i in the cluster j, x_i is the ith of d-dimensional measured data, c_j is the d-dimension center of the cluster, and ||*|| is any norm conveying the resemblance between any calculated data and the center. Fuzzy partitioning is executed through an iterative optimization of the objective function shown above, with the revise of membership u_{ij} and the cluster centers c_j by:

$$\mu_{ij} = \frac{1}{\sum_{k=1}^{c}\left(\frac{\| x_i - c_j \|}{\| x_i - c_k \|}\right)^{2/m-1}} \tag{19}$$

$$c_j = \frac{\sum_{i=1}^{N}\mu_{ij}^{m} x_j}{\sum_{i=1}^{N}\mu_{ij}^{m}} \tag{20}$$

This iteration will end when $\max_{ij}\left\{\left|\mu_{ij}^{k+1} - \mu_{ij}^{k}\right|\right\} < \tau$, where τ a termination criterion between 0 and 1, whilek isthe iteration step. This process unites to a local minimum or a saddle point of O. The collected attributes are subsequently passed to the next process that is dimensionality reduction.

e) Dimensionality Reduction using Principle Component Analysis

For reaching this overview, Principal component analysis is a quantitatively hard method. The method assesses a novel set of variables, called principal components. Each principal component is a linear mixture of the real values. The entire principal components are orthogonal to each other, so there is no unnecessary information. The principal components as a total form an orthogonal basis for the space of the information. Principal component analysis is a changeable reduction process. It is constructive when you have attained data on a number of variables and consider that there is some idleness in those variables. In this case, redundancy represents that some of the variables are linked with one another, probably because they are measuring the similar construct. As of this redundancy, you consider that it should be probable to decrease the observed variables into a smaller number of principal components that will report for most of the variance in the examined variables. For analyzing information, PCA is a dominant device. This will obtain you through the steps you required to execute a Principle Components Analysis on a set of data. At this point, attributes in each cluster are decreased and as a result the reduced cluster features are employed for additional process.

i. *Steps for Reducing the Dimensionality of the Features:*

Step 1: Obtain a set of features from a cluster

Step 2: Discover the difference between the features

Step 3: Compute the covariance matrix

Step 4: Compute the Eigen vectors and Eigen values of a matrix

Step 5: Arrange eigenvectors in descending order of eigen values

Step 6: Create the reduced set of features.

Thus the dimension reduced features are then passed in to FFBNN to continue the recognition process. The obtained feature vector has the length of 6.

f) Recognition

Feed Forward neural Network (FFBNN) is applied to identify the iris. In the training phase, uneven wavelet coefficients and the dimension reduced features are specified as the input to the FFBNN. Using these texture features, the neural network is well educated in order to identify the iris. The neural network contains n number of input units, h hidden units and one output unit. The structure of the FFBNN is specified as below:

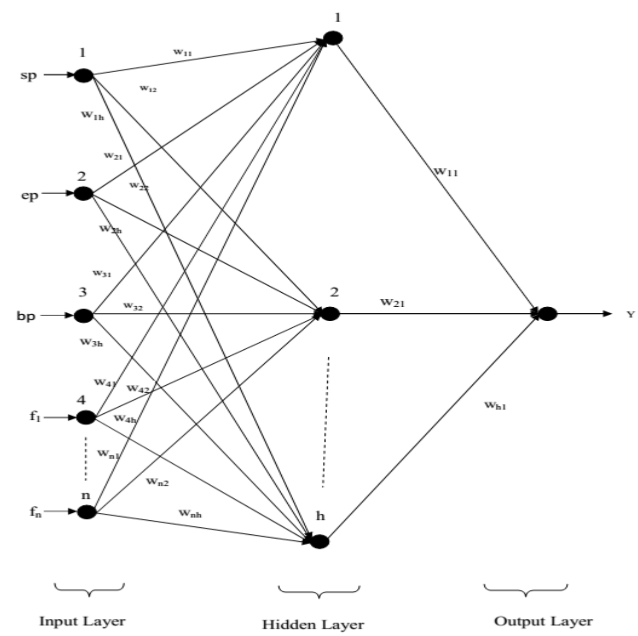


Figure 2 : Diagram of the FFBNN

- For all the neurons, assign weights randomly except for input neurons.
- The bias function and activation function for the neural network is explained beneath.

$$x(t)=\beta+\sum_{n=1}^{H}\left(w_{tn}sp_{tn}+w_{tn}bp_{tn}+w_{tn}ep_{tn}+w_{tn}f_{t1}\ldots,+w_{tn}f_{tn}\right) \tag{21}$$

$$x(a)=\frac{1}{1+e^{-x(t)}} \tag{22}$$

In bias function $sp_{tn}, bp_{tn}, ep_{tn}, f_{t1}, f_{t2} \ldots f_{tn}$ are the uneven coefficients such as starting point, break point, ending point and features attained after dimension reduction correspondingly. The activation function for the output layer is specified in Eq. (16).

- Get the learning error.

$$Er=\frac{1}{h}\sum_{n=0}^{h-1}D_n-A_n \tag{23}$$

Er is the FFBNN network output, D_n *and* A_n are the preferred and actual outputs and h is the total number of neurons in the unseen layer.

i. *Error Minimization*

Weights are assigned to the unseen layer and output layer neurons by arbitrarily selected weights. The input layer neurons have a stable weight.

- Find out the bias function and the activation function.

- Compute BP mistake for every node and revise the weights as follows:

$$w_{(tn)} = w_{(tn)} + \Delta w_{(tn)} \tag{24}$$

$\Delta w_{(tn)}$ is attained as,

$$\Delta w_{(tn)} = \delta . x(t_n).B \tag{25}$$

Where δ is the learning rate, which usually ranges from 0.2 to 0.5, and Be is the Back Propagation fault.

- Next do again the steps (2) and (3) until the Back propagation error gets minimized. The process is continued till it satisfies $B < 0.1$.
- The error gets minimized to a minimum value the FFBNN is well trained for executing the testing phase.

The result of the neural network (y) is compared with the threshold value(τ)after that. If it pleases the threshold value, the iris is known or else not.

$$result = \begin{cases} iris, & y \geq \tau, \\ non\,iris, & y < \tau \end{cases} \tag{26}$$

Using ABC, the FFBNN parameters(w_{tn}, β) are optimized in order to get higher precision and successful presentation in the recognition of iris. White testing more number of input images specified to the well instructed FFBNN-ABC to authenticate whether it makes out the iris images suitably or not.

ii. *Optimization of FFBNN parameters by ABC*

Now we are applying the ABC algorithm for optimizing the parameters of FFBNN while training to acquire competent iris recognition result. ABC algorithm is a swarm based meta-heuristic algorithm which was motivated by the sharp foraging behavior of the honey bees. It contains three components namely, employed bees, onlooker bees and scout bees. The employed bees are combined with the food sources in the region of the hive and they shift the data to the onlookers about the nectar quality of the food sources they are utilizing. Onlooker bees are looking the dance of the employed bees within the hive to pick one food source to use according to the data offered by the employed bees. The employed bees whose food source is discarded turn into Scout and look for novel food source randomly. The number of food sources indicates the location of probable solutions of optimization problem and the nectar amount of a food source represents the quality of the solution. The FFBNN parameters(w_{tn}, β) are optimized by means of ABC. The fitness function desired here is eqn. (15). This optimization of FFBNN parameters by ABC gives higher recognition result and efficient concert.

a. Initial Phase

Initially the population of the food sources x_i $(i = 1,2,....N)$ are produced randomly. N Indicates the size of the population. This food sources encloses the FFBNN parameters(w_{tn}, β). This generation process is called as initialization process. The fitness value of the produced food sources is computed by equation (15) to assess the best food source.

b. Employed Bee Phase

Using the beneath equation, novel population parameters are produced in the employed bee phase,

$$V_{i,j} = x_{i,j} + \phi_{ij}\left(x_{i,j} - x_{k,j}\right) \tag{27}$$

Where, k and j is an arbitrary chosen index, ϕ is randomly produced number in the range [-1, 1] and $V_{i,j}$ is the novel value of the j^{th} position. Next the fitness value is calculated for every novel generated population parameters of food sources. From the calculated fitness value of the population, best population parameter is chosen i.e. the population parameter, which has the highest fitness value by using greedy selection process. Probability of the chosen parameter is calculated by the equation (22) after choosing the best population parameter.

$$P_j = \frac{F_j}{\sum_{j=1}^{d} F_j} \tag{28}$$

Where, P_j is the probability of the j^{th} parameter.

c. Onlooker Bee Phase

Number of onlooker bees is calculated approximately after computing the possibility of the chosen parameter. Next, generate novel solutions $(V_{i,j})$ for the onlooker bees from the solutions $(x_{i,j})$ based on the probability value (P_j). After that the fitness function is computed for the novel solution. In order to choose the best parameter, use the greedy selection process later.

d. Scout Bee Phase

Find out the abandoned parameters for the scout bees. If any abandoned parameter is present, after that substitute that with the novel parameters found out by scouts by means of the equation (28) and assesses the fitness value. After that memorize the best parameters accomplished so far. Afterward the iteration is increased and the process is prolonged till the stopping criterion is arrived.

IV. Experimental Results

Our proposed iris recognition system with FFBNN-ABC is implemented in the working platform of MATLAB (version 7.13).Our proposed iris recognition system is the combination of FFBNN and ABC. In order to reduce the computation complexity and get higher performance, the dimensionality of features is reduced with the help of the well-known optimization algorithm PCA. Then the dimensionality reduced features are given to the FFBNN to achieve the training process. So as to get more accuracy in the process of recognition, the FFBNN parameters are optimized using ABC algorithm. In the testing process, more data are given to the well trained FFBNN-ABC to validate the performance of the proposed technique. The performance of the proposed iris recognition system is evaluated using CASIA database and the proposed technique's performance is compared with the existing iris recognition systems given in [21], [23] and [24].

a) *Performance Analysis*

By applying the statistical measures which is specified in [27], the concert of our suggested iris recognition system is examined. We employ CASIA iris thousand –NG database which has 788 number of iris images to complete the performance analysis process. For one dataset, our proposed technique takes 0.3225 seconds for training and 0.0054 seconds for testing. Totally our database consists of 51 dataset. The performance of the proposed technique is compared with other classifiers such as FFBN, FFBN_GA, Fuzzy, ANFIS&KNN and the corresponding statistical measures are given in Table 1(i). Then the performance of the proposed technique is analyzed by using Unbalanced Haar Wavelet and it is compared with other wavelets such as Haar, Coif let, Symlet & Bi-orthogonal wavelet and the corresponding statistical measures are given in Table 1(ii). Also our suggested iris recognition system performance is assessed and compared with the conventional iris recognition system given in [21], [23] & [24] and the corresponding statistical measures are given in Table 1(iii). Figure 3, 4 and 5illustrate the sample of iris images, preprocessed images and iris segmented images correspondingly.

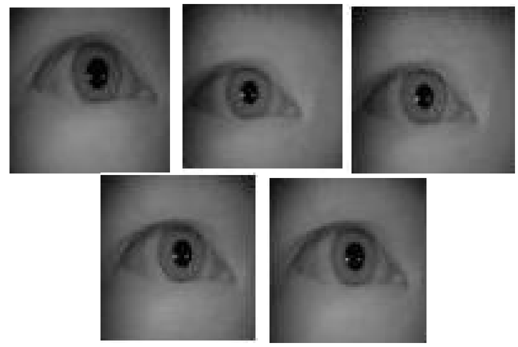


Figure 3 : Sample eye images

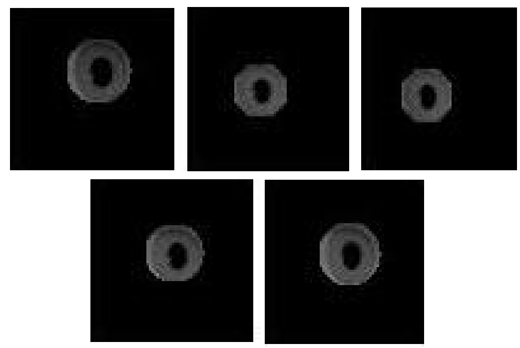


Figure 4 : Preprocessed eye images

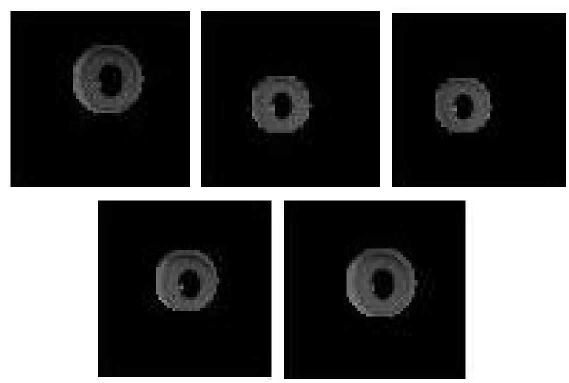


Figure 5 : Segmented iris image

Measures	Proposed Technique	FFBNN	FFBNN-GA	FUZZY	ANFIS	KNN
Accuracy	98.8317757	96.95431472	96.95431472	96.44670051	96.57360406	97.20812183
Sensitivity	98.69451697	97.07446809	97.32620321	96.79144385	97.30458221	97.34042553
Specificity	100	96.84466019	96.61835749	96.1352657	95.92326139	97.08737864
FPR	0	3.155339806	3.381642512	3.8647343	4.076738609	2.912621359
PPV	100	96.56084656	96.2962963	95.76719577	95.5026455	96.82539683
NPV	90	97.31707317	97.56097561	97.07317073	97.56097561	97.56097561
FDR	0	3.439153439	3.703703704	4.232804233	4.497354497	3.174603175
MCC	94.2470505	93.89852174	93.90090616	92.88352799	93.14569616	94.40708603
FAR	0	3.155339806	3.381642512	3.8647343	4.076738609	2.912621359
FRR	1.305483029	2.925531915	2.673796791	3.20855615	2.69541779	2.659574468

(i)

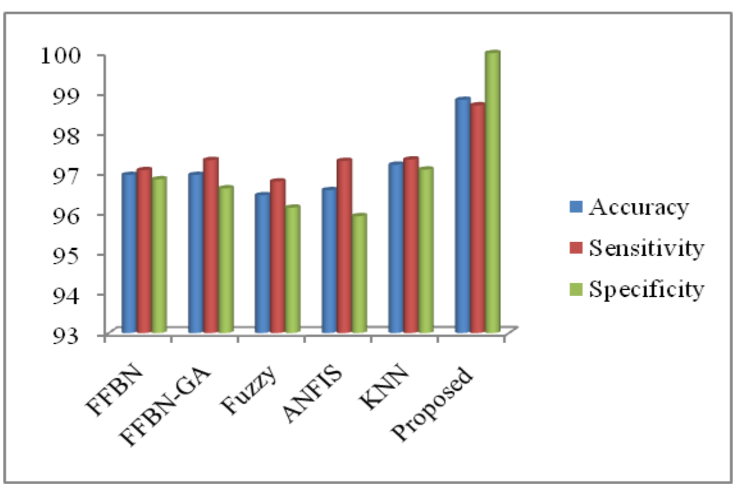
Measures	Proposed Technique (UH)	Haar	Coiflet	Symlet	Bi-orthogonal
Accuracy	98.8317757	97.96954315	97.71573604	97.84263959	97.46192893
Sensitivity	98.69451697	97.38219895	97.36842105	97.37532808	97.35449735
Specificity	100	98.52216749	98.03921569	98.28009828	97.56097561
FPR	0	1.477832512	1.960784314	1.71990172	2.43902439
PPV	100	98.41269841	97.88359788	98.14814815	97.35449735
NPV	90	97.56097561	97.56097561	97.56097561	97.56097561
FDR	0	1.587301587	2.116402116	1.851851852	2.645502646
MCC	94.2470505	95.93901397	95.42610333	95.68227129	94.91547296
FAR	0	1.477832512	1.960784314	1.71990172	2.43902439
FRR	1.305483029	2.617801047	2.631578947	2.624671916	2.645502646

(ii)

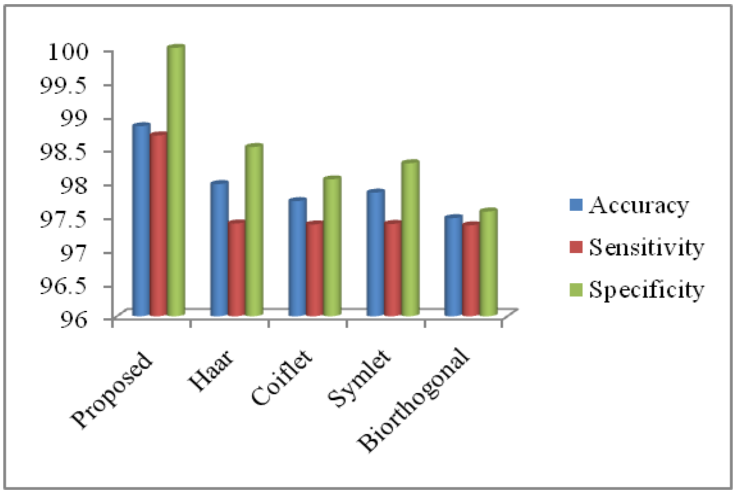
Measures	Proposed Technique	Existing[21]	Existing[24]	Existing[23]
Accuracy	98.8317757	97.84263959	98.0964467	97.20812183
Sensitivity	98.69451697	97.37532808	98.65951743	97.34042553
Specificity	100	98.28009828	97.59036145	97.08737864
FPR	0	1.71990172	2.409638554	2.912621359
PPV	100	98.14814815	97.35449735	96.82539683
NPV	90	97.56097561	98.7804878	97.56097561
FDR	0	1.851851852	2.645502646	3.174603175
MCC	94.2470505	95.68227129	96.19241486	94.40708603
FAR	0	1.71990172	2.409638554	0
FRR	1.305483029	2.624671916	1.340482574	2.659574468

(iii)

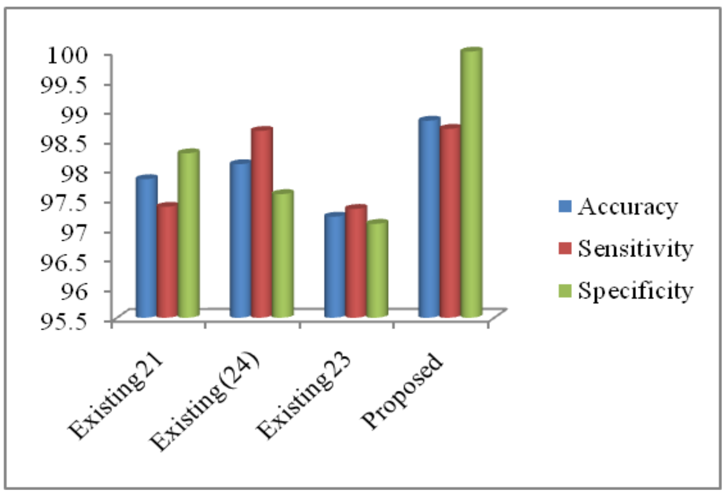
Table 1 : Performance measures of Proposed FFBNN-ABC-PCA technique with other (i) other classifiers (ii) other wavelets (iii) existing techniques



(i)



(ii)



(iii)

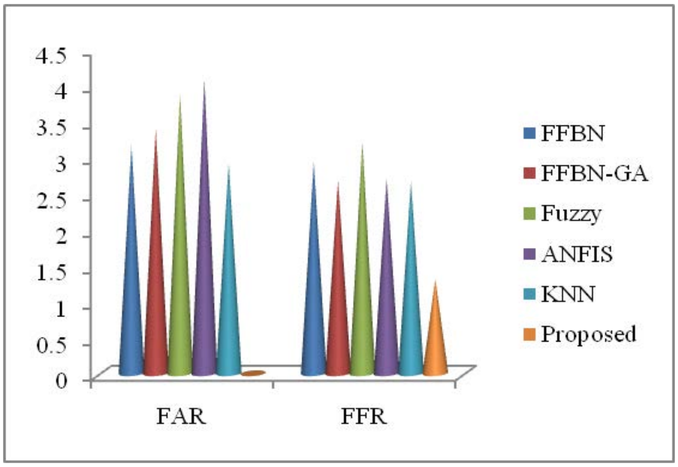
Figure 6 : Graphical Representation for comparison of the performance measures of Proposed FFBNN-ABC-PCA technique with other (i) other classifiers (ii) other wavelets (iii) existing techniques in terms of accuracy, sensitivity and specificity

Discussion: Comparison of the performance of the proposed technique with different classifiers.

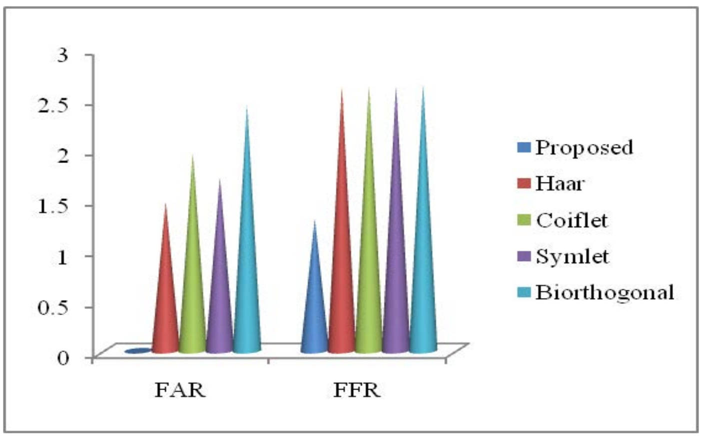
In Table.1(i) and Figure 6.(i), the performance of the proposed technique is compared with various classifiers such as FFBNN, FFBNN-GA, Fuzzy, ANFIS and KNN. By seeing both table and graph, we can say that the proposed technique yields higher rate of accuracy than the proposed technique. From the measurement of the accuracy, we can say that our proposed technique recognize the iris images effectively. In addition to that, the sensitivity and specificity are the two measurements which can provide the additional details about the performance of a technique. On looking at the sensitivity and specificity measures, our proposed technique has given better rate than the other classifiers. In specificity measure, our proposed technique is yielded 100% specificity. Also, when looking at the other measurements such as FPR and FDR, the proposed technique obtained 0% FPR and FDR which indirectly indicates that the proposed technique recognize the iris images accurately.

Discussion: Comparison of the performance of the proposed technique by changing wavelets and existing techniques.

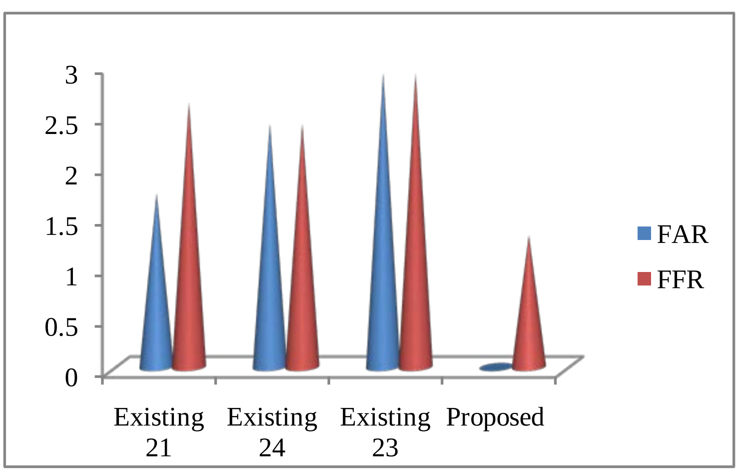
In Table.1 (ii) and Figure (ii), the performance of the proposed technique is compared by changing wavelets such as Haar, Coif let, Symlet and Bi-Orthogonal. In our proposed technique, Unbalanced Haar Wavelet is utilized. On looking at both table and graph, we can say that the proposed technique yields higher rate of accuracy, sensitivity and specificity when compared to the other wavelet techniques. All the performance measures are showed that our proposed technique recognize the iris images efficiently. Similarly, the performance of the proposed technique is compared with the existing techniques such as [21], [23] and [24] and it is given in Table1.(iii) and figure 6.(iii). As discussed above, our proposed technique overcomes the existing techniques by offering higher performance rate. Thus it has shown that, it can be used in real time applications.



(i)



(ii)



(iii)

Figure 7 : Graphical Representation for comparison of the performance measures of Proposed FFBNN-ABC-PCA technique with other (i) other classifiers (ii) other wavelets (iii) existing techniques in terms of FAR and FRR

Discussion: Comparison of the performance of the proposed technique with the other techniques in terms of FAR and FRR.

In Figure.7, the performance of the proposed technique is compared with other techniques in terms of FAR and FRR. Our proposed technique has less FRR rate when compared to the other techniques. While seeing the value of FAR, our proposed technique offers 0% of FAR. It adds additional strength to our proposed technique in its performance. Thus our proposed technique proved its efficiency in the recognition of iris.

V. Conclusion

We have suggested an iris recognition system based on FFBNN and ABC at this point. The suggested system was executed and CASIA iris thousand –NG database is employed to examine the results of the suggested iris recognition system. The presentation study confirmed that the suggested iris recognition system in iris recognition process presents an incredible rate of accuracy (98.8317757), sensitivity, (98.69451697), specificity (100), FAR (0) and FRR (1.305483029). The high value of these measures illustrates that our suggested technique more precisely identifies the iris images from the specified test images. Based on FFBNN-ABC, the comparison result illustrates that our suggested iris recognition system has specified high accuracy than existing methods. Hence our suggested iris recognition system competently identifies the iris imaged by applying the FFBNN and ABC techniques.

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