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Facial Expressions Detection and Recognition Using Neural Networks

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ABSTRACT

Facial Expressions are one of the most robust way of non verbal information exchange in day-to-day life. Changes occurring in emotions of a human being directly efficate the behavior of a person. In this progressive world, a numerous biometric have been evolved, each having its own purport. However, all these statistics play vital job to convey communication from one individual to another but 55% i.e a major part of communication transpire by facial expressions. Facial Expression recognition process concentrates on discerning the changes in expressions of facial muscles that automatically reflect switching of one's mind from one state to another. Humans can recognize Expressions without any effort and almost instantaneously but that are not the case with a machine since its challenges are very dynamic like orientation, lightening, pose, facial expressions, etc.
So, the process of wrenching out or extricating the facial feature points or landmarks is often very challenging. To recognize the fiducial points on the facial features and drawing out these points, that generally lie on eyes corners, chin, eyebrows, etc, facial landmarking is done. Our landmarking technique combines Viola-Jones detection algorithm for feature detection with Harris corner detection and then coarse to fine strategy is implemented using an efficient algorithm. Using the Haar like features reduces the cost of brute force search, also provides advantage of speed. Additional selection of sub-regions is also exploited using anthropometric constraints, to limit the search region. This further reduces false detection rate and improves accuracy significantly. A sub- algorithm named Iterative best fit algorithm is used find a land mark exploiting its commonality and geometric configuration and can be used in other contexts as well. This method is then tested on JAFEE database, Yale database, AT&T database and the database constructed using my own images named as Smart database and this method provides the satisfactory accuracy.
Keywords : Component, Biometrics, Facial Land Marking, Facial Emotions Recognition, Viola-Jones Algorithm, Harris Corner Detection.

I. INTRODUCTION

What we feel, the various situations we are going through, all are reflected efficiently by facial expressions. A facial expression often represents the emotional state that can be seen, visualize and reflect character of a person [20]. In this modern world of science and technology, computer vision, pattern recognition, fingerprinting recognition, bio-metrics, image processing, security, Artificial Intelligence is leading to intelligent machines which has entirely captured our lives in many areas such as surgical assistant [33], offices [34]. Recognizing the facial moods of a person using Machine Learning is gaining high popularity now-a-days. It is the process of detection and recognition of human face and facial expressions or emotions in order to ensure security in many fields. Face detection and expressions recognition have a heavy demand in this era because it is most universal, user friendly and easy accessible system. For the purpose of facial expressions recognition, emotions play a vital role. Emotions represent those internal feelings of a human mind which can't be expressed verbly or by writing. By visualizing the face of a person, one person can easily recognize the mood of another person so that the mood of person can be enhanced easily accordingly using various ways. It is well known concept that each and every technology has its root from some earlier concept. As in the same way, the foundation of facial expression detection is FACS (Facial Action Coding System), that was introduced by Ekman and his friends. Before this system was developed, researchers often relay on human observers for the information but they were not reliable. So this system was developed to improve the robustness and performance of the system. This system generally focuses on determining the alterations that occur in facial muscles. The various muscles associated with human face are as shown in fig1 [1], typically known as Action Units (AU). An action unit the basic unit which is responsible for causing all these internal changes to the facial muscles that in turn cause changes in expressions.

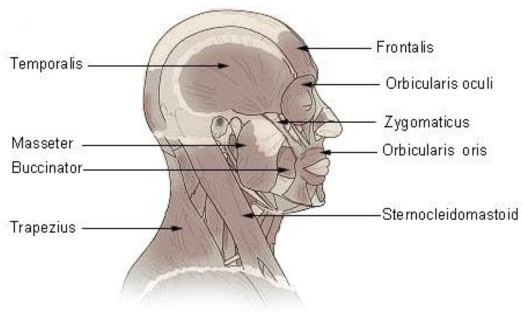

Figure 1. Various types of facial muscles

Facial muscles are divided into two parts. Some of them are related with upper portion of the face and some with lower portion of the face. Depending on different situations, there occur fluctuations in facial muscles. These facial movements are called facial action units (AU's) and the corresponding code is known as Facial Action Coding system [17]. The FACS is composed of 44 facial action units that are the essential part of FACS [1]. Out of them, mainly 30 AUs of them are affiliated to movement of a particular deck of facial muscles that includes: 12 for upper face and 18 for lower face. Facial action units can occur in combinations and vary in intensity. An action unit is in the numerical form used to give detail of all the movements of facial muscles [1, 2].

Recognizing the expressions of a person automatically provides greater support to those applications or areas that very much focuses on face such as coding field, face recollection, expressions/ moods or gesture comprehension, gaze diagnosis, animated applications, face tracing[3,4], face animation[5,6,7], registration[8,9,10], video tracing[27]. Face markers are considered as the renowned hallmark that can play a crucial role and can be treated as bulwark on the entire graph of face. Effects on different landmarks are distinct from one another. Some landmarks such as eyes end points, nose tip are affected on little- scale. So, these are cited as fundamental landmarks. The facial landmarks which are found with the help of the fiducial points are known as ancillary points.

Approaches present today for facial landmark detection can be grouped in two main classes: local and global methods [11]. The global methods [11] are more capable of detecting more landmarks than the local ones, which can mostly detect landmarks quickly. Almost all global methods use either ASM (Active Shape Models) [12] or AAM method (Active Appearance Models) [13]. In the ASM technique, the algorithm make searches in order to obtain the best match using a shape model while as in AAM, the main goal of the algorithm is to obtain the best match with a combined model using texture and shape. In local methods [6], the algorithms are used to detect landmarks such as we can take the example of the eyes end points or the nose peak point, without using information from other parts of the face. There are also some situations in which a combination of global and local method is used where classifiers are trained for different landmark with the Viola & Jones object detection approach.

In this paper, we tender a new facial landmark discernment system to detect landmarks in human faces more frequently and easily. The proposed system is a combination of local and global methods to get a mix of robustness and speed without any complicated pre-processing. It is a coarse to fine strategy which uses haar-like features and corner detection along with geometric constraints to get facial landmarks. The technique is simple and easy in implementation.

II. LITERATURE SURVEY

Facial Expressions recognition is a three phase process such as Face Acquisition, Feature Extraction and Classification as depicted below:-

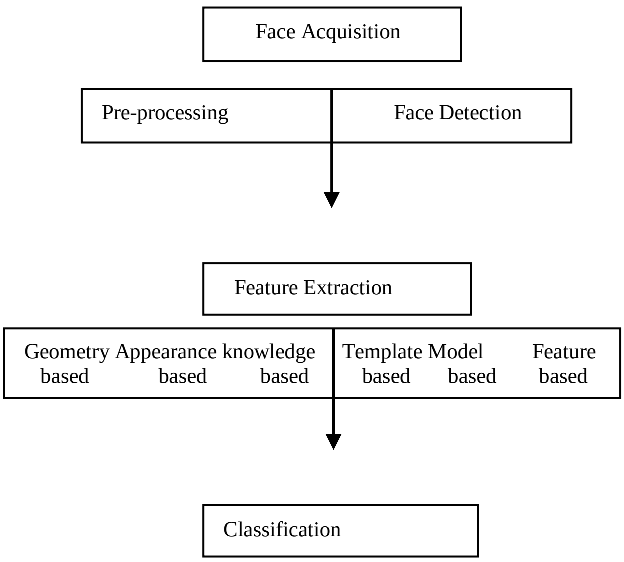

Figure 2. Process Model of Facial Expression Detection

(a) **Face Acquisition:** - is the process of acquiring image. The first step in face acquisition is image pre- processing which involves various techniques such as image cropping, resizing, padding, histogram equalization, etc.

(b) **Feature Extraction:** - Feature extraction is a method in facial expression recognition and involves various methods like dimensionality chopping, trademark extrication and landmark assortment. Feature extraction uses various methods like geomertry based, appearance based, knowledge based, template based, model based and feature based. These methods are planned chiefly for face identification and fiducial points extraction.

(c) **Classification:** - At this stage the extracted feature are used for training the classifier and then testing is done. The various classifiers used are Hidden Markov Model, Neural Networks, Support Vector Machines, Adaboost and Genetic Algorithms.

Thus, over the last few years, there have been numerous face recognition techniques that has been developed and used for the purpose of facial expressions recognition. The whole literature survey is in [35].

III. RESEARCH METHODOLOGY

Facial Expression Detection is a topic with a lot of width and depth, in spite of the amount of research that has been directed

Towards it, there is a lot of work on. Our methodology was to do a literature survey and seek out the areas of improvement.

Our main aim is to make the process more simple and efficient by combining different existing processes. Along with Feature Extraction other parts of the project also had to be developed to get a Facial Moods Recollection System. The basic building blocks of emotion identification system are enlisted below:-

1. Image acquisition: -Acquiring the input image for processing.

2. Image Resizing: - Making the image a square matrix for improved results

3. Image Cropping: - Only keeping the relevant information in the image.

4. Face Detection: - Locating position of face in the given image using pixels of skin.

5. Corner Detection: - Finding corners in the image using sudden change in pixel values.

6. Eyes Detection: - Identification of position of eyes in the face image frame.

7. Mouth Detection: - Determined lip coordinates on the face.

8. Feature extraction: - Extracting token from the image.

9. Emotion Detection: - Emotion is detected by feeding values from database to neural network.

10. Database: - stores values derived from feature extraction.

11. Output Display: - Displays the performance of system on screen.

IV. PROPOSED SCHEME

The proposed method involves the system to detect a set of landmarks in frontal faces. This system is comprised of four major parts. In the first part, there is the pre-processing step and second part has the methodology of detecting features, that is, eyes and mouth in the face. The third part detects the corner in the face and fourth part is the core of the system, where the results of two previous stages is combined and landmark is detected using proposed efficient algorithm called 'Landmarks' and the iterative-best – fit algorithm is also explained there which selects the landmark from a no. of possibilities. A detailed block diagram of the suggested method is depicted by Figure 3 given below

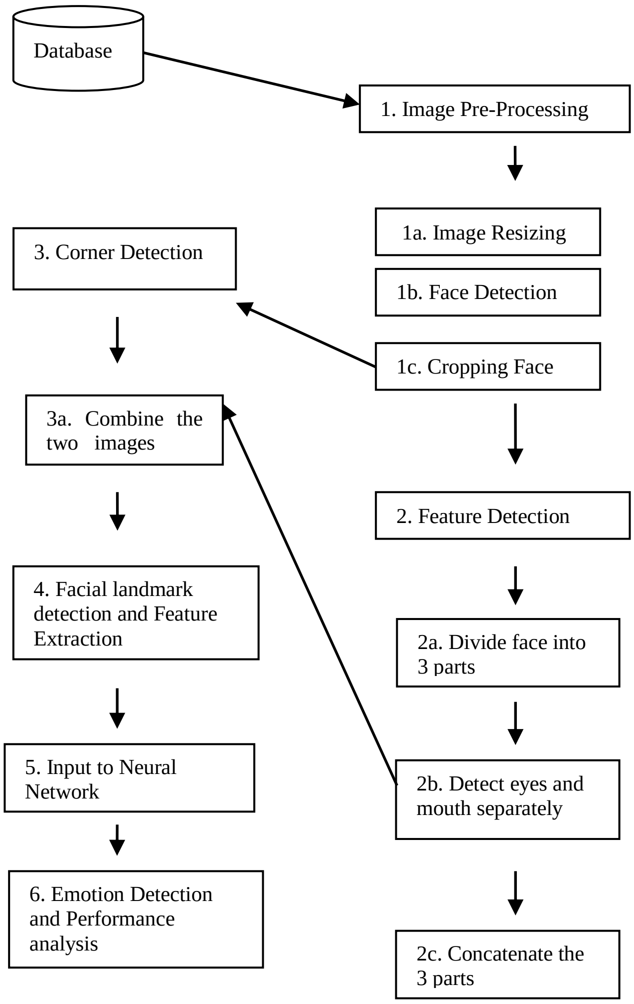

Figure 3. Workflow of Proposed Scheme

A. Image Pre-Processing:-

Almost in every system, a database is the most important information storage unit. A number of databases subsist of variety of facsimile that have sundry resolutions, backgrounds and are captured under diverge radiance. Thus it is necessary to perform preprocessing of image. Preprocessing module is induced to forge the images more comparable. In our system, complex pre-processing module is not required and comprises of successive components: image resizing, identification of face and image cropping. The image is resized to get a square image. From this image face area is discovered by employing the Viola-Jones method [15], ground on Haar-like hallmarks and AdaBoost learning technique. We assumed that there is only one face per image. The Viola and Jones practice has giant diagnostic rates and 15% faster than all supplementary approaches. It is principally planned for the muddle of face identification. It requires full view frontal upright faces. It is very robust framework. Its purpose is to provide the differentiation between faces and non- faces. Adaboost is an effective boosting algorithm required to speed up all the types of learning approaches. It predominantly make use of the combination of weak classifiers in order to create the strong one. So, Adaboost is a greedy algorithm and associates large weight with each good features and small weight with poor features after each round examples are re-weighted. The rearmost part of image pre- processing module is cropping the facsimile to get the area enclosed by rectangle of the Viola-Jones object detector for further processing.

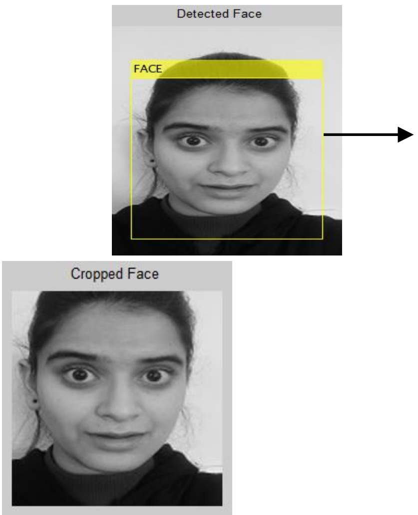

Figure 4. Cropping of face detected by Viola- Jones algorithm

B. Feature Detection:-

This is the second step to reduce the region of interest first being the cropping of face image. In this step, we desire to intuit the position of eyes as well as mouth. The Viola-Jones algorithmic concept is utilized for feature identification. The detected face attained from pre-processing is first divided into three parts such that one part contains the left eye, another contains the right eye and the third part contains the mouth. This is done to overcome the limitation of cascade object detector based on Viola Jones algorithm, which sometimes detects mouth as an eye or vice versa. This method does a multi-scale search and chooses the facial landmark candidates through thresholding [15]. A composite image of the three parts is achieved at the end with detected features. There is the possibility of multiple candidates (multi-size and or different position) for which we choose the candidate with the largest size.

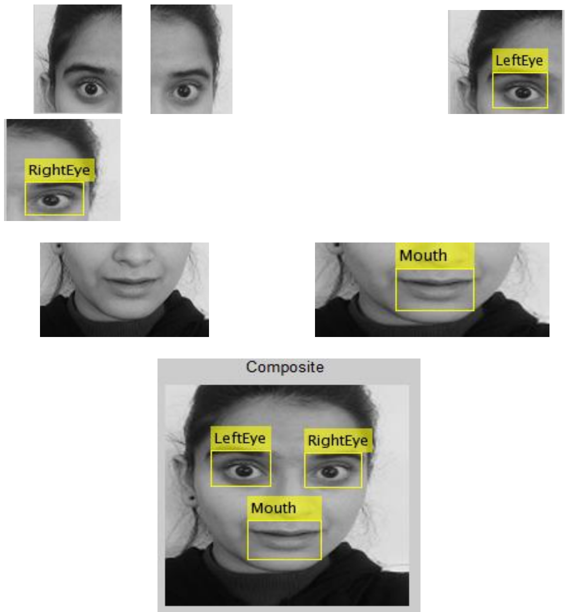

Figure 5. (a) Division of Face (b) feature detection in separate parts (c) Combining the parts of face after detection

C. Corner Detection:-

Identification of corners is an approach employed to wrench out the irrefutable hallmarks and conjecture the contents of an image. Some researchers had applied canny edge detector to calibrate amount and alignment of groove [16] but we have used corner detection. Corner is the intersection of two edges. It is the junction of contours at which intensity changes to larger extent. The significance of this step is that corner detection gives us plausible landmarks as many facial landmarks are corners and by having all corners in an image, landmarks can be chosen from them by further computation. Corner detection projects on the principle that if we spot a small window over an image, if that window is situated at the corner then there is a giant fluctuation in intensity in all the directions and consequently we realize that it must be a corner. If the window is atop the shallow area of the image then there will be no fluctuations in intensity.

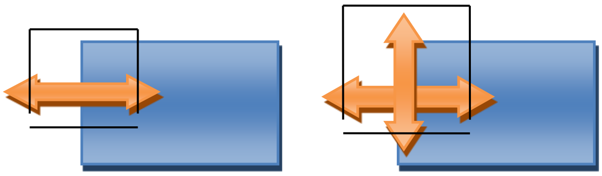

Figure 6. Working of corner detection

Harris Corner Detection algorithm, which is used by us, detects the corners in any given image and is an improvement over Moravec's corner .It is employed to the absolute pre-processed photograph and calculates the points of change in all directions. . Change of intensity for the shift [u, v]:

$$E(u,v)=\sum_{x,y} w(x,y)[I(x+u,y+v)-I(x,y)]^2$$

The function w is the window function, the function I(x + u, y + v) is the switched intensity and the last is the actual intensity. The window function is Gaussian which reduces the noise.

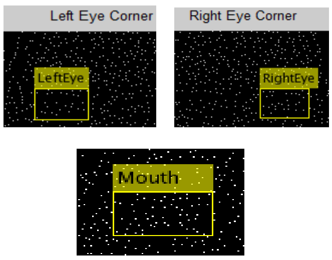

Figure 7. Detected Eyes and mouth corners

D. Facial Landmark Detection:-

This is the final step which is done to select the fiducial points. In this section the prime benefaction of the paper are presented. The results of the feature diagnosing and corner detection are combined to give a resultant image in which the corners detected in the eyes and mouth region are enclosed by a rectangle.

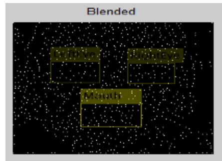

Figure 8. Combination of feature and corner detection

From the corners lying inside the rectangle we have to choose the facial Landmarks. We detect a total of 12 facial landmarks out of which half are primary (left and right landmarks) and (top and bottom landmarks) half are secondary. The procedure to find landmarks are recapitulated for all rectangles demarcating features in the image (w is the width and h is height of the rectangle). The values of x and y have been determined after trying different values and picking the ones which gave best result.

- ALGORITHM:-

Algorithm 1: Landmarks

i. Input the cropped eye image from step 1, dimensions w and h of boundary bounding the feature and values a and b.
ii. Crop image according to mentioned values of ROI.
iii. Find the positions of corners detected in the image.
iv. Subtract a from the column value y and b from the row value x of the corner position to get find points close to the desired position.
v. Call Iterative_Best_Fit_Algorithm to find best fit right facial landmark from current corner points; // see sub-algorithm 1.
vi. Return the position (column, row) of chosen Landmark.

Sub-Algorithm: Iterative_Best_Fit_Algorithm

Step 1: Input x [ ] and y [ ] (from step 5 in algorithm 1).
Step 2: Find value mr = minimum in x [ ].
Step 3: index_X:= positions in x where x = mr
Step 4: Find value mc = minimum in y [ ].

Step 5: index_Y:= positions in y where y = mc.
Step 6: If common: = intersect (index_X, index_Y) is equal to 0.

```
    Min_X:= x [index_X (1)] +y [index_Y (1)];
      Index1:= index_X (1)
      Repeat: K =1 to SIZE (index_X)
      TEMP: = x [index_X (K)] +y [index_Y (K)];
      If (MIN_X > TEMP)
          MIN_X: = TEMP; Index1 = K;
      Min_Y:= x [index_X (1)] +y [index_Y (1)];
      Index2:= index_Y (1)
Repeat: K =1 to SIZE (index_Y)
      TEMP: = x [index_X (K)] +y [index_Y (K)];
      If (MIN_Y > TEMP)
          MIN_Y: = TEMP; Index2 = K;

      If (Min_X >= Min_Y)
            Common: = Index2;
      Else
            Common: = Index1;
```

Step 7: row: = x [Common]; column: = y [Common];
Step 8: RETURN (column, row)

E. Input to neural network:

Distortation mechanisms are employed to facial emotions identification include DCT [37], Gabor wavelets [24] [25], Neural Networks [23, 29, 36] and Active Appearance Models. In our thesis, After landmark detection, input is given to the neural network in the form of training images. A label is assigned to each image such as for sad expression, it is taken 0000, for neutral- 0001, for happy- 1111, etc.

F. Emotion detection and Performance Analysis:-

Once the neural network is trained properly, the images are then tested using different databases one by one and the expressions are detected in the form of performance rate or accuracy.

V. IMPLEMENTATION

MATLAB is a multi feature programming language, emerged from Math Works in 1984. In our research work, we used Matlab for the implementation of various types of databases having different properties. Our proposed algorithm for the detection of facial landmarks was first tested using the Smart database. This expressions database contained 28 images of six primer facial expressions i.e. happy, sad, neutral, surprise, angry and fear.

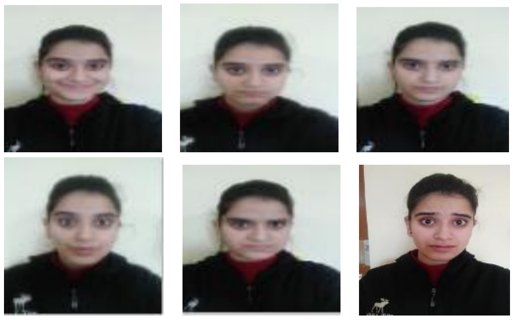

Figure 9. Smart Database

Each image was of size 256*256 pixels and in the jpg format. The images of this database are taken with an OPPO camera (CPH1701). The camera was positioned straight facing the motif. The subject performed different facial displays and these displays are based on descriptions of prototypic emotions. We have detected about 6 facial expressions, so we had used 20 images of this database for training our neural network and 8 images for testing our neural network .We had follow the above proposed algorithm and 12 facial landmarks are detected and then selected as depicted by following figures:-

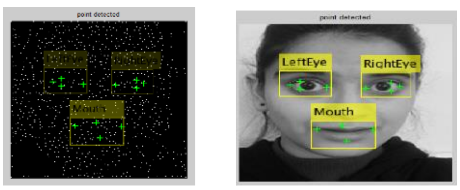

Figure 10. (a)Landmarks detected (b)Detected Landmarks mapped to the face.

Following this, the same algorithm was tested on three more databases i.e JAFFE database, Yale database and AT&T database. The Jaffee database is a Japanese Female Facial Expression database [31] encompassing 213 images of 7 facial expressions in distinct poses. 13 images of this database are used to train the neural network and 7 images are used to test the neural network. Each image in this database is of size 256*256 pixels. Yale face database embody 165 greyscale images in GIF format of 15 persons. 21 images are used for training and 17 photographs for testing the neural network. In AT&T database, there are 10 pictures of 40 dissimilar subjects. All the images are in PGM format and the size of every individual image is 92*112 pixels.

VI. RESULTS AND ANALYSIS

To determine the facial landmarks in Smart database, every image is checked and each landmark is given one of the three labels- right, bearable or wrong. Right is given if landmark is detected at the correct position. Bearable is given if there is slight change in the position Wrong is for the landmark which is entirely at the wrong position and leads to incorrect results when used. We have gone through each image and keenly observed the corner points available from which the landmarks are chosen, to label them into a category.

The results are as follows:

Table1. Analysis of different landmarks

S.No.	LANDMARKS	CORRECT	BEARABLE	WRONG
1.	Left (eyes)	86%(L)+ 89%(R)	6%(L)+ 7%(R)	8%(L)+ 4%(R)
2.	Left (mouth)	85%	15%	0%
3.	Right (eyes)	88%(L)+ 86%(R)	10%(L)+ 12%(R)	2%(L)+ 2%(R)
4.	Right (mouth)	90%	6%	4%
5.	Top (eyes)	88%(L)+ 80%(R)	9%(L)+ 14%(R)	3%(L)+ 6%(R)
6.	Top (mouth)	75%	14%	11%
7.	Bottom (eyes)	84% (L)+ 80%(R)	12%(L)+ 12%(R)	4%(L)+ 8%(R)
8.	Bottom(mouth)	84%	9%	7%

Once the facial landmarks are correctly identified and extracted for the images of all the databases, the neural network is trained and then tested and it shows variable performance for different databases. There are various parameters which were taken into amount that affects overall accuracy of the system. Performance is the most important parameter we have considered for the comparison among databases. On testing, it is analyzed that Smart database shows remarkable performance of 96% for unalike expressions like happy, sad, neural, surprise, angry and fear. It shows reliable identification of these emotions. For Jaffee database, it gives the performance of 90% that is somewhat less than the Smart database. Further, performance rate of 78% is achieved while working on the Yale database and similarly on applying the same approach on AT&T database, performance rate of 67% is achieved. The main reasons behind the low performances and accuracy of both Yale and AT&T database is due to different lightening effects, rotations of images to certain angles. The another important reason is the presence of different concerns that includes the pictures of dissimilar persons with beard and glasses also due to which neural network can't able to identify the expressions correctly.

If we take these parameters critically into account, it is observed that illumination conditions should not be present in the image otherwise it will affect the system's performance to larger extent. As seen in the Table1. No illumination conditions are present in first two databases hence achieving high performance rate. On the other hand, there are three illumination conditions in Yale database and further these conditions are not under the control while taking pictures of AT&T database, hence showing low performances. Another important parameter is the size of the image. More is the size of the image, more is the recognition rate and lesser is the distortion of image.

Thus, to analyze the performance correctly, there are various parameters on which the performance of a facial expressions recognition system depends such as different illumination conditions, size of each image, noise level, head positions, pixel intensities [21], age factor, and gender. All the information about databases is tabulated as in table 2. One of the prime factors among all is the presence of noise in the image. For Smart database, we used high resolution front camera so that we can take clear and detailed images even when the light is very low. This is possible with the help of an exclusively large image sensor present in it. It also provides the feature of Beautify 4.0 mode due to which we can take HD images with natural color tones.

Table2. Different parameters effecting performance of the facial emotion recognition system

Database	Illumination conditions	Size of image (pixels)	Noise in image	Head positions in image	Age factor
Smart	No illumination condition	256*256	Not present	straight	young
Jaffee	No illumination condition	256*256	Little bit	straight	Middle age
Yale	3 illumination conditions	320*243	Present	Presence of glasses, beards	Middle age-old age
AT&T	Conditions was not controlled during record	192*112	Present	Frontal but tilt of head	Middle age-old age

Its main spatiality is that it uses Stacked sensor i.e. CMOS which is sensitive to light and make use of PDAF (phase Detection Autofocus) and also rich filters. Due to all these features of smart database images, we have achieved high performance. In Jaffee database, low pass filter is used that also remove noise to larger extent and in last two databases no such filters are used. An important reason behind remarkable performance of smart database and Jaffee database is the presence of only upright faces while in other databases use of glasses, scarf's, beard make the system inefficient. Similarly, as the age of the person increases, the skin becomes wrinkled and it becomes difficult to identify the person. Our database consists of young age person as compared to another databases so neural network shows reliable performance.

After analyzing all the results obtained for each database, comparison on all the databases is performed as depicted by Figure 11. X-axis typifying the type of database used and Y-axis represents or typifying the performance rate achieved by different databases.

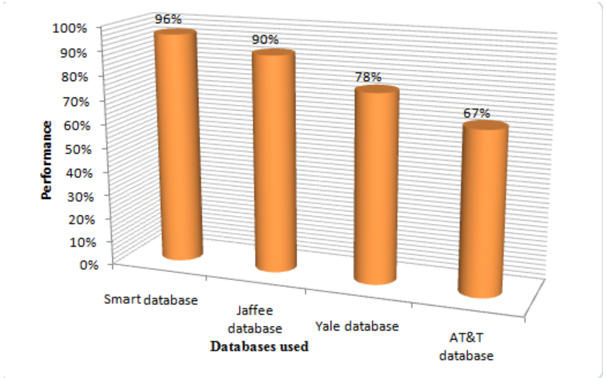

Figure 11. Performance of different databases

Besides the performance it shows the gradient for each database. The gradient descent approach works by picking the gradient of the weight space to perceive the trail of steepest or abrupt descent. The gradient descent is basically the algorithm used to minimize an error function. Smart database have gradient of 0.98, Jaffee database having 0.92 gradients. Similarly, Yale and AT&T databases have 0.87 and 0.80 gradients value.

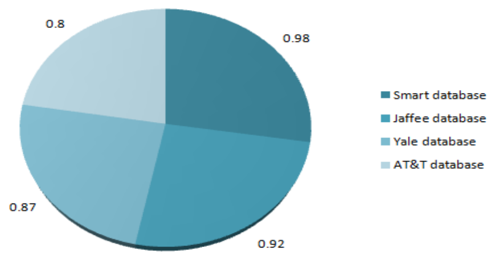

Figure 12. Gradient values for different databases

Therefore, with the increase in performance the capability of neural network to minimize the error function also increases as shown in Figure 12. A regression plot represents the network output in terms of target of training data. For a perfect fit, the training data should lie along the 45 degrees line. On testing, it is observed that for Smart database, training data satisfies the above criteria, which represents good training of the system as shown in Figure 13

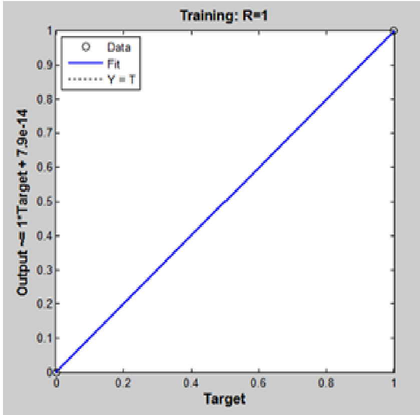

Figure 13. Regression plot

Besides all the image parameters effecting performance of a system also includes no of expressions involved, no of images used for training and testing.

Table 3. Data used for different databases

Database	Training data	Testing data	Performance/ Accuracy	No. of expressions
Smart	20	8	96%	6
Jaffee	13	7	90%	6
Yale	8	5	78%	5
AT&T	23	14	67%	5

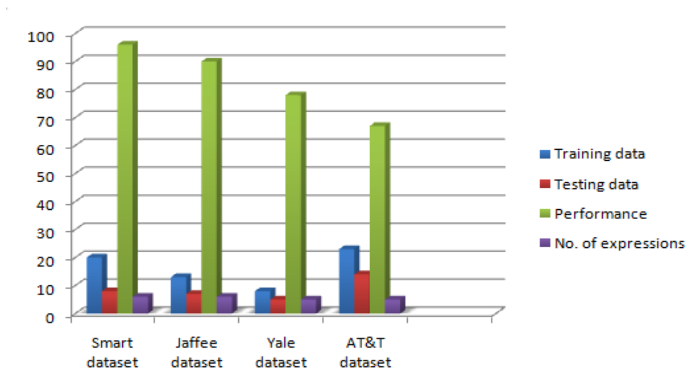

Figure 14. Image factors effecting performance of system

Accordingly these parameters, performance varies. Preferably more images should be taken for training the system. As seen In Fig13. more images are taken in AT&T database but since it involves both genders i.e. different individuals with different subjects, which results in decreased accuracy and if we compare other three datasets, Smart database has more no of training and testing images and it also depends on no of expressions. A greater variety is generally better. By taking control over all the discussed factors, one can improve the accuracy of the system in determining facial expressions of an individual.

Thus, it is analyzed that for Smart database neural network shows the highest performance in identification of different expressions effectively with low error rate and then followed by Jaffee database. Yale database has satisfactory performance and among all the databases, least performance and accuracy is shown by AT&T database and having more error rates.

VII. CONCLUSION

Facial expressions analysis can be done using both static and video images [18, 19]. There are various databases that were used by researchers such as FERAT database, have been employed for involuntary facial expression recognition by multiple researches [22, 23, 30]. In the paper we proposed a reliable landmark detection algorithm with low detection time. The usage of Haar like features reduces the search area significantly in very less time without any complex computation. Also this algorithm has exhibit the great significant performance on different databases. It shows the performances above 90% which is difficult to achieve. In spite of all these, it requires some improvement on certain areas. The designed algorithm has a big potential with the opportunity of further improvements. If the face in distorted significantly like in the mouth curled up to one side in disappointment or when the lips are parted significantly, the feature detection shows error in mouth detection which affects the land marking. Also this algorithm can't able to work much better with the images having great amount of rotations.

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