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Structured Connectivity - Face Model for Recognition of the Human Facial Expressions

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Abstract: Facial Expression of the human being is the one which is the outcome of the inner feelings of the mind.

In the proposed method, the three facial expressions viz Happy, Sad and Anger of the different persons are recognized using the geometrical features of the face like triangular features, Rectangular features, Orientation, Perimeter, and Distance. The experimental results and the Structured Connectivity face model. The Structured Connectivity (SC) face model is a geometric approach in which the spatial relationships among the facial features are determined for the purpose of facial expressions.
Facial expressions are the facial changes in response to a person's internal emotional states and intentions. In this paper, the facial expressions are recognized by Triangular Features and Rectangular features using comparative analysis demonstrate the effectiveness of this approach.

Keywords— Face Model, Feature Extraction , Facial Expressions, Structured Connectivity.

INTRODUCTION

Expression refers to the facial changes of a person, a message about something internal thoughts of the expresser. In the context of the face and the nonverbal communication, expression usually refers to the change of a visual pattern over time. The concept of facial expression includes:

1. The changes in the expressions of the face represents the mood of the person/expressor.
2. The physical characteristics of the face is based on the values of the facial regions. Eg, The Orientation, Length, Perimeter of Eyebrows, Eyes and Mouth.
3. By interpreting the values of these regions, expressions of the person can be recognized.

Facial expression plays a principal and vital role in human interaction and communication since it contains critical and necessary information regarding emotions. The task of automatically recognizing and detecting the different facial expressions in human-computer environment is significant and also challenging. A variety of systems have been developed to perform facial expression recognition. These systems possess some of the common and similar characteristics.

First, they classify facial expressions using facial expression databases. For instances, many of the researchers used the JAFFE database to recognize seven main facial expressions: happy, neutral, angry, disgust, fear, sad and surprise. Here, we are also using the same database to recognize the facial expressions. Some other researchers used AR database to classify the facial expressions:

Second, most of the systems conduct two stages.

- Feature extraction
- Expression classification.

Feature extraction involves segmentation of the human face. Segmentation of the face in an image involves keeping only the necessary regions of the face in order to process the facial parts and removing all the other unwanted regions. Here, we are considering the regions viz Eyebrows, Eyes and Mouth. Based on these standard five regions, we are extracting the features of the face and proposed the face model. Expression classification involves identifying various facial expressions.

LITERATURE SURVEY

Automatic human facial expression recognition is a thrust research area in video surveillance and law enforcement applications as a prerequisite for face recognition. Until now much research work has been done on detecting the human faces based on templates, neural networks and example-based techniques. However, some of these methods are computationally expensive, dealt with single frontal view and work on gray scale images. C. Garcia and G. Tziritas [8], 1999, presented a system on face

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detection using quantized skin color regions merging Srihari and D. B. Sher [9], 1990, presented a system, which detects faces in photographs of newspapers, but the approximate size and the expected number of faces must be known in advance. R. Chellappa, C. L. Wilson and S. Sirohey [3], 1995, proposed a methodology on Human and machine recognition of faces. J.L.Crowley and J. Coutaz [4], 1997, introduced a method on Vision for man machine interaction. Lee, Dileep M.R and Ajit Danti [6], proposed LC face model for recognition of human facial expressions.

Facial expression recognition can be applied to medical treatment of patients. Gagliardi, Frigerio E, Burt DM, Cazzaniqa I, Perrett DI, Borgatti R [7], 2003, investigated the facial expression ability for individuals with Williams's syndrome. Bowyer, Kevin W [1], investigated on a survey of approaches to three-dimensional face recognition. D. Chai and K. N. Ngan [2], introduced a methodology of Face segmentation using skin color map in Videophone applications. De Silva, Liyanage Chandratilake [5], proposed method of Facial emotion recognition using multi-model information.

Since JAFFE database is commonly used in measuring the performance of facial expression recognition systems, we concentrate on applying our system on this database and perform comparisons with other systems.

An approach has been proposed by P.S.Hiremath and Danti [10], 2004 in which the Lines-of-Separability (LS) face model is constructed for finding the eyes and detection of the face.

Here, we have worked on the three expressions viz **Happy, Sad and Anger**. The probability of finding these three expressions in any of the image is more compared to the above methodologies proposed by different researchers. This implementation is not limited to a single database, but also can be applied to different databases and also the images which can be downloaded from the internet.

In this paper, the algorithm has been proposed to recognize the facial expressions using statistical and geometrical features of the human faces.

In this paper, we present a systematic comparison of feature extraction and classification methods to the problem of fully automatic recognition of facial expressions and to find the optimal solution to it.

The rest of this paper is being organized as follows. Section 2.2 describes about the JAFFE database of experimental images. Section 3 presents the proposed methodology. Section 4 provides the proposed algorithm. Section 5 gives the and wavelet packet analysis. Govindaraju, S. N. experimental results. Finally, we draw the conclusions in section 6.

FACIAL EXPRESSION DATABASE

The proposed methodology is experimented on JAFFE database. JAFFE stands for Japanese Female Facial Expression. This dataset is used as the benchmark database for Performance Comparisons of Facial Expression Recognition. The database contains the faces of ten Japanese females. There are seven different expressions of the face, such as neutral, happy, anger, disgust, fear, surprise and sad. Each female has two to four examples for each expression. There are of 213 grayscale facial expression images in this database. Each image is of size 256 × 256.

Fig-1 shows two expressors comprising seven different facial expressions from the JAFFE database.

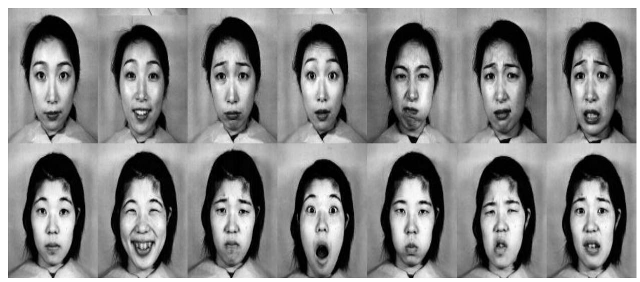

Fig 1: Samples of two expressors containing 7 different expressions.

PROPOSED METHODOLOGY

The basic step in recognizing the facial expressions in a given image is pre-processing of the image. The pre-processing of the image involves the following steps.

First the image containing the face will be read. From the given image, the possible parts of the face are detected by the process of facial features extraction such as eyes, mouth and eyebrows. Extraction of the facial features can be done by removing the unwanted regions by putting the constraints on Orientation **Error! Reference source not found.**, Major axis length **Error! Reference source not found.**, Minor axis length **Error! Reference source not found.**, ratio of Major axis length to minor axis length **Error! Reference source not found.**. The regions satisfying these constraints will be considered as the potential regions of the face and remaining regions are not taken into consideration. Each of the potential regions of the face is preprocessed by the morphological operations to remove isolated noisy pixels. The grayscale skin region is filtered by Sobel edge operator and then

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binarized using global threshold which is then denoised by morphological operations making the essential facial features clearly visible. The denoised image is labeled to group the active pixels into connected blocks. These blocks are candidate blocks of the facial features.

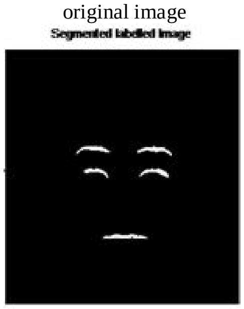
With each labeled candidate block, its center of mass (x',y'), orientation **Error! Reference source not found.**, bounding rectangle, length of major axis, length of minor axis, Perimeter and other basic parameters are computed.

Along with all the above specified basic parameters some of the parameters will be derived to extract the invariant features of the face like distance with respect to eyes, ratio between distances of the two regions, ratio between radius of width of any two regions and so on.

Sample experimental results are given in fig-2 for preprocessing of the given image.

original image

Binarized Image



Denoised Image

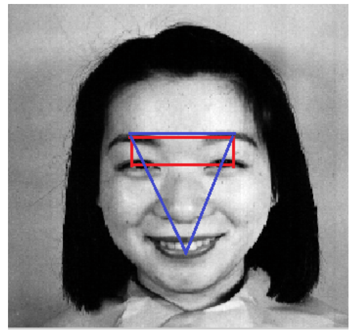
Fig-2: Preprocessing Results.

A. Structured Connectivity Face Model

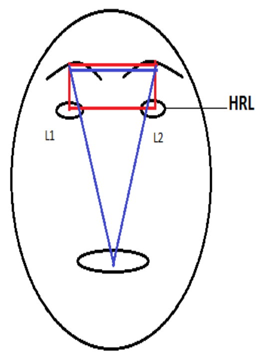
In this paper, facial expressions are detected using the triangular features along with the rectangular features. Here, the triangle and the rectangle will be constructed to the face in order to extract the invariant features of the different expressions. First, the Horizontal Reference Line(HRL) will be drawn to connect two eyes.

In the same way, with respect to the eyes, two eyebrows will be connected by a line. Then, from both the eyebrows, eyes will be connected by drawing the lines to form a rectangle. Then, from both the eye brows, mouth will be connected by drawing the lines to form a triangle.

Fig-3 gives the diagrammatic representation of the Structured-Connectivity face model for extracting the triangular and rectangular features.



Original Image



Representation of SC Face Model

Fig-3: Diagrammatic Representation of SC Face Model

The upcoming sub-sections will give a detailed approach of construction of the Structured Connectivity (SC) face model for recognizing the different facial expressions viz **Happy, Sad** and **Anger**.

B. Detection Of Eyes

The eyes are searched as per the procedure followed by P.S.Hiremath and Ajit Danti, 2006. The eyes are searched by selecting each pair of facial candidate blocks randomly from the denoised feature image as shown in fig-2(c) as probable eyes and they are checked for orientation constraint. Evaluation value **Error! Reference source not found.** for eye will be computed for all the possible pair of blocks that satisfy the orientation constraint, then a pair of blocks with the maximum **Error! Reference source not found.** will be considered as the potential eye candidates. The following description gives the procedure for detecting the eyes.

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Initially, select any two feature blocks randomly and assume them as probable eye candidates. Their corresponding center of mass (x', y') and orientation **Error! Reference source not found.** are computed. Let **Error! Reference source not found.** and **Error! Reference source not found.** be, respectively, the centers of right and left eye candidates. The line passing through the center of both the eyes is called the *horizontal-reference-line* (HRL) as shown in the fig-4(a).

The slope angle **Error! Reference source not found.** between the HRL and x-axis is given by:

$\theta_{hrl} = \tan^{-1}\left(-\frac{a}{b}\right)$	*(1)*

Where $-\pi/2 \leq$ **Error! Reference source not found.** $\leq \pi/2$;

a = **Error! Reference source not found.**– **Error! Reference source not found.**; b= **Error! Reference source not found.**–**Error! Reference source not found.**;	*(2)*

Since the proposed face model is a frontal view model, the face in a too-skewed orientation is not considered in this model. Hence, the slope angle **Error! Reference source not found.** is constrained within the range of −**Error! Reference source not found.** to **Error! Reference source not found.**. If the current pair of feature blocks does not satisfy these orientation constraints, then they are rejected and another pair of feature blocks from the remaining feature blocks is taken for matching. Only for the accepted pair of features, the normalized lengths of the semi major axis **Error! Reference source not found.** and **Error! Reference source not found.** are computed by dividing the length of the semi major axis by the distance *D*, which is the Eucledian Distance between these two features. *D* is given by the equation.

D =**Error! Reference source not found.**	*(3)*

The following evaluation function **Error! Reference source not found.** is computed to check whether the current pair of features is a potential eye pair or not:

$E_{eye} = e^{-1.2\left[(l1-l2)^2+(l1+l2-1)^2+(\theta_1-\theta_{hrl})^2+(\theta_2-\theta_{hrl})^2\right]}$	(4)

Here the term **Error! Reference source not found.** enforces similar length between two eyes. The term **Error! Reference source not found.** enforces the distance *D* between two eyes to be twice the length of each eye. The term **Error! Reference source not found.** and **Error! Reference source not found.**enforces both the eyes to be aligned with the HRL. This evaluation function ranges from 0 to 1 and can be given the interpretation of a probability value. It is a negative exponential distribution function of the form $f(x)$ =**Error! Reference source not found.**, where α is the mean of the distribution function and x is a measure of dissimilarity of the facial features. For a given x (degree of dissimilarity of features), higher the α lower is the probability of accepting the features as potential features. For a given α, lower the x higher is the probability of accepting the features as potential features. For $\alpha < 1$, even features with higher x value have higher probability of acceptance. For $\alpha \geq 1$, even features with lower x value have low probability of acceptance. Hence, the suitable value of α is near unity but greater than unity. With respect to the sample images considered for investigation, α is empirically set to 1.2 as the mean of the negative exponential distribution. Hence, higher the evaluation value **Error! Reference source not found.**, higher is the probability of the two selected feature blocks to be eyes. If this evaluation value **Error! Reference source not found.** is greater than the empirically determined threshold value 0.7, then accepted these two feature blocks as the potential eye pair candidates. The reasonable threshold value is experimentally determined by considering the eyes of the several face images of the database.

The experimental results of detection of the eyes with line (HRL) connecting eyes is shown in the fig-4(a)

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C. Detection Of Eyebrows

All possible candidate blocks above the HRL are considered for the detection of the eyebrows. The eyebrows are searched by selecting each pair of facial candidate blocks above the HRL randomly as probable eyebrows and they are checked for Distance and Orientation constraints with respect to the eyes. If the distance **Error! Reference source not found.** between any two candidates is nearer to distance of the eye, **Error!**

D. Detection Of Mouth

All possible candidate blocks below the HRL are considered for the detection of the Mouth. The Mouth is searched by selecting each facial candidate blocks below the HRL randomly as probable Mouth and they are checked for the Major Axis Length and Orientation constraints. If the Major Axis Length of the probable Mouth is greater and the Orientation **Error! Reference source not found.** of the probable Mouth is within **Error! Reference source not found.** of the **Error! Reference source not found.**,then
that block will be considered as the potential Mouth candidate.

Fig-4 gives the detailed sequence of the Structured Connectivity face model. The Experimental results of connecting the potential eyes to the eye brows to form a rectangle, is shown in the fig-4(d). The lines connecting the potential eyebrows to the Mouth to form a triangle, is shown in the fig-4(d).

Reference source not found. and also the orientation of the probable eyebrows **Error! Reference source not found.** is nearer to the orientation of the eyes **Error! Reference source not found.**, then the pair of blocks with these satisfied conditions will be considered as a potential eyebrow candidates.

The experimental result of detection of the eyebrows and the line connecting the potential eyebrows is shown in the fig-4(d)

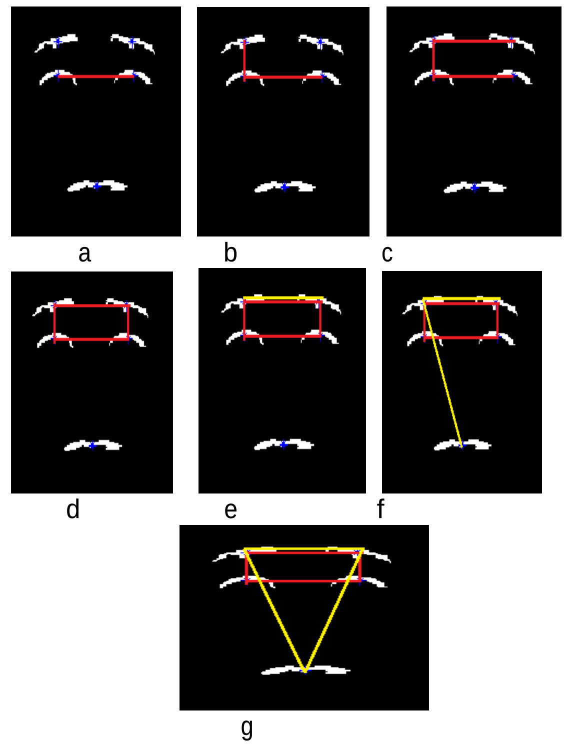

Fig-4: Proposed Structured Connectivity(SC) Face Model for recognition of the facial expressions.

PROPOSED ALGORITHM

The algorithm for the proposed SC face model to find the different facial expressions in a given image is as given below:

Step 1: Input the image and binarize and denoise.
Step 2: Segment the potential facial regions and label.
Step 3: Select randomly, one pair of feature blocks to be probable eye candidate blocks in the potential face region.
Step 4: Compute the slope angle **Error! Reference source not found.** using equation(1) and if it is between −**Error! Reference source not found.**to **Error! Reference source not found.** then compute evaluation value **Error! Reference source not found.** using equation(4).
Step 5: Repeat the step 3 and compute **Error! Reference source not found.** for all possible pair of block. Consider a pair of blocks as potential eyes where **Error! Reference source not found.** is maximum.

Step 6: connect the above potential eyes by Horizontal Reference Line(HRL).

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Step 7: consider a facial feature block found below the HRL as potential mouth whose Major axis length is maximum and Orientation is nearest to **Error! Reference source not found.**.

Step 8: Consider a pair of feature block found above the HRL as potential eyebrows whose Major axis lengths are nearly equal and their Orientations are nearly equal to **Error! Reference source not found.**.

Step 9: Compute Geometric features such as ebRadius, mouthPerimeter, ebEccentricity for the above mouth and eyebrows.

Step 10: SC face model is constructed by forming a rectangle between eyes to eye brows and forming a triangle between eyes and mouth.

Step 11: Detemine feature vector **Error! Reference source not found.** by computing features such as distance with respect to eyes, ratio between the distances, areas and slopes of triangle, area of rectangle, eccentricity and other invariant features.

Step 12: Find the distances between feature vector **Error! Reference source not found.** and standard templates **Error! Reference source not found.**of database of n facial expressions which have been created previously for the database images of Happy, Anger and Sad.

Step 13: Consider the **Error! Reference source not found.** expression as recognized facial expression whose matching distance between **Error! Reference source not found.**and **Error! Reference source not found.** is nearest using the equation

matchDist =**Error! Reference source not found. - Error! Reference source not found.**)	*(5)*

Where, X is the feature vector **Error! Reference source not found.** and Y is the feature vector **Error! Reference source not found.**.

EXPERIMENTAL RESULTS

JAFFE database of facial expression images were collected for our experiments. Ten expressers posed 3 or 4 examples of each of the seven basic facial expressions such as happy, sad, surprise, anger, disgust and fear and a neutral face images are taken.

The segmentation by the proposed method is found to be more efficient in terms of speed and accuracy. Each of the segmented regions is then searched for the facial features using the Structured Connectivity face model to recognize the facial expressions in it.

The proposed approach is implemented using MATLAB 7 software on Pentium IV @ 2.6GHz. The test images are expected to contain single frontal human faces under normal lighting conditions. The different expressions has been detected successfully. In the experimental results, 204 expressions are detected out of 213 faces, leading to success rate is 95% (approximately). The average time taken to detect one expression is about 1 second. The Structured Connectivity face model has better success rate of 95% and is also faster than the geometrical face model proposed by Jeng which has a success rate of 86% and L-C face model by Dileep M R and Ajit Danti which has the success rate of 93.8%.

However, proposed method fails to detect the side-view faces and occluded faces. This is due to the fact that the SC face model is constrained to detect only the frontal view face.,

Our proposed method is compared with the previous methods i,e Lines of Connectivity face model for the recognition of human facial expressions proposed by Dileep M R and Ajit Danti [6], 2013, and found higher success rate as shown in figure-5 and figure-6.

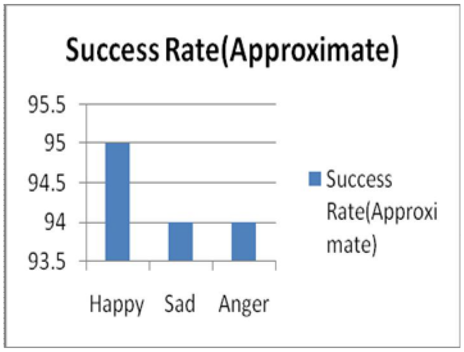

Fig-5: Success rate of the proposed SC face model.

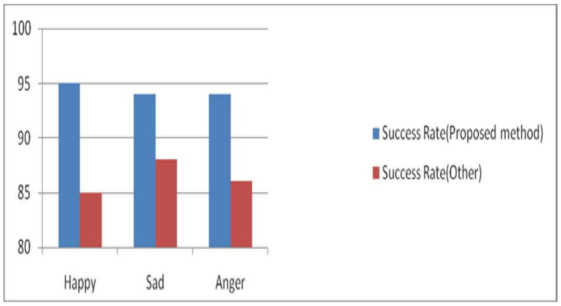

Fig-6: Comparing proposed SC face model with other models.

CONCLUSION

In this paper, a novel algorithm for the recognition of the facial expressions in an image

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using Structured Connectivity(SC) face model is presented. The potential facial regions are segmented and resized to the standard of 256 X 256 matrix in the simple methods in order to make it processing easier. The proposed method is better in terms of speed and accuracy. Single frontal human faces in the images with different expressions are detected successfully with success rate of 95%.

A misdetection occurs if the input image contains side or profile view of faces having one eye missing. The sample misdetected faces are shown in Fig-7.

a. b

Fig-7: Images which has been misdetected.

In future studies, these aspects and conditions are considered for further improvement in the proposed approach, so that it becomes more pertinent to the design of a real-time video surveillance system.

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