# SOM based Face Recognition using Steganography and DWT Compression Techniques

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# SOM based Face Recognition using Steganography and DWT Compression Techniques

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***Abstract- Biometrics*** **is used in day to day life of human beings to access mobile phones, computers, vehicles etc. In this paper, we propose SOM based Face Recognition using Steganography and DWT Compression Techniques. The various available standard face databases such as ORL, JAFFE, NRI, YALE, Indian male and Indian female are used to test the performance of the algorithm. The number of face images per person is reduced using stenography compression technique. The preprocessing techniques such as resize and Gaussian filter are applied on reduced number of face images for uniform size and good quality of images. The initial features are extracted using Discrete Wavelet Transform (DWT) and Local Binary Pattern (LBP). The DWT and LBP features are fused using arithmetic additions and connected to input of Self Organizing Map (SOM). The final features are extracted from SOM. The test image features are compared with face database images using Euclidian Distance (ED) to compute performance parameters. It is observed that the performance of the proposed method is better than the existing methods.**

## I. INTRODUCTION

Biometrics is the metrics which is related to the characteristics of humans. Biometric verification is the means through which a person can be uniquely identified by evaluating some of the distinguishing biological traits. Unique identifiers which are commonly used are fingerprints, earlobe geometry, hand geometry, retina and iris patterns, voice, DNA, and signatures. The law enforcement uses face recognition system to identify an individual from an array of people and it has been quite reliable. A facial recognition system is a software application based on biometrics that is capable of identifying a person from a digital image or a video frame. The identity of an individual is verified by analyzing the selected facial features from an image with a facial database and is mainly used for security purposes. Most recent facial recognition systems works on numeric codes known as face prints that are identified on a human face. Face points are used to analyze the characteristics of an individual's face; these characteristics can be classified into nose length or width, eye socket depth and cheekbone size.

Given the required prerequisites, face recognition system can effectively identify an individual with the help of face prints. If the target's face is obscured or inclined rather than facing forward, or if there is no sufficient lighting, the software is less reliable. However, the technology is quickly evolving and 3d modeling can be used as an alternative to overcome the failures of the system. There is a vast use of this system in Smart Phone applications. The most widely used applications of face recognition are image tagging. They are also used for social media networking integration purposes and personalized marketing. A research team from Carnegie Mellon has instigated a proof-of-concept iPhone app that can take a picture of an individual and quickly provide the individuals name, date of birth and social security number. Face book uses face recognition system to help the user to in tagging of images, also known as image tagging. When enough data about a person has been compiled to successfully identify him/her, the system uses the complied data to identify the same face in different images, and will suggest tagging of those pictures with the individual's name. Facial recognition software also enables enhancement of marketing personalization. For example, billboards are developed with integrated software which determines the gender and approximate age of passers to deliver targeted advertisements.

*Contribution*: In this paper SOM based Face Recognition using Steganography and DWT Compression Techniques is proposed. The steganography technique is used to reduce number of images per person. The resize and Gaussian filter is used in the preprocessing. The initial features are extracted by fusing DWT and LBP coefficients. The fused features are applied as input to SOM and the output of SOM is considered as final features.

*Organization:* The rest of the paper is organized as follows, the literature survey of existing techniques are discussed in section II. Section III provides proposed face recognition method with novel technique of steganography. The proposed algorithm is discussed in section IV. The performance analyses with experimental results are discussed in section V. Finally, we conclude with future direction in section VI

## II. Literature Survey

In this section the review of existing research on face recognition using various techniques are given. Ben Niu et al., [1] proposed face recognition using two dimensional (2D) Laplacian faces method. The projection features are extracted in the 2D Laplacian faces in the form of vectors. The features in the matrix form are classified using nearest neighbor method. Chao-Chun Liu and Dao-Qing Dai [2] developed face recognition using Dual Tree Complex Wavelet Transform (DT-CWT). The features are extracted using Complex Wavelet Transforms (CWT), which are improved version of DTCWT. The nearest neighbor classifier along with cosine distance is used for classification. Xiao Zeng and Hua Huang [3] presented a regression based face recognition method that clearly recognizes the challenges of variation in image resolution, pose variations and only one gallery image per person. The non linear regression modes form the specific non frontal low resolution image to frontal high resolution features are learnt by radial basis functions in subspace built by canonical correlation analysis. The nearest neighbor classifier is used for classification. Andrew Wagner et al., [4] have proposed face recognition system from images taken under practical conditions i.e., conceptually simple, well motivated and competitive recognition system for access control scenarios. A Sparse Representation (SRC) based classification is proposed for recognition. They have


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achieved extremely stable performance under a wide range of variations in illuminations, misalignment and under small amount of pose and occlusions.

Abhijith Punnappurath et al., [5] proposed a method for face recognition with non –uniform blur, illumination and pose effects. They have developed a Non-Uniform Motion Blur face recognition algorithm (NUMOB). They showed that a bi convex set is formed when a given image undergoes non uniform blurring and illumination changes. Using this result they've derived a non-uniform motion blur and illumination-robust algorithm MOBIL. This can be used to overcome the drawback of non-frontal faces by transforming the gallery to a new pose. Anila and Devarajan [6] have presented a work on face recognition in the compression domain. Discrete wavelet transforms (DWT), Discrete Cosine Transforms (DCT) and Fast Fourier Transform (FFT) methods are used for compression. Feature extraction and feature matching is done using Principal Component Analysis (PCA) and Euclidean distance. They have achieved reduced computational complexity, time consumption and storage space of recognition system.

Debaraj Rana et al., [7] proposed face recognition using DCT, DWT and PCA. These techniques are applied on different face images which are rotated $15^{o}$, $30^{o}$ towards right as well as towards left with different facial expressions with low illuminations. Comparative analysis of face recognition rate has been done for all three techniques. They have used Euclidean distance for classification. A novel feature selection method for face recognition using gravitational metaheuristic optimization algorithm is proposed by Tapabrata Chakraborti and Amitava Chatterjee [8]. In this Local Binary Pattern (LBP) and Modified Census Transform (MCT) algorithms are used for feature extraction. Feature selection is done by formulating a fitness function as a ratio of within class distance to the between class distance and then Gravitational Search Algorithm (GCA) is developed. In each algorithm Back Propagation Neural Network (BPNN) is used for classification.

Wen-Hui Lin et al., [9] have developed an online face recognition system. This is done by training Support Vector Machine (SVM) based on user facial features with wavelet transforms and a spatially enhanced local binary pattern. They have shown that classification error decreases with an increase in the size of the training samples. The proposed method gives better precision of face recognition compared with existing methods for low resolution face images. Vidya et al., [10] proposed a face recognition system using Selective Illumination Enhancement Technique. In this technique the selected dark regions are illuminated by a correction factor which is determined by energy function. Threshold based DWT has been used for feature extraction. To search for a feature vector space A Binary Particle Swarm Optimization algorithm (BPSO) has been implemented. A new Color Local Texture Features for color face recognition is proposed by Jae Young Choi et al., [11]. They have developed two color local texture features namely Color Local Gabor Wavelets (CLGWs) and Color Local Binary Patterns (CLBP). Encoding of discriminative features derived from spatiochromatic texture patterns of different spectral channels of face images are possible from the proposed features. They have also done feature level fusion technique to maximize complementary effect in face recognition.


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## III. PROPOSED FACE RECOGNITION METHOD WITH NOVEL TECHNIQUE OF STEGANOGRAPHY

The proposed steganographic technique based face recognition using DWT, LBP and SOM is shown in figure 1.

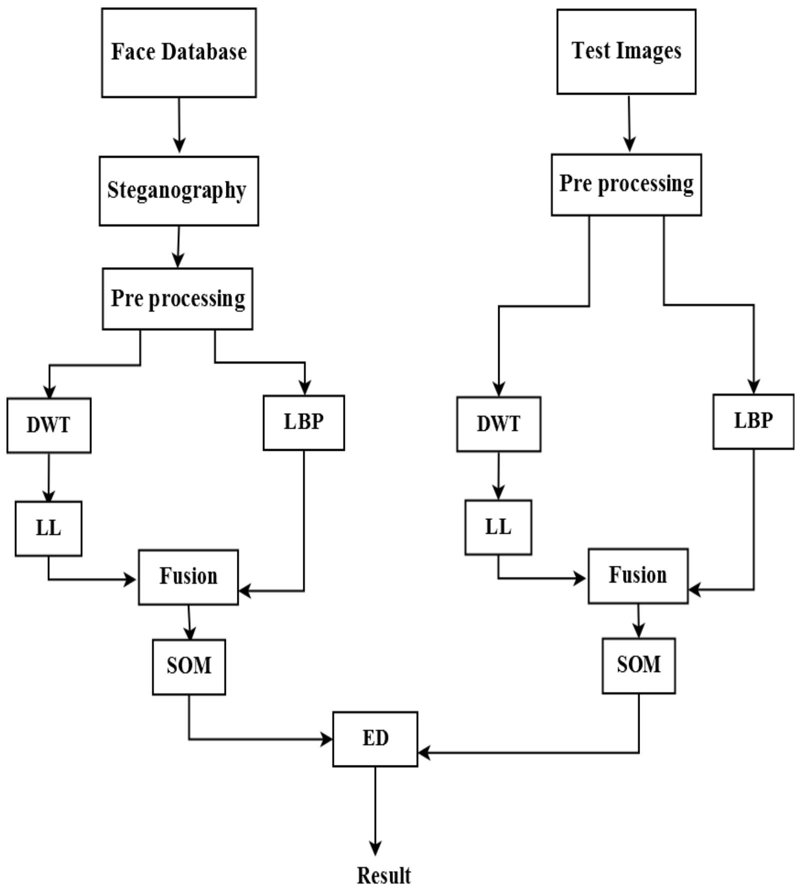


Fig. 1. Proposed steganographic technique based face recognition model

The total number of images per person is reduced to fifty percent using steganographic technique. The initial features are obtained by fusing DWT and LBP features. The final features are generated using SOM from initial features.

*A. Face databases*: The biometric algorithms are tested for various performance parameters using available face databases such as Olivetti Research Laboratory (ORL), Near Infra Red (NIR), Japanese Female Facial Expression (JAFFE), Yale, Indian Male Database and Indian Female Database.

1) ORL Face database [12]: The images are captured in April 1992 and April 1994 at AT & T laboratories, Cambridge. The database has forty persons with ten samples per person. The face images of single person with different expressions and pose angles are shown in figure 2.


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Fig. 2. Face images of ORL database

2) JAFFE Face database [13]: The database images are captured at the Psychology Department in Kyushu University. There are ten subjects, twenty one images per subject. The face images of different person in different pose are shown in the figure 3.

Fig. 3. Face images of JAFFE Database

3) NIR Database [14]: The database introduced in order to reduce the illumination effect and also avoid the misinterpretation due to the variation of luminance intensity. The database consists of 120 persons; each person's 15 different pose variations are captured. The figure 4 shows the NIR face database.

Fig. 4. Face images of NIR Database

4) YALE Database [15]: The database is generated at Yale Center for Computational Vision and Control. Data base consists of 15 persons of each person 10 images with different facial expressions like happy, sad, sleepy, surprised, wink and with and without glass right sided, left sided. Each image is a color image of size 240X320. The sample of database image is shown in figure 5.

Fig. 5. Yale Database samples



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5) Indian Male Database [16]: The database is created at Indian Institute of Technology, Kanpur. The database consists of twenty persons with each person eleven face images of different posed images. Images are in color and size of an image is 640X480.The samples of database face image are shown in figure 6.

Fig. 6. Indian male database

6) Indian Female Database [16]: The database consists of twenty two persons, eleven images per person. The images are color images of size 640X480 each are with different facial expressions and different poses. The samples of database are shown in figure 7.

Fig. 7. Indian female sample images

*B. Steganographic Image Conversion:*

The number of face images of a person in the face database are converted into fifty percent to save the memory and increase the speed of computation of proposed algorithm. Every two images of a person are converted into one image using spatial domain steganographic technique. The LSB's of first image are replaced by the corresponding MSB's of second image to obtain stegoimage which is almost same as first image [17].

Illustration: A first pixel intensity value of first image is say 42 and the corresponding binary is 0010 1010, in which MSB is 0010 and LSB is 1010. A first pixel intensity value of second image is say 202 and the corresponding binary is 11001010, in which MSB is 1100 and LSB is 1010. The first and second images are converted into single image (stegoimage) using steganographic technique by replacing LSB's of first image by MSB's of second image .The first pixel intensity value of stegoimage is 00101100 and the corresponding decimal value is 44, which is almost same as first pixel intensity value of first image. The stegoimage has significant information of both first and second images. Hence the steganographic technique is used to reduce the number of images in the database to fifty percent. The steganographic image conversion is as shown in figure 8.The stegoimage is same as the first image.


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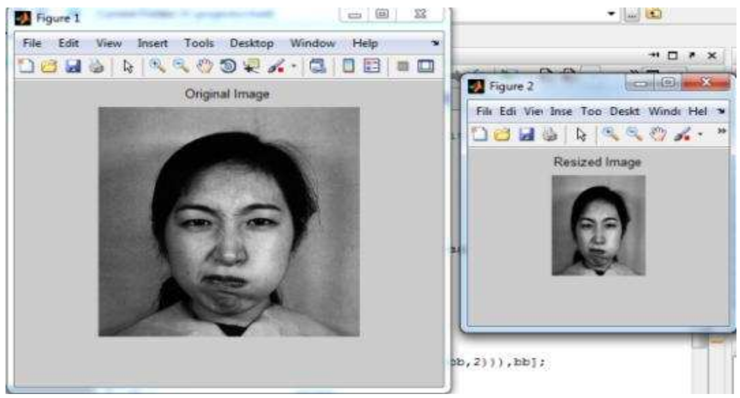
Fig. 8. The database new image creation using two images

*C. Pre-Processing:* The face images of various databases are resized and the quality is improved using filters in preprocessing unit.

1) Face Image Resize: The face images of different face databases are having different image dimensions; hence images are converted into uniform sizes of 112*92 to test the performance of the proposed algorithm. The JAFFE face database image of size 256*256 is resized to 112 *92 is as shown in figure 9.




(a) Original image (b) Resized image

Fig. 9. Resized Face image

2) Gaussian Filter [18]: The image has noise due to camera quality and surround environment. The filter is most suitable to remove gaussian noise. The impulse response is given in equation 1 and the corresponding curve is shown in figure 10.

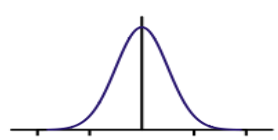


Fig.10. Impulse Response of Gaussian Filter

$$g(x,y) = \frac{1}{2\pi\sigma^2} e^{-\left(\frac{x^2+y^2}{2\sigma^2}\right)} \text{-------------------} \qquad (1)$$

Where, σ is standard deviation of Gaussian distribution

x is the distance from origin in the horizontal direction

y is the vertical distance from the origin

For σ=1, the impulse response is given in equation (2).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$$g(x,y) = \frac{1}{2\pi} e^{-\left(\frac{x^2+y^2}{2}\right)} \text{-----------------------------------------------------------------} \quad (2)$$

The values of x and y are ranging between -1 and 1 as shown in 3X3 matrix Table 1.

TABLE 1: x and y coordinates

| | | |
|---|---|---|
| **(-1,1)** | **(0,1)** | **(1,1)** |
| **(-1,0)** | **(0,0)** | **(1,0)** |
| **(-1,-1)** | **(0,-1)** | **(1,-1)** |

The different combinations of x and y values of table 1 are substituted in equation 2 to obtain approximate numerical values which yields gaussian mask as given in table 2.

g (-1,-1) = 0.0585≈0.0625=g (1, 1) =g (-1, 1) = g (1,-1)

g(0,1) = 0.096 ≈0.125=g(-1,0)= g(1,0)= g(0,-1)= g(0,1)  g (0,0) = 0.159 ≈ 0.25

TABLE 2: Gaussian Mask

(1/16)

| | | |
|---|---|---|
| 1 | 2 | 1 |
| 2 | 4 | 2 |
| 1 | 2 | 1 |

For obtaining filtered image, firstly the image is divided into 3X3 overlapping blocks as shown in the fig. 11(a). Then pixel values of each block is multiplied with the 3X3 Gaussian mask position wise to obtain equivalent 3*3 matrixes as shown in fig. 11(b). The coefficient values of 3*3 resultant matrixes are added to generate one value of 1797 from figure 11.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 106 | 113 | 116 | 120 | 119 | 119 | 122 | 123 |
| 108 | 116 | 114 | 118 | 116 | 116 | 117 | 119 |
| 103 | 110 | 118 | 114 | 114 | 119 | 116 | 116 |
| 106 | 111 | 116 | 114 | 117 | 118 | 119 | 117 |
| 106 | 110 | 112 | 112 | 119 | 116 | 116 | 118 |
| 105 | 112 | 114 | 116 | 120 | 119 | 118 | 115 |
| 108 | 109 | 112 | 115 | 120 | 121 | 118 | 118 |

(a) The 3X3 moving window

| | | |
|---|---|---|
| 106 | 113 | 116 |
| 108 | 116 | 114 |
| 103 | 110 | 118 |

X

| | | |
|---|---|---|
| 1 | 2 | 1 |
| 2 | 4 | 2 |
| 1 | 2 | 1 |

=

| | | |
|---|---|---|
| 106 | 226 | 116 |
| 216 | 464 | 228 |
| 103 | 220 | 118 |

(b) Computation of Gaussian filter pixel of a 3X3 block

Fig. 11. Illustration of Gaussian Filter computation

The resultant value 1797 is divided by 16 to generate final equivalent value of 112.3125 and is approximated to 112 for 3*3 matrix of an image. The original and Gaussian filtered images are as shown in figure 12.


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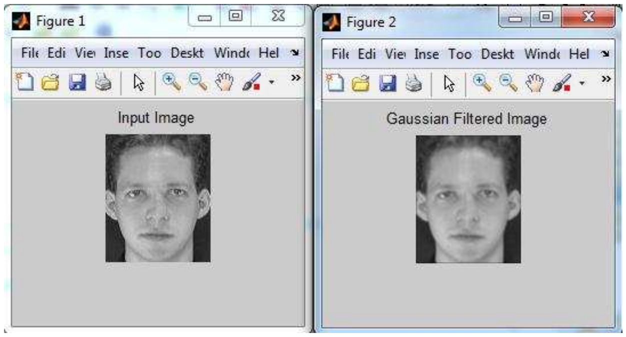



(a) Original Image (b) Filtered Image

Fig. 12. Gaussian Filtered Image

*D. Feature Extraction:* The initial features are obtained by fusing spatial and transform domain techniques such as LBP and DWT respectively. The final features for biometric system are generated using SOM from initial features.

1) Local Binary Pattern (LBP) [19]: The spatial domain texture pattern features are generated using LBP to identify face images effectively. The face image pixel intensity matrix values are decomposed into 3*3 overlapping matrices. The center pixel value of 3*3 matrix is converted into effective new value based on binary pattern of surrounding eight pixel values. The binary pattern of surrounding pixels is generated using an equation 3.

$$X_i = \begin{cases} 1 & I_p \geq M_{avg} \\ 0 & I_p \geq M\_avg \end{cases} \text{----------} \quad (3)$$

Where, Xi is the binary bit obtained after comparing of $i^{th}$ pixel

$I_p$ is the center pixel in the considered 3X3 matrix.

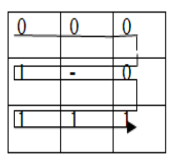
$M_{avg}$ is Average absolute value of eight surrounding pixel values

$$= \frac{(|m1| + m2| + |m3| + \cdots + |m8|)}{8}$$

$m_1$ to $m_8$ = pixel intensity values of surrounding eight pixels.

| | | |
|---|---|---|
| 106 | 108 | 103 |
| 113 | 116 | 110 |
| 116 | 114 | 118 |

(a) 3X3 Matrix




(b) Binary Values

| | | |
|---|---|---|
| 128 | 64 | 32 |
| 16 | | 8 |
| 4 | 2 | 1 |

(c) Binary weights

Fig. 13. Local Binary Pattern Generation of 3X3 Matrix

An example of LBP on 3*3 matrix is shown in figure 13. The absolute value of 3*3 boundary pixels is equal to 111. The each neighboring pixel intensity values are compared with absolute pixel intensity value 111 and the corresponding binary values are assigned. The binary weights are shown in figure 13(c). The center pixel intensity value of 3*3 matrix is replaced by decimal equivalent of 23 from binary value 00010111. Similarly each pixel value of an entire image is converted into new values based on surrounding eight pixels to extract texture features of an image. The LBP matrix of size 112*92 is generated for face image size of 112*92 by padding zeros to the boundary sides of face image matrix. The computed LBP matrix is converted into descending order row vector of size 1*10304. The highest 2576 coefficient values are considered as features of LBP to match the number of coefficients of DWT for fusion.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2) DWT (Discrete Wavelet Transform) [20]: The transformation specifies information of frequency along with location and is used to extract face image features effectively. The DWT decomposes an image into Low frequency band i.e., LL and High frequency bands viz., LH, HL and HH. The LL band has significant information of an image. The detailed information i.e., insignificant information of an image is present in detailed bands such as LH, HL and HH. The original image can be reconstructed using only LL band. The DWT decomposition on 8X8 Matrix of figure 14 is given in figure 15.

$$\begin{pmatrix} 160 & 170 & 180 & 185 & 185 & 174 & 165 & 155 \\ 165 & 180 & 167 & 84 & 147 & 176 & 164 & 152 \\ 169 & 125 & 34 & 59 & 105 & 162 & 162 & 149 \\ 165 & 48 & 8 & 21 & 91 & 166 & 162 & 150 \\ 148 & 56 & 8 & 73 & 123 & 152 & 162 & 145 \\ 104 & 14 & 20 & 99 & 123 & 98 & 120 & 108 \\ 125 & 30 & 38 & 109 & 134 & 117 & 119 & 118 \\ 120 & 58 & 75 & 128 & 125 & 125 & 119 & 114 \end{pmatrix}$$

Fig. 14. Original 8 X 8 Matrix

$$\begin{pmatrix} 337.5 & 308 & 341 & 318 \\ 253.5 & 61 & 262 & 311.5 \\ 161 & 100 & 248 & 267.5 \\ 166.5 & 175 & 250.5 & 235 \end{pmatrix}$$

(a)

$$\begin{pmatrix} -7.5 & 57 & 18 & 2 \\ 40.5 & 32 & 5 & -0.5 \\ 43 & -19 & 27 & 39.5 \\ -11.5 & -28 & 0.5 & 2 \end{pmatrix}$$

(b)

$$\begin{pmatrix} -12.5 & 39 & -9 & 11 \\ 80.5 & -19 & -66 & 12.5 \\ 91 & -72 & -2 & 14.5 \\ 78.5 & -62 & 8.5 & 3 \end{pmatrix}$$

(c)

$$\begin{pmatrix} 2.5 & -44 & 20 & -1 \\ -36.5 & -6 & 9 & 0.5 \\ 1 & 7 & -27 & 2.5 \\ 16.5 & -9 & 8.5 & -2 \end{pmatrix}$$

(d)

Fig. 15. Sub-bands obtained after one level 2D Decomposition (a) LL (b) LH (c) HL (d) HH

The 2X2 elements of original matrix is considered and the values are a=160, b=170, c= 165 and d= 180. The sub-bands LL, LH, HL and HH are computed using equations 4, 5, 6 and 7.

$$LL = \frac{(a+b+c+d)}{2} \quad (4)$$

$$= \frac{160+170+165+180}{2} = 337.5$$

$$LH = \frac{(a+b-c-d)}{2} \quad (5)$$

$$= \frac{160+170-165-180}{2} = -7.5$$

$$HL = \frac{(a-b+c-d)}{2} \quad (6)$$

$$=\frac{160-170+165-180}{2} = -12.5$$

$$HH = \frac{(a-b-c+d)}{2} \quad (7)$$

$$=\frac{160-170-165+180}{2} = 2.5$$

Similarly LL, LH, HL and HH sub bands are generated for other 2X2 set of elements of original matrix.

The DWT is applied on image size of 112X92 and sub bands are as shown in figure 16. It is observed that the whole image information is present in LL band where as significant information such as vertical, horizontal and diagonal details are present in LH, HL and HH sub bands. The LL band matrix size of 56*46 is converted into row vector of size 1*2576.

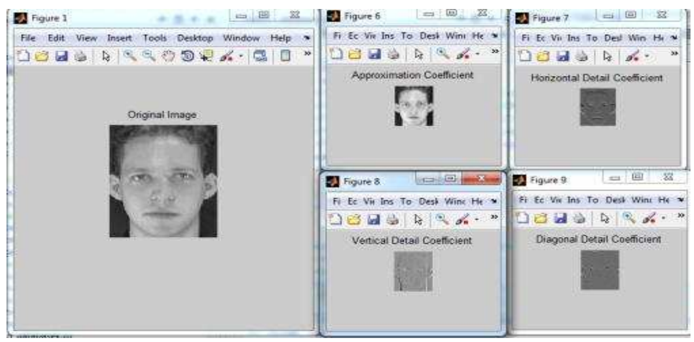


Fig. 16. Original image and all sub-bands

3) Fusion: The LBP features and LL band features are fused using arithmetic addition.

4) Self Organizing Map (SOM) [21]: An ANN is configured for a specific application, such as pattern recognition or data classification through a learning process. The ANN mainly consists of three layers input, output and hidden layer. The neural networks are mainly used for its new information processing system. The neural network is mainly divided into two types based on the scheme of learning and is Supervised Learning, Unsupervised Learning.

The SOM is a kind of unsupervised learning ANN which is applied for classification and image compression to reduce the number of features. The input to the SOM has number of samples and each sample has number of elements indicates a vector. The hidden layer consists of number of neurons specified by the user. Every input neuron is connected to each neuron in the hidden layer and each neuron in the hidden layer is connected to the every output neuron. The hidden neuron is assigned with random weight; the dimension of weight vector is same as input vector and then it is compared with the input vector. For comparison, Euclidean distance is calculated between the hidden neuron weight and the input vector. Similar distance forming input vectors are classified into one class. In


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the same way, all the input vectors are compared with the every hidden neuron weight vector to obtain different classes. This procedure is called training phase and it is mapped for different set of input samples.

The dimension of the SOM indicates the number of neurons available. The input vectors to the SOM dimension is PXQ, the each sample of input is treated as vector consists of P elements and the dimension of hidden neurons is NXN then the SOM will produce the two outputs one is classes and the other is weights. The value of class's ranges from 1 to $N^2$ and $N^2$XP weights are produced. The block diagram of SOM is as shown in figure 17.

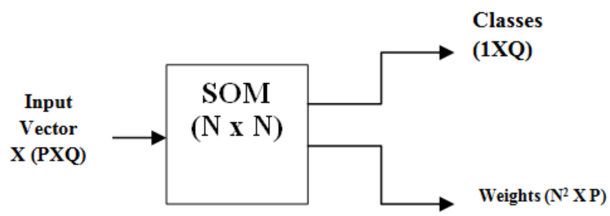


Fig. 17. Example of SOM

*E. Matching Unit:* The features of database images are compared with test image features using Euclidian distance (ED) using equation 8.

$$ED = \sqrt{\sum_{i=1}^{N} |(D_i - T_i)|^2} \text{-----------------------------} \quad (8)$$

Where, N = Total Number of features

$D_i$ = Feature coefficient values of database images

$T_i$ = Feature coefficient values of test image

## IV. ALGORITHM

*A. Problem Definition*: The face recognition is used to identify a person effectively. The concept of steganography is used in face recognition to reduce number of images per person along with DWT, LBP and SOM for feature extraction.

*B. Objectives:* The efficient face recognition technique is developed for the following objectives:

(i) To increase TSR

(ii)To decrease FRR, FAR and EER

The proposed algorithm for face recognition is given in the table 3.


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Table 3: Proposed algorithm Face Recognition Algorithm

- Input**:** Face database and Test Face images
- Output: Recognition of Query Face images

1. The face images of different databases are considered
2. The concept of steganography is used to reduce number of images per person into fifty percent.
3. The different sizes of face images from different databases are resized to uniform size. The filters are also used to improve quality of images in preprocessing.
4. The DWT is applied on preprocessed face images and LL coefficients are considered as DWT features.
5. The LBP texture features of preprocessed face images are extracted and considered dominant features.
6. The DWT and LBP features are fused to generate fused features.
7. The fused features are applied to SOM to obtain final dominant features.
8. The ED is used to compare final features of database and test images to identify test images efficiently.

## V. PERFORMANCE ANALYSIS

In this section, the definitions of performance parameters and performance variations using different face databases are discussed.

### *A. Performance parameter Definitions:*

1) False Rejection Rate (FRR): It is an error and defined as the ratio of numbers of genuine persons inside database is rejected falsely to the total number of persons inside the database. The percentage FRR equation is given in the equation 9.

$$\%FRR = \frac{\text{Number of genuine persons falsly rejected}}{\text{Total Number of persons inside the database}} \times 100 \quad \text{---------------------} \quad (9)$$

2) False Accept Rate (FAR): It is an error; the numbers of unauthorized persons from outside database are accepted as genuine to the total number of persons in the outside database. The FAR equation is given in the equation 10.

$$\%FAR = \frac{\text{Number of Falsely accepted unauthorized persons}}{\text{Total Number of unauthorized persons outside the database}} \times 100 \text{ ----------------} \quad (10)$$

3) Equal Error Rate (EER): Equal Error Rate is the percentage of error rate at which both FAR and FRR are equal. In another way, the intersection of FRR and FAR is known as EER.


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4) Total Success Rate (TSR): It is measure of accuracy of the method. It is defined as the ratio of number of persons matched correctly to the number of persons present in the database. The TSR is computed using an equation 11.

$$\%TSR = \frac{\text{Number of persons matched correctly}}{\text{Number of authorized persons inside the database}} \times 100 \text{ -----------------} \quad (11)$$

*B. Performance Variations*: The performance parameters such as FRR, FAR, EER and TSR are computed using proposed algorithm for different face databases.

1) ORL Face database: The different combinations of persons inside database (PID) and persons outside database (POD) are considered to test the proposed algorithm. The variations of FRR, FAR and TSR with threshold for PID: POD combinations of 20:20 and 30:10 are shown in fig.18 and 19 respectively.

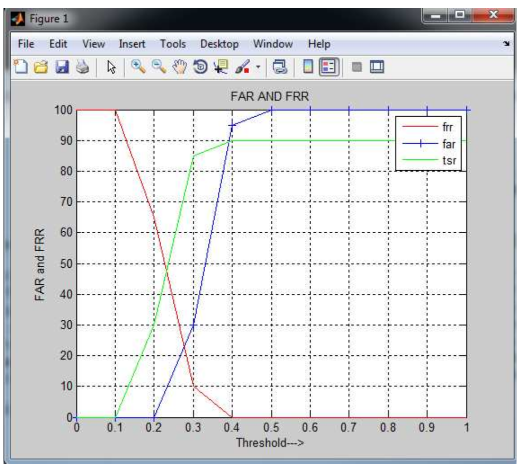


Fig. 18. Variations of FRR, FAR and TSR for PID: POD 20:20

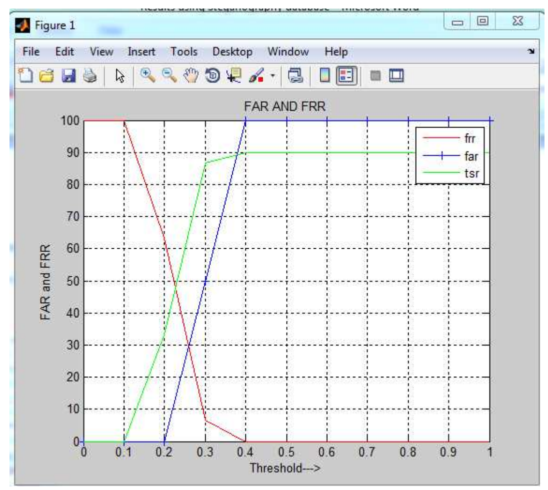


Fig. 19. Variations of FRR, FAR and TSR for PID: POD 30:10

The FRR and TSR decreases with increase in threshold whereas, the values of FAR increases with threshold values. The value of EER is obtained with intersection of FRR and FAR. The EER values are 0.25 and 0.3 for 20:20 and 30:10 respectively.

TABLE 4: Variations of Opt.TSR, Max.TSR and EER for combinations of PID and POD

| PID | POD | EER | Opt. TSR | Max. TSR |
|---|---|---|---|---|
| 20 | 20 | 0.25 | 60 | 90 |
| 30 | 10 | 0.3 | 60 | 90 |

The variations of performance parameter such as EER, Opt. TSR and Max.TSR for different combination of PID and POD for ORL face database are given in table 4. It is observed that as PID increases, the values of EER increases, where as Opt. TSR and Max. TSR are almost constant.

2) JAFFE Database: The proposed algorithm is verified using JAFFE database with various combinations of PID and POD. The variations of TSR, FRR and FAR with threshold for 4:6, 6:4 and 8:2 combinations of PID and POD are shown in fig. 20 and 21 respectively.

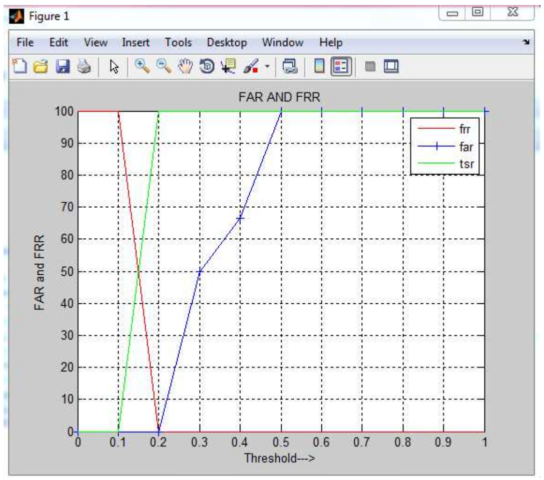


Fig. 20. Variations of FRR, FAR and TSR for PID: POD 4:6

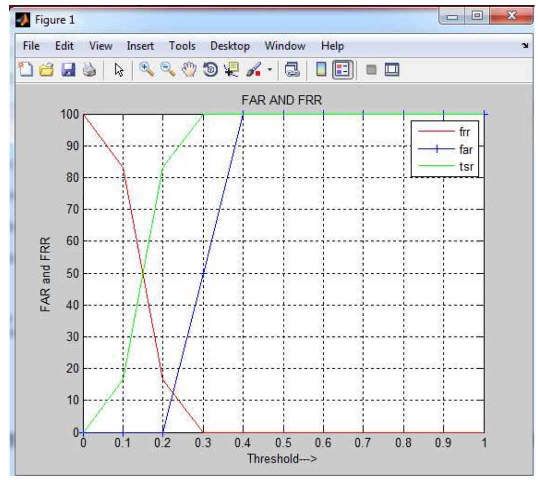


Fig. 21. Variations of FRR, FAR and TSR for PID: POD 6:4

The FRR and TSR decreases with increase in threshold whereas, the values of FAR increases with threshold values. The value of EER is obtained with intersection of FRR and FAR. The EER values are 0, 0.12 and 0.2 for 4:6, 6:4 and 8:2 PID and POD combinations respectively.

TABLE 5: Variations of Max. TSR, Opt. TSR and EER for combinations of PID and POD

| PID | POD | EER | Opt. TSR | Max. TSR |
|---|---|---|---|---|
| 4 | 6 | 0 | 100 | 100 |
| 6 | 4 | 0.12 | 90 | 100 |
| 8 | 2 | 0.2 | 80 | 100 |

The variations of performance parameters for different combinations of PID: POD for JAFFE database given in table 5. It is observed that, with increase in inside database the Opt. TSR decreases and the error rate EER increases.

3) NIR Database: The proposed method is evaluated using NIR database for the different combination of PID: POD. The graphs show the variations of performance parameters with threshold for different combinations of PID: POD in fig.22 and 23.


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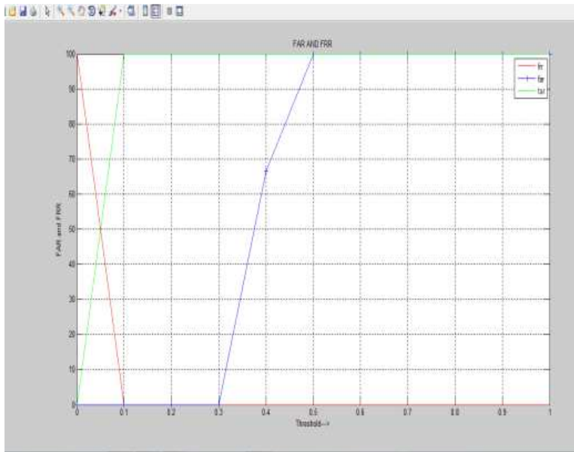

Fig. 22. Variations of FRR, FAR and TSR for PID: POD 2:3

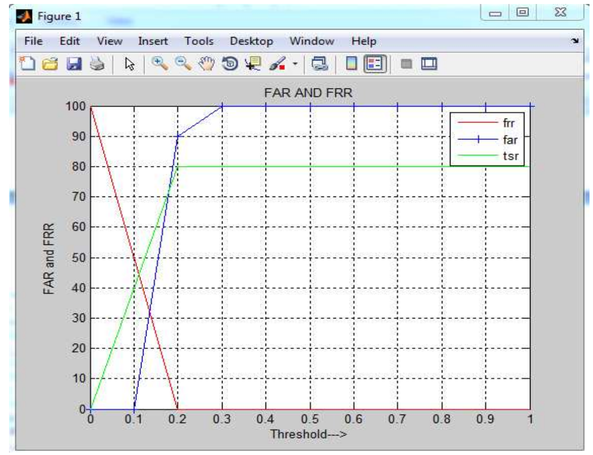


Fig. 23. Variations of FRR, FAR and TSR for PID: POD 10:30

The FRR and TSR decreases with increase in threshold whereas, the values of FAR increases with threshold values. The value of EER is obtained with intersection of FRR and FAR. The EER values are 0, 0.4 and 0.4 for 2:3, 10:30 and 20:20 PID, POD combinations respectively.

TABLE 6: Variations of performance parameters for different combinations of PID and POD

| PID | POD | EER | Opt. TSR | Max. TSR |
|---|---|---|---|---|
| 2 | 3 | 0 | 100 | 100 |
| 10 | 30 | 0.4 | 50 | 90 |
| 20 | 20 | 0.4 | 40 | 55 |

From the table 6, it is observed that as the inside database increases, the optimum TSR reduces where as the equal error rate increases.

4) Yale Database: The proposed method is evaluated using Yale database for the different combination of PID: POD. The graphs show the variations of performance parameters with threshold for different combinations of PID: POD in fig.24 and 25.


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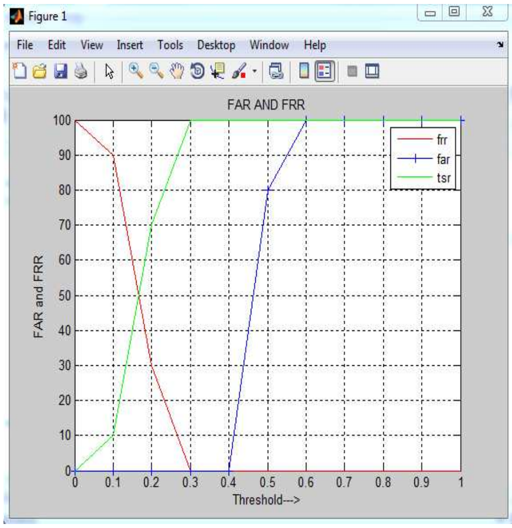


Fig. 24. Variations of FRR, FAR and TSR for PID: POD 10:5

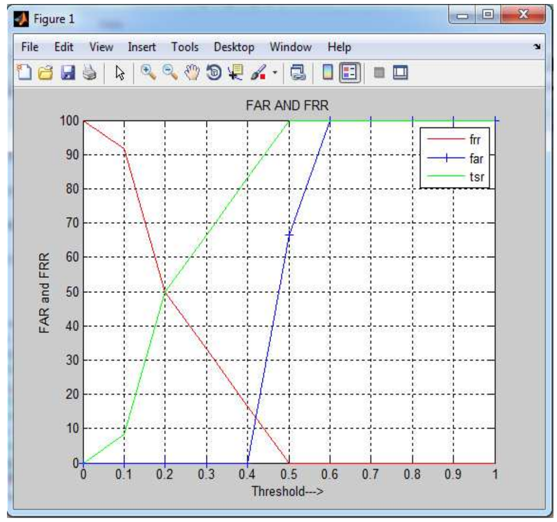


Fig. 25. Variations of FRR, FAR and TSR for PID: POD 12:3

The FRR and TSR decreases with increase in threshold whereas, the values of FAR increases with threshold values. The value of EER is obtained with intersection of FRR and FAR. The EER values are 0, 0.12 for 10:5, 12:3 PID, POD combinations respectively.

TABLE 7: Variations of performance parameters for different combinations of PID and POD

| PID | POD | EER | Opt. TSR | Max. TSR |
|---|---|---|---|---|
| 10 | 5 | 0 | 100 | 100 |
| 12 | 3 | 0.12 | 85 | 100 |

From the table 7, it is observed that as the inside database increases, the optimum TSR reduces where as the equal error rate increases.

5) Indian Male: The proposed method is evaluated using Indian Male database for the different combination of PID: POD. The graphs, shows the variations of performance parameters with threshold for different combinations of PID: POD is shown in fig.26 and 27.


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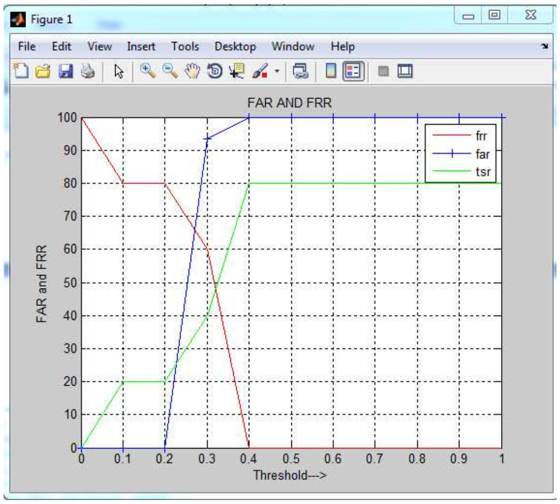


Fig. 26. Variations of FRR, FAR and TSR for PID: POD 5:15

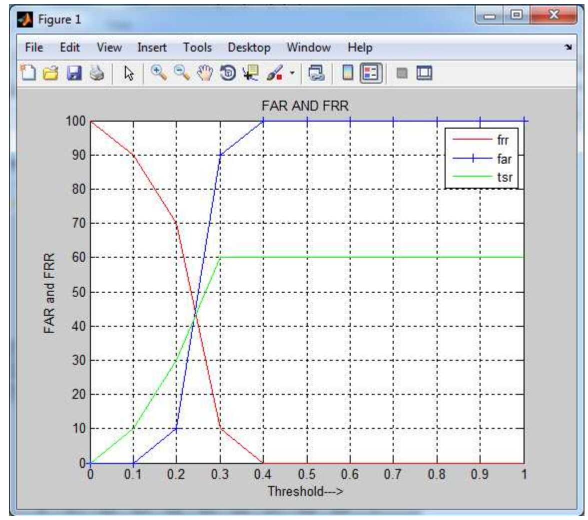


Fig. 27. Variations of FRR, FAR and TSR for PID: POD 10:10

The FRR and TSR decreases with increase in threshold whereas, the values of FAR increases with threshold values. The value of EER is obtained with intersection of FRR and FAR. The EER values are 0.4 and 0.45 for 5:15, 10:10 PID, POD combinations respectively.

TABLE 8: Variations of performance parameters for different combinations of PID and POD

| PID | POD | EER | Opt. TSR | Max. TSR |
|---|---|---|---|---|
| 5 | 15 | 0.40 | 55 | 80 |
| 10 | 10 | 0.45 | 45 | 60 |

From the table 8, it is observed that as the inside database increases from 5 to 10, the optimum TSR and Max. TSR reduces from 55 to 45 and 80 to 60 respectively; whereas the equal error rate increases.

6) Indian Female: The proposed method is evaluated using Indian Female database for the different combination of PID: POD. The graphs show the variations of performance parameters with threshold for different combinations of PID: POD in fig.28 and 29.


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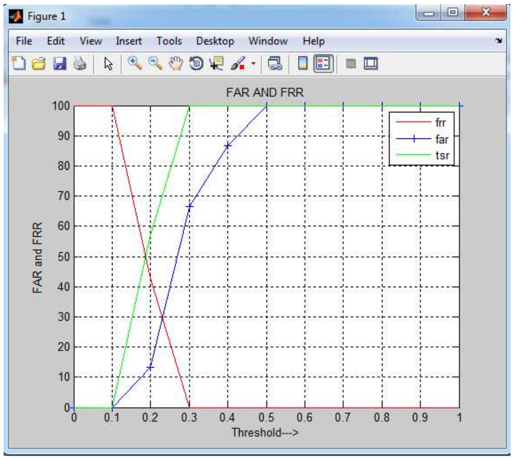


Fig.28. Variations of FRR, FAR and TSR
for PID: POD 7:15

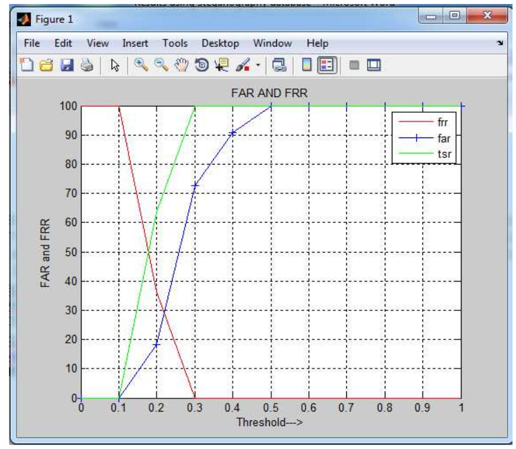


Fig. 29. Variations of FRR, FAR and TSR
for PID: POD 11:11

The FRR and TSR decreases with increase in threshold whereas, the values of FAR increases with threshold values. The value of EER is obtained with intersection of FRR and FAR. The EER values are 0.3, 0.3 and 0.24 for 7:15, 11:11 and 15:7 PID, POD combinations respectively.

TABLE 9: Variations of performance parameters for different combinations of PID and POD

| PID | POD | EER | Opt. TSR | Max. TSR |
|---|---|---|---|---|
| 7 | 15 | 0.3 | 70 | 100 |
| 11 | 11 | 0.3 | 72 | 100 |
| 15 | 7 | 0.24 | 65 | 86.667 |

By observing the table 9, the increase in inside database, the Max.TSR, Opt. TSR and EER are reduced as shown.

### *C. Comparison of Proposed Algorithm with Existing Algorithms for ORL Database*

The table 10 compares the proposed method with the existing face recognition methods presented by Mohammad Said El-Bashir [22] and Mayank Agarwal et al., [23]. It is observed that the proposed method is better compared to the existing techniques.

TABLE 10: Comparison of Proposed Method with existing methods using ORL Face Database

| Method | % Recognition Rate |
|---|---|
| Mohammad Said El-Bashir [22] | 96 |
| Mayank Agarwal et.al., [23] | 97.68 |
| **Proposed** | **100** |


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The novel concepts introduced in the proposed method are listed below:

1. The insignificant information of LSB bits of database images are eliminated using steganographic technique, which reduces total number of face images per person into fifty percent.
2. The spatial domain texture features using LBP are fused with LL band of DWT.
3. The SOM is used to obtain dominant features for comparison between database and test face images.

The advantages of the proposed method are:

1. The steganographic technique reduces number of face images per person in the database, which contributes to increase in speed of comparison between database images and test images.
2. The DWT LL band coefficients are considered as transformed domain by leaving LH, HL, HH bands that reduces number of features in the transform domain.
3. The texture features are extracted using LBP in the spatial domain and only dominant features of LBP equivalent to the number of LL band features are considered and fused with LL features. The effective features from transform domain and spatial domain are used for efficient recognition.
4. The SOM extracts final dominant features from fused features of transform and spatial domain to recognize face effectively.
5. The computation speed is high for the usage of steganography, DWT, dominant features of LBP and SOM.

## VI. CONCLUSION

The face recognition is used in variety of applications. In this paper, we proposed SOM based Face Recognition using Steganography and DWT Compression Techniques. The Steganography is used as compression technique to reduce number of face images per person. The resize and Gaussian filter techniques are used in the preprocessing to obtain uniform image sizes and improve image quality. The DWT is applied on face images and only LL band coefficients are considered for further processing. The LL coefficients and LBP coefficients are fused using arithmetic addition. The fused features are applied to the input of SOM to derive SOM output as final features. The Euclidian Distance is used to compare final features of test and face database images to compute performance parameters of the proposed method. It is observed that the computed performance parameters of the proposed method are better compared to existing methods. In future the algorithm can be implemented using hardware as three types of compression techniques namely Steganography, DWT and SOM are used.

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