Journal of Theoretical and Applied Information Technology
15th May 2017. Vol.95. No 9

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

A NOVEL FUSION BASED HYBRID APPROACH FOR FACE RECOGNITION SYSTEM

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ABSTRACT

Face recognition plays a challenging role in the field of image processing. Though one of its benefit is that the person can easily be identified among the crowd through face recognition, but it has several issues that need to be overcome such as facial expressions, ageing, occlusion etc. Face recognition method can only be entertained, if it can identify the face correctly. Global features (DWT, PCA) and point based features (Harris corner, SURF) both are considered to create a fusion based system for automatic face recognition. Accuracy, sensitivity and precision are the performance evaluation parameters are evaluated. The comparative study of various standard and conventional feature extraction techniques is carried out in this paper in order to decide which approach is more suitable for accurate face recognition. Fusion based approach gives 99.4 percent accuracy.

Keywords: *PCA, SURF, DWT, Harris Corner.*

1. INTRODUCTION

During the last twenty years, the automatic recognition of faces has a major challenge, particularly in the areas of indexing of multimedia and especially in security, this is due to the needs of the present world but also to its characteristics. Advantages of which the availability of acquisition equipment, their simplicity and low costs. Passivity of the system: a face recognition system does not require any of the individual, of the kind: putting the finger or the hand on a device or speak in a microphone. Indeed, the person only has to stay or walk in front of a camera so that it can be identified by the system. In addition, this technique is very effective for non-standard situations. The individual's cooperation in identifying, for example, the arrest of criminals. Although the recognition of the faces is not the most reliable compared to the others biometrics, but it can be so if more effective approaches are more of the right choice of identification characteristics representing the face in question [1]. Generally, a face recognition system is characterized by its classifier that can be designed according to two types of approaches[2]:

Global approaches:

This type of approach uses the entire face as a source of information, without segmentation of its parts, they rely mainly on pixel information. These algorithms rely on well-known statistical properties and use linear algebra. They are relatively quick to implement but are sensitive to illumination problems, Pose and facial expression. Among the most important approaches within this class are: PCA,LDA [3]

Local approaches:

They are also called linear, local, or analytical methods. This is to apply transformations at specific points in the image, often around characteristic points (corners of the eyes, the mouth, the nose, ...). They therefore require an a priori knowledge of the images [Moa 05]. The advantage of these methods is that they take into account the particularity of the as a natural form to be recognized, in addition they use a reduced number of parameters and they are more robust to the problems caused by variations in lighting, installation and of facial expression [4], [5]. But their difficulty arises when it comes to take into consideration several facial views as well as the lack of precision in the phase "Extraction" of the points constitute their major disadvantage [6-7]. Following are the approaches for automatic face recognition:

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Image Acquisition:

This step consists of extracting the image of the user from the outside world in a state static using a camera or dynamically using a camera. Afterwards, the extracted image will be digitized, which gives rise to a two-dimensional representation of the face, characterized by a matrix of gray levels. The image in this step is in a raw state which creates a risk of noise that can degrade the performance of the system[8].

Pre-treatment:

The role of this step is to eliminate the parasites caused by the quality of the devices optical or electronic devices when acquiring the input image, with the aim of not retaining as essential information and therefore prepare the image to the next step. There are several types of treatment and improvement of the image quality, such as: normalization, equalization and the median filter.[9]

The extraction of parameters:

In addition to the classification, the parameter extraction step represents the core of the recognition system, it consists in carrying out the processing of the image in another space easier to use and which ensures better exploitation of data,the use, only, of useful, discriminating and non-redundant information.

Classification: (Modeling)

This step consists in modeling the parameters extracted from a face or a set of faces of an individual based on their common characteristics. A model is a useful, discriminating and non-redundant information that characterizes one or more individuals with similarities[10].

Learning:

This is the stage where people are taught the system, it consists in memorizing the parameters, after extraction and classification, in a well-ordered database for to facilitate the recognition and decision-making process, it is system memory.

Decision :

This is the step that makes the difference between a system of identifying individuals and a other verification. In this step, an identification system consists of finding the model which best corresponds to the face taken as input from those stored in the base of data, it is characterized by its recognition rate. On the other hand, in a system of Verification it is a matter of deciding whether the face is the face of the individual (model) proclaimed or it is an impostor, it is characterized by its EER (equal error rate).

Hybrid Methods as their name suggests, these approaches combine holistic and local authorities. The idea is to combine them in a way to use the advantages of one to counterbalance the defects of the other. The effective combination of local characteristics for the time being is a problem and little work on its application to the problem of facial recognition exist [11-15].
The algorithms like PCA, ICA and DWT derives features out of face image and in second stage use a matching formula based on extracted features [16-17]. Generally these formulas are the standard mathematical tools for static comparison of test and dataset image. The advance algorithms like Neural Network (NN) [18-19] generates the output based on training of classification method and serves better in complicated scenarios where large no. of test images are subjected to recognition.

This paper is organized as follows. In section 2, we discuss in brief about the related work involves in face recognition systems .In section 3 pre-processing is discussed .In section 4 different database is discussed. In section 5, we discuss in brief about different approaches for features extraction and its impact on training for machine learning. In section 6, we discuss the experimental setup for face recognition system. In section 7,proposed method for combination of different methods for the face recognition has been developed. In section 8, It deals with analyse of the results and its outcome.
Face recognition can further be divided as:-

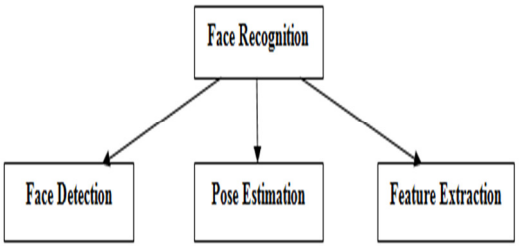

Fig. 1 : Face Recognition Technique

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A. Face Detection:-

In face detection process, first step is to correct illumination effect and conversion of RGB to YCbCr image. Then the second step is to extract the face part from the image .The background part is changed to black pixels. This process is known as segmentation. In some images, segmentation is done manually because the hair section sometimes gets into the face section [4].

B. Pose Estimation:-

The pose of a person can be recognized by detecting its face orientation. The orientation of eyes, nose and mouth guides us to recognize the actual pose orientation of the person. The Cr-Cb properties also give an idea about the eyes, nose and mouth orientation. The region around eyes gives high Cb value and low Cr value whereas the region around mouthgives high Cr value and low Cb value [4].

C. Feature Extraction:-

The major step in face recognition technology is feature extraction. The features are the part of image that describe image locally or globally. There are various feature extraction techniques such as PCA, LDA, ICA, DWT, SIFT, SURF etc.

2. RELATED WORK

There are many feature extraction methods based on shape and geometry. PCA is one of the robust feature extraction algorithms. It has certain limitations but still it is worth using due to its low computation cost [5]. The main motive of PCA (Principal Component Analysis) is to transform large set of variables into small sets. PCA creates Eigen-values for the face images from the database. These are known as eigenvectors. Each eigen-valued image is different from its adjacent image. The features of Eigenvectors is characterized by the weighted sum of eigen vectors. The weights of eigenvectors is compared in order to recognize an individual [6]. PCA is used for reducing the dimensionality of feature vector.

ICA (Independent Component Analysis) works similar to PCA. Different researchers have different opinions on the comparison between PCA and ICA. ICA was firstly used in face recognition technology by Bartlett et al., Yuen et al. and Liu [7,8,9]. There analysis says that ICA performs better than PCA whereas Baek et al [10] claims that PCA performs better than ICA. While on the other hand, Moghaddam [11] and Jin [12] observed no difference among the two methods. To resolve such contradictions, Draper et al [13] researched and compared the performance of PCA and ICA and came to the conclusion that both methods rely upon ICA architecture and the distance.

DWT (Discrete Wavelet Transform) is the signal analysis method that divides the image into no. of segment. The discrete wavelet transform represents the signal into time-frequency domain. DWT was introduced to overcome the drawback of STFT that is STFT uses constant resolution technique whereas DWT gives an option to analysis local features according to various frequency range [5].

Another method proposed as a pattern classifier is support vector machine (SVM). SVM has a two-class problem [14] where interclass differences are represented by one class and intra class differences are represented by second class. SVM is an efficient technique. It concentrates on the problem of face recognition and states that the SVMs models gives better accuracy then PCA, MLP classifier.

In [16] SURF(Speeded Up Robust Features) descriptor is explained as a novel-scale and rotation invariant detector. The SURF descriptor posses similar properties to that of SIFT but it performs better than SIFT descriptor. In this firstly the orientation is fixed on the basis of the data achieved from the circular region-of-interest (ROI). Then a square area is created oriented to the previous alignment and then the SURF descriptor is removed from it. In [17] SURF method is employed for feature extraction from elliptical face area for face recognition and detection for human-robot-interaction. This technique proved to be worth in real-time applications.

In [18], Alak Das uses Harris-corner detection method for detecting the eye-corner. There has been some disadvantages occurred previously in the Harris-corner eye detection because there is a chance of detecting lots of corners near the eyes in the image. Therefore, to avoid this issue of detecting more than two corners, Das proposed an updated method in which eye detection is done with only two eye corners (one for each eye). It contains following four steps:-

1. Pre-processing
2. Skin pixel separation
3. Face detection and extraction

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4. Post-processing

Harris corner detection is also used to detect the automatic smile recognition in [19] because of its ability to detect the corners successfully. It is compared with FAST corner detection algorithm and gives around 77.5% of accurate smile recognition.

3. PRE-PROCESSING

The face recognition goes through many steps. Pre-processing is a mandatory step before face detection. It filters noise and improves image quality. Image preprocessing includes gray-scaling of the colored image [20]. The RGB image is converted to YCrCb image where Y denotes luminance/brightness of image and Cr-Cb denotes tone of the image. Y component is called as the gray value of the image. Further the image quality (linearity, pixel value etc.) is improved by histogram equalization. There are different filters available to take care of noise [20]. The comparison of an image prior and post image pre-processing is depicted in Fig. 2.

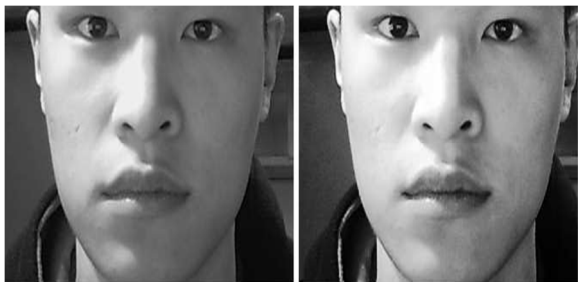

Fig. 2 : Image Comparison After Preprocessing

4. STANDARD DATASETS

While working on a specific approach, it is necessary for the researchers to work on a standard dataset in order to compare results. Following are some of the standard datasets used widely.

A. Indian Face Dataset

The files in this database are in JPEG format. Each image is having a size of 640x480 pixels and a gray level of 256 per pixel. There are two main directories in which the image is saved accordingly i.e. males and females. Each directory contains the details regarding image like name, serial no. etc. Each directory possesses 11 different images per subject having different looking orientations i.e. up, down, right, left etc. and the stored emotions are smile, laughter, sad/disgust, neutral.

B. Yale Face Dataset

The files contain 165 grayscale images of 15 personsin GIF format. Each subject has 11 images, one for each facial expression: center-light, with or without glasses, sad, sleepy, surprised, wink and many more.

C. ORL Face Database

Here 40 different persons have 10 images for each. The images for few subjects were captured under distinct circumstances like light variation, varying face expressions, with or without glasses.

5. SYSTEM MODEL

DWT-PCA

This is a hybrid algorithm which integrates two methods i.e. DWT and PCA together.

In this algorithm, both images are resized and then converted from RGB to gray image. Now the discrete wavelet transform is applied. The wavelet transform is represented here by dilation of primary wavelet

$$\Psi_{(a,b)}(x) = \frac{1}{\sqrt{a}}\Psi\frac{x-b}{a} \quad \text{eq----------(1)}$$

Where, Ψ is the primary wavelet function

a and b are the scaling parameter.

After DWT, simultaneously PCA is also applied in order to fuse the decomposed coefficients of both the images. Then IDWT (inverse-DWT) is applied to reconstruct the fused image.

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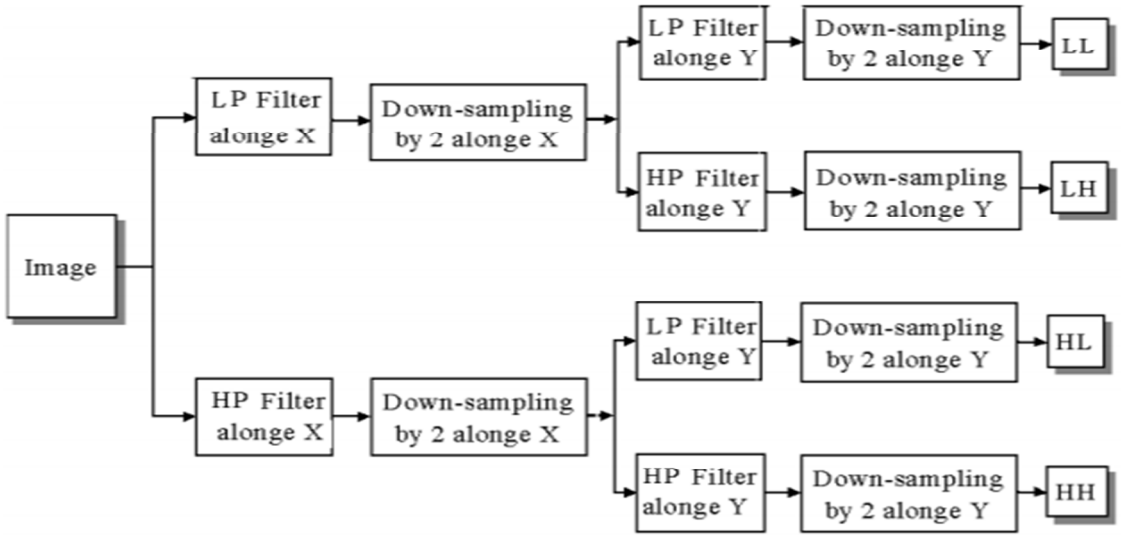

Fig. 3 : Dwt Decomposition Model

In DWT, filters are specially designed so that it has details that are not available previously. The 2D-DWT has four images as its output which is exactly half in size to that of the original image. Now the input images are changed into 2-column vectors. The following steps are involved in converting this data into two dimensional subspaces: 1. The data from input image matrix is arranged into a matrix vector 'X'of dimension 2xn. After that the mean image vector of dimension of 1 x 2 is evaluated for every column.

2. The difference between the mean vector and data matrix S is evaluated. The resultant matrix 'X' has the dimensionality of 2 x n.
3. 'C' covariance matrixis calculated using formula $C=XX^T$.
4. The main task is to find the eigen vector'V' and eigen value 'D' of covariance matrix, both of dimension 2 x 2.
5. The vectors then form eigen faces using 'V' training sets.

Harris Corner Detection:-

The aim of Harris Corner Detection method is to detect the corner of eye [18] or lips [19] of human face I_F. Harris corner detector is capable of analyzing corners in image using autocorrelation among intensity values. The mathematical expression for gradient covariance matrix G is given by

$$G = \begin{pmatrix} x1 & x2 \\ x2 & x3 \end{pmatrix} \qquad \text{eq----(2)}$$

Where, x1,x2 and x3 can be given as

$$X1 = (I_x)^2 \otimes w \qquad \text{eq----(3)}$$

$$X2 = (I_y)^2 \otimes w \qquad \text{eq----(4)}$$

$$X3 = (I_x I_y)^2 \otimes w \qquad \text{eq----(5)}$$

$\otimes$ represents convolution operation

I_x and I_y are spatial coordinate of input image(I) .

SURF based Method

SURF(i.e. Speeded Up Robust Features) based descriptor can be explained well rotation invariant detector. The SURF descriptor posses similar properties to that of SIFT (scale-invariant-feature-transform) but it performs better than SIFT descriptor. In this firstly the orientation is fixed on the basis of the data achieved from the circular region-of-interest (ROI). Then a square area is created oriented to the previous alignment and then the SURF descriptor is removed from it. SURF technique is invariant to variations such as variation in alignment, scale, brightness, viewpoint etc. The SURF process can be explained well in two steps.

1. **Interest point Localization**

Hessian matrix calculation is the key aspect of SURF, as it gives better performance in terms of operating-time and accuracy. Hessian matrix of image I at point X with scale σ can be given as follows:

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$$H(X, \sigma) = \begin{bmatrix} Z_{xx}(X,\sigma) & Z_{xy}(X,\sigma) \\ Z_{xy}(X,\sigma) & Z_{yy}(X,\sigma) \end{bmatrix} \quad \text{eq----(6)}$$

Where, $Z_{xx}(X,\sigma)$ is the convolution of Gaussian 2nd order derivative at point X ($i.e.\ \frac{d^2}{dx^2} g\ (\sigma)$). The 2nd order Gaussian derivative is approximated using filters which calculate the Laplacian of Gaussian and difference of Gaussian.

2. Interest point Descriptor

The SURF descriptor creates a circular region-of-interest to assign orientation in x and y directions (which is done by Haar wavelet response) .The region of interest is divided into sub region of 4x4 sizes. The structure of each sub region is represented by the vector as follows:-

$$V = \left[\sum d_x, \sum d_y, \sum |d_x|, \sum |d_y|\right] \quad \text{eq---(7)}$$

6. EXPERIMENTAL SETUP

Experiment was conducted on three datasets i.e. Indian dataset, Yale dataset and ORL dataset. There are 400 images in the database. Hence 40 sets are created such as each set having 10 images. Each database (Indian, Yale, ORL) contains front view images of 20 persons (10 male, 10 female)

for experiment. The database images have variation in brightness, change in facial expressions like wink, sad, happy, with or without glasses. Hence the expressions of each individual image are observed from different viewpoints.

Dataset I:

The training dataset I contains front images of individuals from Indian Database. Fig.4 contains female dataset and Fig. 5 contains male dataset.

Fig. 4 Indian female Database for experiment

Fig. 5 Indian Male Database For Experiment

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Dataset II :

The training dataset II contains front images of individuals from Yale Database. Fig.6 contains dataset of individual with different expressions/emotions like sad, happy, smiling, wink, with glasses or without glasses.

Fig. 6Yale Database For Experiment

Dataset III:

The training dataset III contains front images of individuals from ORL Database. Fig.7 contains dataset of individual with different expressions/emotions like sad, happy, smiling, wink, with glasses or without glasses.

Fig. 7ORL Database For Experiment

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The system model is designed such that it requires 1 image for training from each set and we are having 40 sets of 10 images. Hence total number of training information is 40.

1	2	3	.	.	.	.	.	.	10
2									
.									
.									
.									
.									
.									
40									

Let x_k be the set of images required for training

where x is the size of image (mxn)

Here 'm' represent row

and 'n' represent column

'k' is the number of sets depending upon the selected dataset i.e. k=1,2,3,4…….40

The wavelet transform of x is the square function of Haar wavelet which is the best suitable filter for this case.The output received from the wavelet is the

approximation coefficient of Haar wavelet will be the input of PCA.The extracted PCA will be the projected image feature of image. If we say, we are using 40 images for training then we will be having 40 projected feature vectors for training. Now rest of the images (i.e. 400-40 = 360) can be taken for testing as a test input. The test input is processed through DWT/PCA and thus its projected vector is compared with trained database.

Similarly, measure is performed using Euclidean distance. The Euclidean distance (D) can be given by the formula as below:

$$D = \sqrt{\sum_{i=0}^{n}(d_{1i} - d_{2i})^2} \quad \text{eq---(8)}$$

Based on this distance accuracy is calculated. So at the end, the output of DWT + PCA is generated as the ID. In similar way each prototype (method) will have its unique ID as an outcome. The resulted ID of each prototype may differ from each other. So it is difficult to choose which ID is accurate. Thus, we proposed a fusion based approach for all IDs gathered by different prototypes. At last the fusion rule will decide the final outcome.

7. PROPOSED METHODOLOGY

According to figure 3 after pre-processing the face is sampled for feature extraction, once feature is extracted with DWT+PCA, Harris corner and SURF, it is further fused to get the maximum benefits of techniques.

The fusion rules can be defined as follows:-

Let's have three ID as below:

1. ID_SURF
2. ID_DWT_PCA
3. ID_HARRIS

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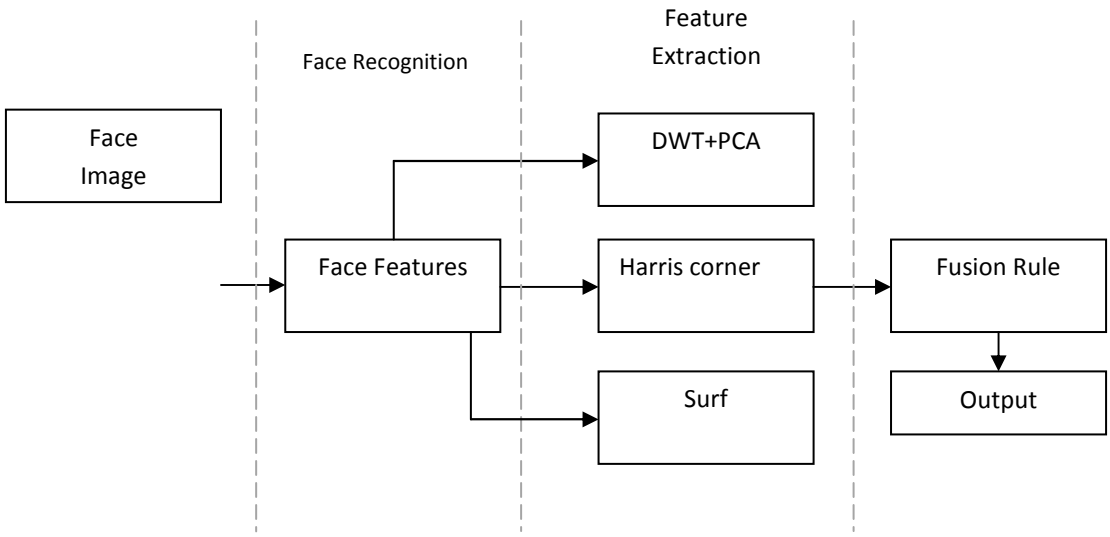

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Fig. 8. Face Recognition By Proposed Hybrid Approach

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So there may be only three cases:

1. All IDs are same, means (ID_SURF = ID_DWT_PCA = ID_HARRIS). This is desired and shows perfect recognition.
2. Two out of Three IDs are same, means
   a. ID_SURF == ID_DWT_PCA ≠ ID_HARRIS
   b. ID_SURF == ID_HARRIS ≠ ID_DWT_PCA
   c. ID_HARRIS == ID_DWT_PCA ≠ ID_SURF

In this case majority will be the output.

3. No two of the IDs are same, means (ID_SURF ≠ ID_DWT_PCA ≠ ID_HARRIS). This is the worst condition and not desirable but if arises, we do following:

a. Giving priority to SURF as it gives highest recognition rate among these method. We will check how many SURF features of test image are matched with reference image. If the number is greater than 20, than the ID_SURF will be output.

b. If SURF fails, giving next priority to DWT-PCA, if the normalized Euclidean distance between the test and reference is less than 0.01 than output will be ID_DWT_PCA.

c. If DWT-PCA also the fails, than we will check how many Harris features of test image are matched with reference image. If the number is greater than 10, than the ID_HARRIS will be output.

d. If all of a, b and c fail than ID_SURF would be default output.

8. RESULTS

For training purpose, only one single face is chosen. The test was performed using the same training set procedure. The test was evaluated on the basis of following:-

1. Accuracy= $\frac{truepositive+truenegative}{truepositive+truenegative+falsepositive+falsenegative}$

2. Precision= $\frac{truepositive}{truepositive+falsepositive}$

3. Sensitivity= $\frac{truepositive}{truepositive+falsenegative}$

The images used are of various combinations i.e. taken from different angle, varying in brightness, having different facial expressions of an individual, some images having occlusion etc. The performance of the system using each algorithm is evaluated individually on the basis of sensitivity, precision and accuracy and then the three algorithms are fused to enhance the performance of the system. The results are illustrated as follows:-

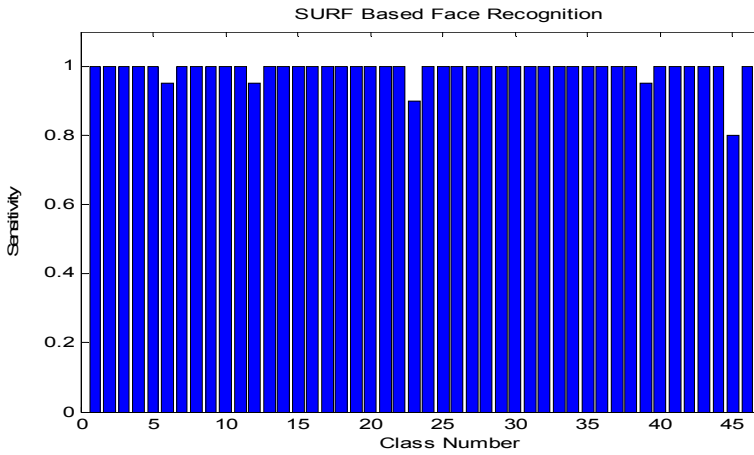

Fig. 9 : Performance Of SURF Based Face Recognition On The Basis Of Sensitivity

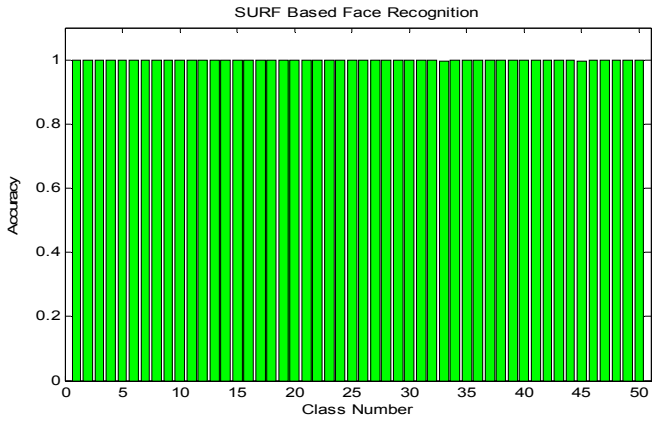

Fig. 10 : Performance Of SURF Based Face Recognition On The Basis Of Accuracy

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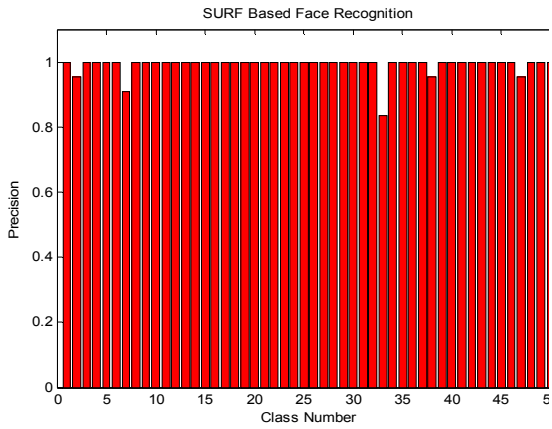

Fig. 11 : Performance Of SURF Based Face Recognition On The Basis Of Precision

The Fig 9,Fig10 and Fig11 represents the sensitivity ,accuracy and precision for the surf based approach. The system is evaluated under FERET database with 20 images in each class, there are total 50 class has been taken .One image from each class has been taken for reduction in training overhead. Experimetal results claims the accuracy and sensitivity according to class. Average accuracy is clamed with this method is 99.10%.

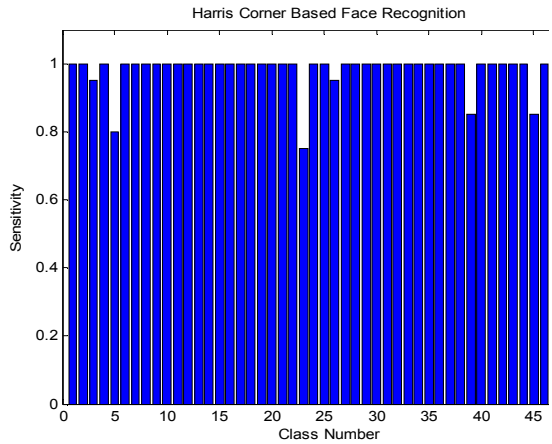

Fig. 12 : Performance Of Harris Corner Based Face Recognition On The Basis Of Sensitivity

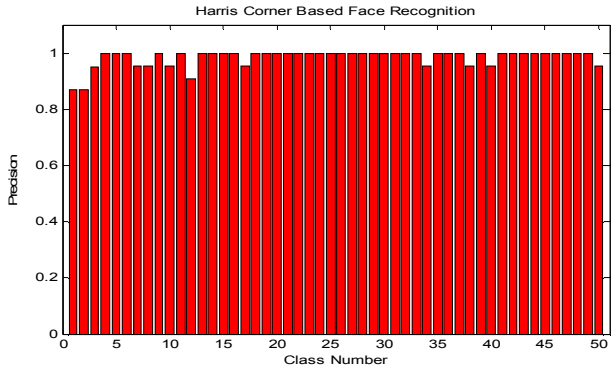

Fig. 13 : Performance Of Harris Corner Based Face Recognition On The Basis Of Precision

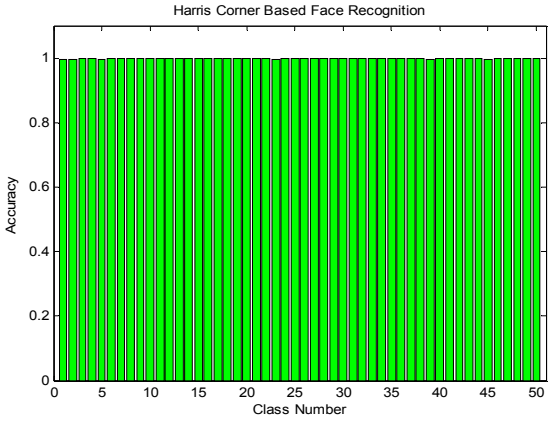

Fig. 14 : Performance Of Harris Corner Based Face Recognition On The Basis Of Accuracy

The Fig 12,Fig13 and Fig14 represents the sensitivity ,accuracy and precision for the Harris Corner based approach. The system is evaluated under FERET database with 20 images in each class, there are total 50 class has been taken .One image from each class has been taken for reduction in training overhead. Experimental results claim the accuracy and sensitivity according to class. Average accuracy is clamed with this method is 98.30%.

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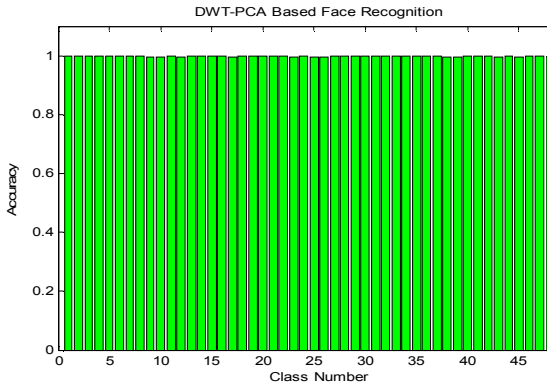

Fig. 15 : Performance Of DWT-PCA Based Face Recognition On The Basis Of Accuracy

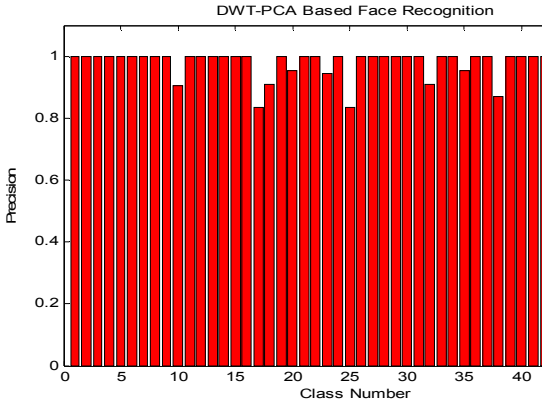

Fig. 16 : Performance Of DWT-PCA Based Face Recognition On The Basis Of Precision

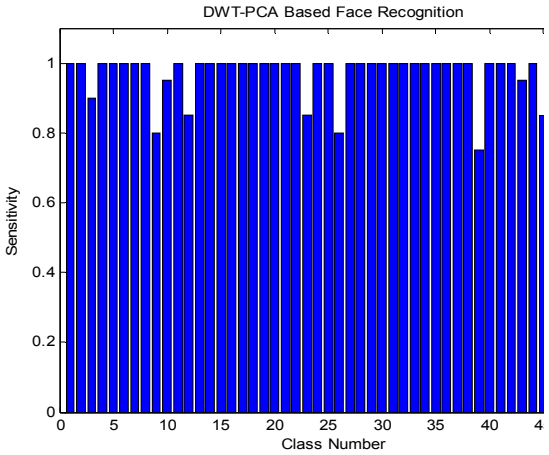

Fig. 17 : Performance Of DWT-PCA Based Face Recognition On The Basis Of Sensitivity

The Fig 15,Fig16 and Fig17 represents the sensitivity ,accuracy and precision for the DWT-PCA based approach. The system is evaluated under FERET database with 20 images in each class, there are total 50 class has been taken .One image from each class has been taken for reduction in training overhead. Experimental results claims the accuracy and sensitivity according to class. Average accuracy is clamed with this method is 97.4%.

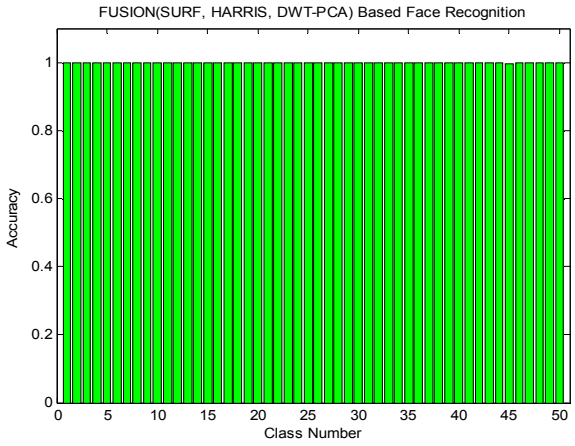

Fig. 18 : Performance Of Fusion Based Face Recognition On The Basis Of Accuracy

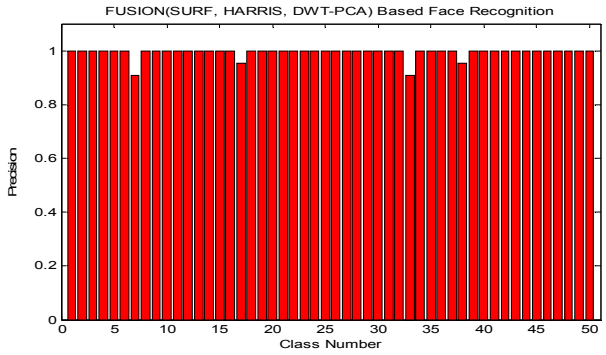

Fig. 19 : Performance Of Fusion Based Face Recognition On The Basis Of Precision

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

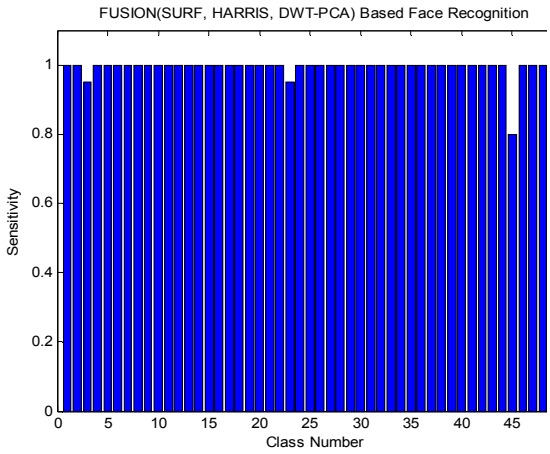

Fig. 20 : Performance Of Fusion Based Face Recognition On The Basis Of Sensitivity

The Fig 18,Fig19 and Fig20 represents the sensitivity ,accuracy and precision for the DWT-PCA based approach. The system is evaluated under FERET database with 20 images in each class, there are total 50 class has been taken .One image from each class has been taken for reduction in training overhead. Experimental results claims the accuracy and sensitivity according to class. Average accuracy is clamed with this method is 97.4%.

Recognition Rates

Recognition rates are evaluated using all the four methods (SURF, Harris-corner, DWT-PCA, Fusion). And it can be seen clearly that the Fusion based face recognition method has the highest recognition rate.

Type of Recognition Method	SURF	Harris Corner based	DWT-PCA based	Fusion (SURF, DWT-PCA, Harris corner)
Recognition Rates	0.991	0.983	0.974	0.994

9. CONCLUSION

In the experimental part and from the results obtained, we deduce that The integration of the DWT discrete wavelet transform to the PCA settings method seems to be the most fast in the process of face recognition .This is due to the rapid new vectors, it has good recognition rates and takes less than computation time than other methods during learning and recognition. Considering the hybrid of holistic and point based results a fusion approach yields better results than traditional results. In this paper, 3 feature extraction algorithms are used i.e. SURF, DWT-PCA and Harris-Corner based face recognition. Further these three algorithms are fused to achieve the improvement in performance of the face recognition system. Fusion based face recognition method gives around 99.4% accurate recognition rates. But still there are some factors which can be the obstacle in the face recognition technique such as ageing, facial expression, different hair-style, wink etc. These factors creating problem in recognizing the actual face are considered as the noise elements with respect to the image database taken for experimentation. Though till now, none of the face recognition based algorithms has given 100% accurate results under all conditions, still the proposed algorithm can be considered as meeting the accuracy rate.

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