Performance Evaluation of Feature Level Fusion for Multimodal Biometric Systems

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Abstract
The biometrics authentication using multimodalities provides superior facilities over the traditional by means of identity verification due to their unique characteristics as biometric traits are not transferrable. The physiological (palmprint, signature, face, iris, etc.,) and behavioral (voice, key stroke dynamics, etc.,) characteristics of human beings are used to identify the individual. It plays an important role in several applications such as international border crossings, restricting physical access to places like nuclear plants or airports, controlling logical access to shared resources, remote financial transactions, distributing social welfare benefits etc. In this research work, an algorithm based on the fusion of face and iris modalities using Stationary Wavelet Transform (SWT) and Local Binary Pattern (LBP) is discussed. Firstly, the samples of face and iris are applied on SWT to extract the geometric and statistical features of face and iris. Next, the sample of low frequency (LL) sub band component of SWT is applied on LBP to extract the features. Principal Component Analysis (PCA) is used to reduce the dimensionality of each sample. The relevant characteristics of both face and iris are fused to create a patten for every individual. The obtained features are compared with the features of database images using Euclidean Distance classifier The ORL and CASIA iris datasets are used to evaluate the performance of the proposed model. The accuracy of 99.42% is recorded for the proposed model and showed robustness when compared with the other state-of-the-art method.

Keywords: Biometrics, trait, face, iris, multimodal, stationary wavelet transform.

1. Introduction:

In recent, there is a more demand for reliable and authenticated biometric recognition systems. These biometric systems were commonly used in many application areas considering private and government sectors [1]. It is observed that, the traditional biometric systems are based on single characteristics of an individual due to noise produced at the intermediate stage of acquiring the image samples. To overcome the above limitations, multimodal biometric systems were developed. Figure 1 shows the multimodal biometric system.

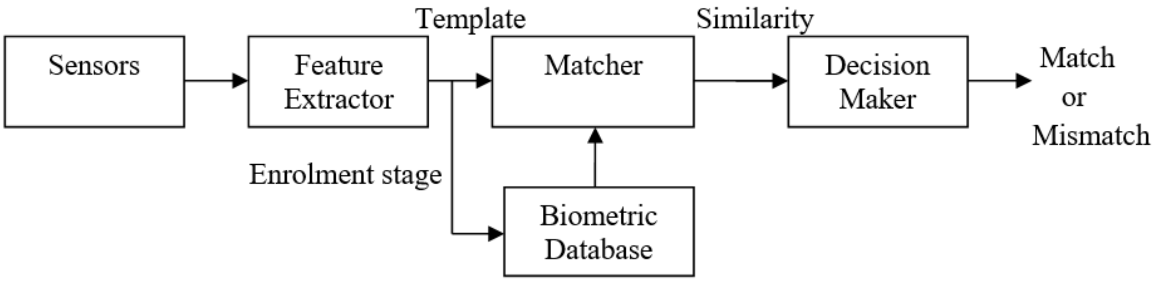


Fig 1: Biometric recognition system

The biometric model consisting of Sensors, Database, Feature extractor, Classification components to accept or reject the samples [2]. The types of multibiometric to secure the data is shown in Figure 2.

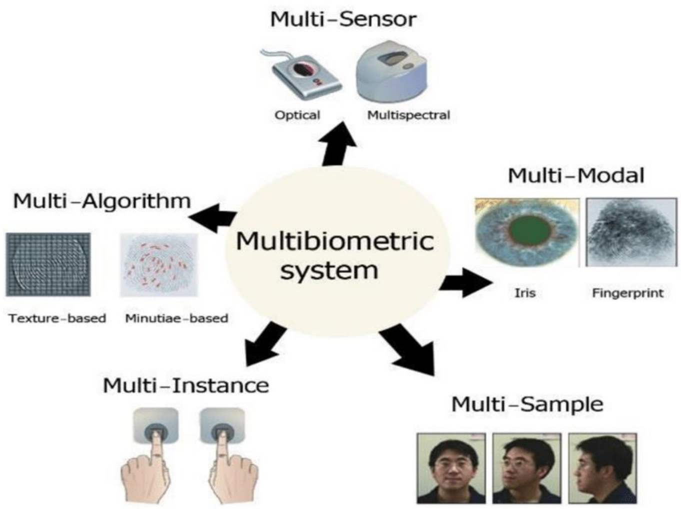


Fig 2: Types of Multibiometric

The multiple images are captured through different sensors, where they can be combined at different levels which includes sensor level, feature level and score level [3]. In sensor level, the samples generated from the various sensors is treated to form a combined version as a new dataset [4]. In feature level, the new feature vectors are formed after extracting the significant features from the dataset samples. In case of the score level, a match score will be seen by comparing the scores of both training and testing phase [5]. The Fusion levels in Multimodal Biometric Systems is shown in Figure 3 [6].

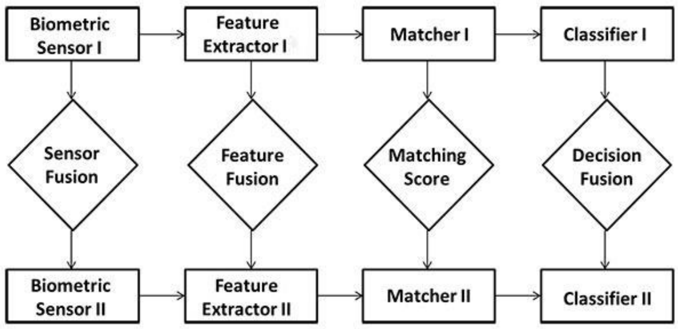


Fig 3: Fusion levels in Multimodal Biometric Systems

In this research work, the feature level fusion is carried [7]. The phases of training and recognition is carried out in biometric system. In training phase, the biometric modality is captured to process it using some algorithms to form a template for each user and later stored in the database. Whereas in case of recognition phase, the samples are captured followed by processing the samples and later compared with the templates stored in the datasets. Then, the results may be matched or not matched [8] [9].

The main contribution of the research work is to preprocess the image samples obtained through face and iris datasets before applying to recognition model. Next, the SWT and LBP are used to extract the features of face and iris samples and later fusion at the feature level is performed. The PCA is applied on the samples to reduce the dimensionality of the images. The Euclidean distance is used as classifier to match the trained and testing images.

The rest of the paper is organized as follows section 2 covers the various related work on multimodal biometrics. The proposed model is explained in section 3. The evaluation parameters, result analysis is discussed in section 4 and the proposed model is concluded in section 5.

2. Related Work

In this section, the existing models based on the multimodalities for face and iris are addressed. Eskandari M et al., [1] developed multimodal biometric system for face and iris at score level fusion. Here, the local and global features are extracted using PCA, LDA and LBP. Then obtained features are classified by Transformation-based score fusion. The experiments are conducted on ORL face and CASIA iris dataset. Ammour et al., [2] explained hybrid level fusion. The 2D-log Gabor filter is used on face and iris samples to make it bimodalities and then the templates are created based on feature vectors. The model is evaluated on CASIA. Kabir W et al., [3] performed score normalization techniques for genuine and non-genuine scores. The normalization and a weighting technique encases the confidence from the matched scores using scores of mean-to-maximum and mean-to-minimum of genuine and non-genuine scores respectively. Jamdar C et al., [4] describes few of the approaches for multimodalities of biometric traits. Here, the working model of different state-of-the-art methods are explained along with the different database used to carry out the work. In addition, the limitations of the existing models are clearly described.

Anil Jain et al., [5] performed the experiments on multimodal biometric system face, fingerprint, and hand-geometry traits. A database of 100 users with min–max, z-score, were made available at the score level fusion. Elhoseny et al., [6] combines fingerprint and iris traits for recognition. The model is tested on CASIA-Iris V1 database and FVC 2000 fingerprint database. Morizet et al., [7] presented multimodalities on face and iris traits. Here, score level fusion was performed at the matching stage. The wavelet denoising is adopted as a part of the model. The model was evaluated on FERET and CASIA datasets. Ammour B et al., [8] uses face–iris traits combination for recognition. The 2D Log-Gabor filter to fetch the textural data for different orientations. The SSA with the WT are used to extract the features for the model. The fusion of feature level is adopted in this domain instead of score level fusion. The ORL and FERET for face and CASIAv3.0 for iris database is used in the process. Eskandari et al., [9] performed both the matching score and feature level fusions for recognition. The CASIA and IITD database were used to evaluate the model. The PSO and BSA were adopted to select the optimum features at feature level. Here, ORL dataset were used to carry out the experiments for face traits. Huo G et al., [10] addressed face-iris recognition on feature level fusion. Here, the 2D Gabor filter bank is adopted to extract the features of both face and iris samples. The PCA and SVM are considered to reduce the dimensionality of the images and classification of genuine and imposter samples respectively. Eskandari [11] discussed threshold-optimized decisions to perform the fusion of features generated at the feature extraction approach. The feature vectors are created before classification of the samples. Matin et al., [12] performed at the weighted score level fusion for face and iris traits. The Doughman and PCA were used to extract the details of the iris and face samples. Identification and recognition are done based on the weighted score level fusion. Bouzouina et al., [13] extracted the features using DCT and PCA. The algorithm is developed for face and iris traits. The feature level fusion is performed. The feature selection was performed using Genetic algorithm. The SVM acts as classifier to match the samples generated by training and testing samples of face and iris. The CASIA dataset is used for experimentation of the model. Madhusmita et al., [14] developed an algorithm based on DWT feature extraction to analyze face and iris data features. The feature vectors are formed to classify the samples of the patient. The MGA is used to optimize the classifiers. Bharadwaj et al., [15] performed both the matching score and feature level fusions for recognition. The real time datasets were used to evaluate the model. Thakral S et al., [16] used HT, FT, RT, WT approaches for extraction of features and later feature vectors are formed. The importance of IP and classifications are explained clearly to address the different score level and feature level fusion mechanisms. Li M et al., [17] addressed the different feature extraction techniques where DWT is applied on the samples to extract the four different sub bands such as LL, LH, HL and HH bands. The fusion is performed in the score level at the classification phase.

The performance of the existing models is decreased due to the more error rate and lack of robustness of the algorithm. So, to overcome the above limitations, a fusion of SWT, LBP and PCA is contributed by the researcher at the feature level to increase the performance of the proposed model.

3. Proposed Methodology

The main contribution of the research work is to preprocess the image samples obtained through face and iris datasets before applying to recognition model. Next, the SWT and LBP are used to extract the features of face and iris samples and later fusion at the feature level is performed. The PCA is applied on the samples to reduce the dimensionality of the images. The Euclidean distance is used as classifier to match the trained and testing images. Figure 4 shows the proposed model.

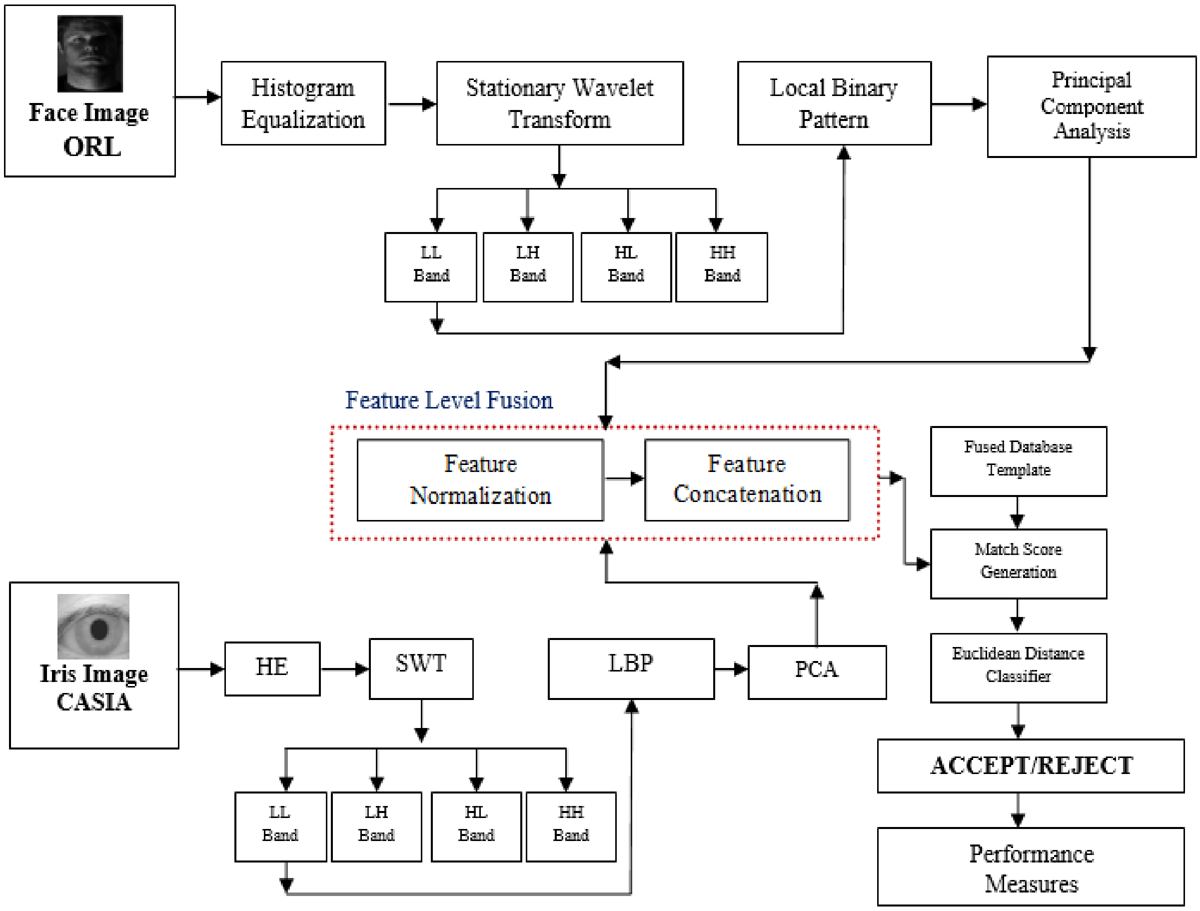


Fig. 4: Proposed Methodology

Dataset [18]

The face images having 400 samples with 40 distinct patterns are presented in the ORL database. The samples are captured with the different times, for different emotions of face. The size of each sample of the dataset is 92x112 pixels. The samples of ORL dataset are shown in Figure 4.

Fig. 4: ORL Face samples

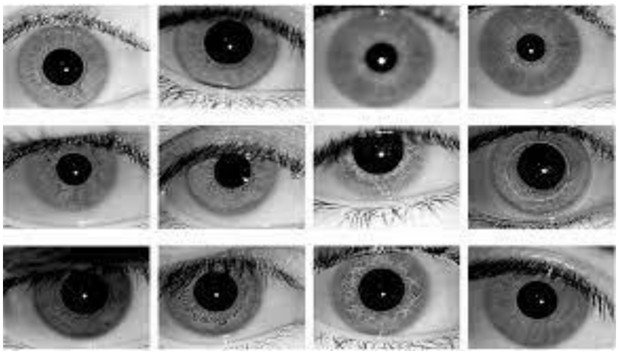
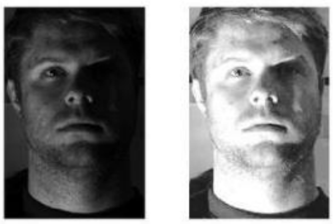


Fig. 4: CASIA Iris samples

The CASIA [19] iris dataset has 756 samples of iris from 108 eyes of an individual. Each individual sample having the size of 320x280 captured in two sessions, available in BMP format. The sample of the dataset is shown in Figure 4.

Preprocessing

The face and iris images of the ORL and CASIA are fetched to carry out the preprocessing step [20]. The images are cropped and resized to 128x128 to maintain uniformity throughout the experiments. The Histogram Equalization is applied on the samples to enhance the quality. The preprocessing process for face and iris samples is shown in Figure 5.



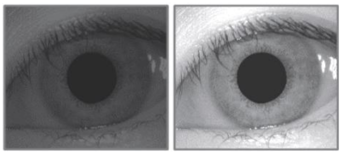
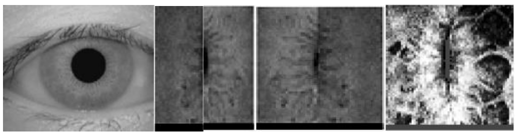


Fig. 5: Preprocessing process

Iris Extraction

The circular icon of the eye, where the part ‘iris’ located in between pupil and sclera [21]. To extract the iris region from the CASIA image, few of the portions related to pupil is neglected. The iris template is formed using the concatenation of right and left region (having 40 pixel) of the pupil [22]. The template of iris is shown in Figure 6.



Eye image left region right region Iris template Histogram Equalized

Fig. 6: Formation of iris template

Feature extraction

Feature extraction is an important task, that can be done before the classification phase. In this stage, the significant and relevant features of the image samples are extracted to result with maximum matching score [23]. In this paper, Stationary Wavelet Transform (SWT) is applied on the face and iris samples to extract the useful information of both the samples. The SWT is decomposed into four sub bands which includes LL, LH, HL and HH sub bands. The maximum representative and relevant information are relied on LL sub band. So, neglecting the higher sub bands (LH, HL and HH) the Local Binary Pattern (LBP) is applied on LL sub band to extract the more significant coding of the process. Later, the Principal Component Analysis (PCA) is applied on the LBP features to reduce the dimensionality throughout the experimentation. Finally, the feature level fusion is performed by adopting the features normalization and concatenation. The process of SWT, LBP and PCA is explained in detail.

Stationary Wavelet Transform (SWT)

The face and iris samples are through the filter to record the significant information along with the detailed information. Due to the characteristics of NO decimation, the coefficients remain the same in every sub bands [24]. Further, the response of low pass and high pass are given as an input to LPF and HPF to generate the approximation band (LL) and detailed bands (LH, HL, HH). The decomposition of SWT is shown in Figure 7. The sub bands of SWT for ORL face and CASIA Iris data samples are shown in Figure 8 and Figure 9 respectively.

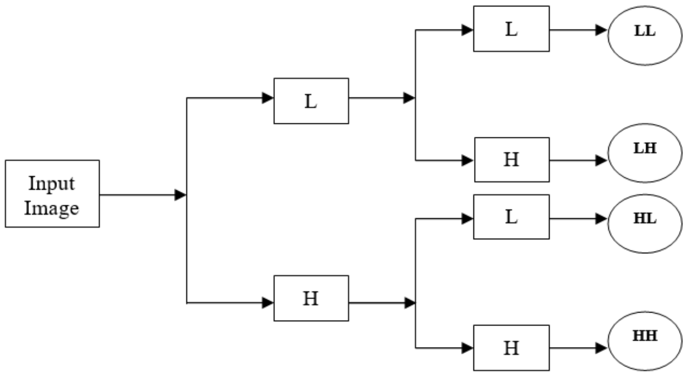
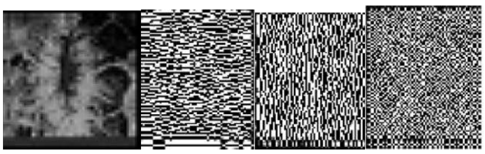


Fig. 7: SWT Decomposition [25]

Original Image LL Sub band LH Sub band HL Sub band HH Sub band

Fig. 8: SWT four subband images

From the Figure 8 and 9, it is observed that, the approximation band (LL sub band) of face and iris samples are composed of significant information. The approximation band (LL sub band) contains the same significant coefficients of the original ORL and CASIA image. The horizontal, vertical, and diagonal details are represented as LH, HL and HH respectively.



Approximation Band Horizontal Band Vertical Band Diagonal Band

(LL Sub band) (LH Sub band) (HL Sub band) (HH Sub band)

Fig. 9: SWT four subband images [26]

For a 2x2 matrix shown in equation 1, the SWT sub bands LL, LH, HL and HH are calculated using equation 2.

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$$A = \begin{bmatrix} a & b \\ C & d \end{bmatrix}$$

(1)

$$LL= \frac{(a+b+c+d)}{2}$$

$$LH= \frac{(a+b-c-d)}{2}$$

$$HL= \frac{(a-b+c-d)}{2}$$

$$HH= \frac{(a-b-c+d)}{2}$$

(2)

Local Binary Pattern

Local Binary Pattern will handle many occlusions and problems existing from handle illumination changes and used in many issues includes such as image/facial and motion analysis [27]. The procedure for extracting the LBP features are as follows:

- Creation of tiny cells with the provision of radius and number of neighbors.
- Thresholding with the consider of pixel existing in central position and its neighbor pixels. Binary number will be the outcome for thresholding and intern the same will be converting into decimal numbers.
- Each of the LBP will be store in ‘count’ and later, calculate the histogram for the frequency of each ‘count’.
- Concatenation of the histograms to compute the feature vector is performed.

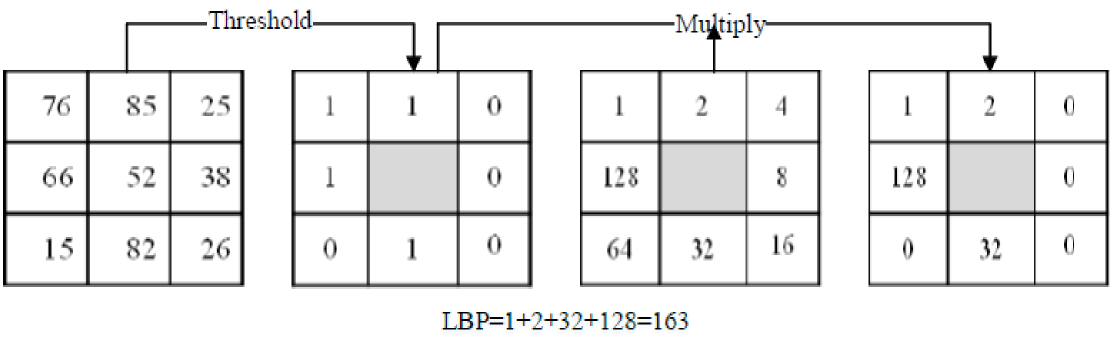

Fig. 10: Local Binary Pattern Process

The process of LBP is shown in Figure 10. The input patterns having threshold and weight is addressed, a radius of 1 with 8 neighbors surrounding the center pixel is considered in the LBP process [28]. The LBP equation is stated in equation 3.

$$LBP_{P,R}(x,y) = \sum_{p=0}^{P-1} S\left(f(x,y)\right)f\left(x_p, y_p\right)2^p$$

(3)

Here, P and R represents neighborhood and radius of neighbors around the pixels.

Primary component Analysis (PCA)

The PCA is applied on the LL sub band of SWT to reduce the dimensionality of the samples [29]. The computations of the Eigen vectors and corresponding Eigen values are made to identify the strength of the variations in the image data [30].

Feature Level Fusion

The features produced by the hybrid model based on SWT, LBP and PCA are fused and combined to generate the features consisting of 43 features. Using these feature vector, the fusion is performed and results in the generation of match scores [31].

Euclidean Distance

Based on the matching scores, the ED is used as a classifier to match the data of trained and testing sample. The result of ED may be recognized as Genuine or Imposter [32]. Finally, the performance of the proposed model is measured and compared with the different state-of-the-art multimodal face and iris methods.

The Precision (P) and Recall (R) curve and the ROC curve are considered to plot the graphical representation of the proposed model. The PR tells about the precesion and recall, where as the TPR and FPR relation will be brought by ploting the ROC curve [33]. Here, TPR and FPR are considered to know the images either genuine or imposter. By considering the low threshold, we can achieve more TP and FPR. The evalaution parameters are given in equation 4, 5, 6.

$$TPR = Recall = \frac{Tp}{Tp + FN}$$

(4)

$$FPR = \frac{Fp}{Fp + TN}$$

(5)

$$P = \frac{Tp}{Tp + Fp}$$

(6)

For desired face and iris sample, True positive (TP) is accepted (positive) and False Positive negative (FN) is rejected [34]. Whereas, for Undesired face and iris sample, False positive (FP) is accepted (positive) and True negative (TN) is rejected [35].

4. Proposed Algorithm

The proposed algorithm is tabulated in Table 1. The objective of the proposed work is as follows

- To develop the efficient algorithm for face and iris multimodal traits on ORL and CASIA dataset.
- To increase the performance rate and decrease the error rate of the model.

Table 1: Proposed algorithm

Input: Read the images from ORL and CASIA Dataset
Output: Recognition of multimodalities

1. The images from the ORL and CASIA dataset is taken and resized to 128X128, followed by cropping the sample.
2. The HE is applied on both the samples to enhance the output image.
3. The SWT is applied on both the samples to extract the features. The SWT is decomposed to LL, LH, HL and HH sub bands.
4. Next, The LBP is applied on approximation band LL, to extract the significant local and statistical features. Later, the PCA is applied on the statistical features to reduce the dimensionality of the image. The LBP is calculated using equation 7.

$$\mathrm{LBP}(x_c, y_c) = \sum_{i=0}^{7} s(g_i - g_c)2^i$$

$$s(x) = \begin{cases} 1 & x \geq 0 \\ 0 & x < 0 \end{cases}$$

(7)

Where x_c represents neighbors, y_c indicates the neighborhood radius, g_i and g_c indicates gray value of neighbors and central pixel respectively. The mean of each vector is given in equation 8.

$$Xm = \frac{1}{N}\sum_{k=1}^{N} Xk$$

(8)

The Eigen Vectors and values are given in equation 9.

$$[C - \lambda I]e = 0$$

(9)

Where, ‘λ’ is Eigen value and e is Eigen vectors.

5. The feature level fusion is performed before the generation of match score. The fusion feature ξ in sum rule is given in equation 10.

$\xi = (x_1+y_1 \ldots\ldots, x_d+y_d)$

(10)

6. The Euclidean distance is used to classify the samples of face and iris give in equation 11.

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

(11)

Where, $p=(p_1, p_2, p_3, \ldots p_n)$ is the known feature vector and $q=(q_1, q_2, q_3, \ldots\ldots q_n)$ is test feature vector.

7. Performance of the proposed model is computed and evaluated.

5. Results Analysis and Discussions

In this research work, the two public datasets ORL and CASIA are used to conduct an experiment. The ORL datasets contains face samples and CASIA contains iris images. The simulation of the proposed model is carried with MATLAB tool [36]. The images of the two datasets are grouped in a single dataset having 168 folders of both face and iris. The iris images whichever considered are different from the face that are presented in the ORL. The model is tested for different combinations of the feature extraction techniques such as state-of-the-art method (DWT+DCT+HT) and proposed (SWT+LBP+PCA+ED) model for 1600 image samples having different matrix sizes. It is observed that, the fusion of SWT, LBP and PCA results better in testing phase for the matrix size of 128. The ROC of existing DWT+DCT+HT multimodal is shown in Figure 11. It is observed that, that, as threshold value maximized, the values of FAR and FRR minimizes and maximizes respectively. In addition, the TSR results 88.86% for the given threshold with an error rate of 12.14%. The performance of the existing model can be improved bu considering the hybrid model combining SWT+LBP and PCA.

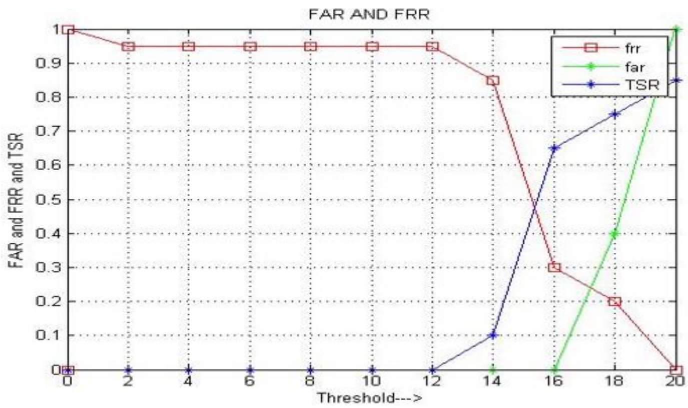

Fig. 11: ROC for the proposed model

In the proposed SWT+LBP and PCA multimodal, it is recorded that, as threshold value maximized, the values of FAR and FRR minimizes and maximizes respectively. In the Figure 11, the TSR results 99.42% for the given threshold with an error rate of 0.58%.

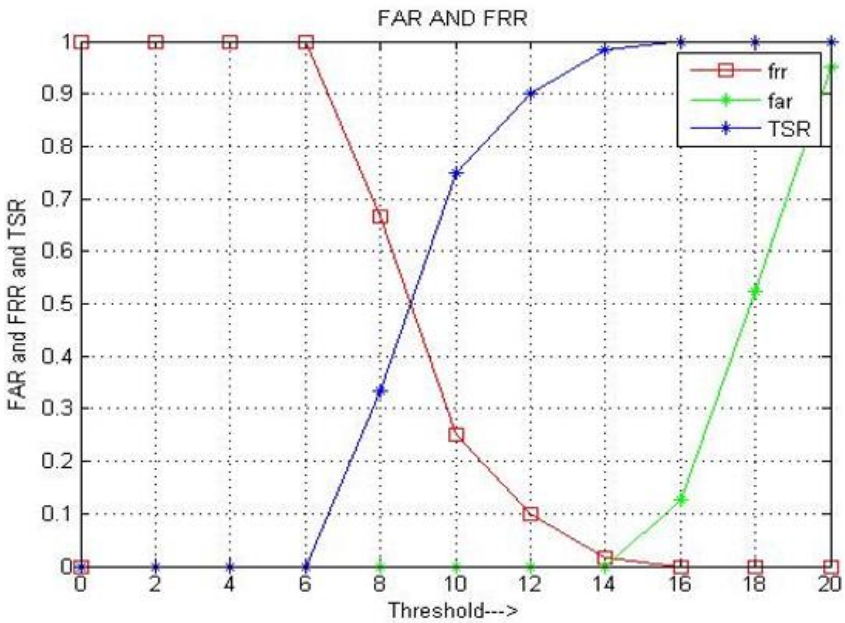

Fig. 12: ROC for the proposed model

Based on the experimentation results, the performance of the proposed model for face and iris multimodalities are improved with an accuracy of 99.42% and is compared with the different state-of-the-art methods which is tabulated in Table 2.

Table 2: Comparison of proposed model with state-of-the-art methods

Authors	Method Descriptions	Matrix size	Face and Iris Recognition rate (%)
Bouzouina et al., [13]	DCT, Log-Gabor and Zernike moment, Genetic algorithm and SVM	128	96.72
B. Ammour et al., [2]	Log Gabor filter spectral regression kernel discriminant analysis and Euclidean	128	97.45%
Sulaiman et al., [36]	DWT+SVD+Euclidean	128	98.90%
B. Ammour et al., [8]	Singular Spectral Analysis and Normal Inverse Gaussian, Log-Gabor filter, and spectral regression kernel discriminant analysis and KNN	128	98.18
Proposed Model	**SWT+LBP+PCA+ED**	**128**	**99.42%**

6. Conclusions and Future Scope

In this research study, the model is tested for different combinations of the feature extraction techniques such as state-of-the-art method (DWT+DCT+HT) and proposed (SWT+LBP+PCA+ED) model for 1600 image samples having different matrix sizes. It is observed that, the fusion of SWT, LBP and PCA results better in testing phase for the matrix size of 128. The ORL and CASIA are used to conduct an experiment on proposed model. The ORL datasets contains face samples and CASIA contains iris images. The experimental results show better recognition rate of 99.42% on proposed multimodal approach compared with the different existing multimodal face and iris techniques. In future, the model may be implemented using deep learning techniques for different multimodal traits such as ear, fingerprints, face, and iris.

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