Thesis Report

# Emotion Detection from Frontal Facial Image

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# Abstract:

Emotion recognition from facial images is a very active re-search topic in human computer interaction (HCI). In order to detect Emotion from an image I have used frontal view facial images. If computers can understand more of human emotion, we can make better systems to reduce the gap of human computer interaction .To handle the emotion recognition problem from arbitrary view facial images. The facial region and others part of the body have been segmented from the complex environment based on skin color model. Thus, in this paper I showed some differences between different color models that are used to implement the system and which color model can be used where. Another aspect is to extract facial parts from the face. And for that I have used Viola - Jones algorithm to detect the eye and lips region from a face and then by the help of neural network I have detected emotion from those features. From the positioning of mouth and eyes I tried to detect emotion of a face. In this research I will propose an effective way to detect neutral, happy, sad and surprise these four emotions from frontal facial image of Human Being.



**Keywords**: Emotions, Color Model, Feature Extraction, Viola- jones, Neural Network, Emotion recognition

# 1.Introduction:

Facial expressions play a key role for understanding and detecting emotion. Even the term “interface” suggests how important face plays in communication between two entities. Studies have shown that reading of facial expressions can significantly alter the interpretation of what is spoken as well as control the flow of a conversation. The ability for humans to interpret emotions is very important to effective communication; accounting for up to 93% of communication used in a normal conversation depends on emotion of an entity. For ideal human-computer interfaces (HCI), we would desire that machines have the capability to read human emotion. For that this research is all about how computers can detect emotion properly from its various sensors. For this experiment I have used facial image as a medium to read human emotion. The research on human’s emotion can be traced back to the Darwin’s pioneer working and since then has attracted a lot of researchers to this area. There are seven basic emotions that are universal to human beings. Namely neutral, angry, disgust, fear, happy, sad, and surprise, and these basic emotions can be recognized from human’s facial expression. In this research I will propose an effective way to detect neutral, happy, sad and surprise these four emotions from frontal facial emotion. During the past decades, various methods have been proposed for emotion recognition. Many algorithms were suggested to develop systems/applications that can detect emotions very well. Computer applications could better communicate by changing responses according to the emotional state of human users in various interactions. Emotion of a person can be determined by speech or his face or even one’s gesture. The work presented in this paper explores the recognition of expressions from face.

## 2.Field of Usage:

With the Enhancement of communication between human and computer, this would open a variety of possibilities in robotics and human-computer interfaces such as devices that warn a drowsy driver, attempt to soothe an angry customer, or even in the field of Investigation to detect psychological condition of a criminal. The most important use it can provide that , in case of emergency for medical patient it can determine patience agony and alarm doctor or nurse to help that patience quickly. Field of psychology has played an important role in understanding human emotion and in developing concepts that may aid these HCI technologies.

## 3.Existing Techniques:

So far, numerous research projects have been done on recognizing emotion from Face. Many used many methods to implement their systems. Facial expressions provide the building blocks with which to understand emotion. In order to effectively use facial expressions, it is necessary to understand how to interpret expressions, and it is also important to study what others have done in the past.

**Facial Action Coding System** (**FACS**) is a system to determine human facial expressions, originally developed by Paul Ekman and Wallace V. Friesen, and published in 1978. Ekman, Friesen, and Joseph C. Hager published a significant update to FACS in 2002. Movements of individual facial muscles are encoded by **FACS** from slight different instant changes in facial appearance. It is a common standard to systematically categorize the physical expression of emotions. Recently, FACS has been established as a computed automated system that detects faces in videos, extracts the geometrical features of the faces, and then produces temporal profiles of each facial movement. **FACS** is a key system to determine Facial Feature Extraction.

Fasel and Luettin performed an in depth study in an attempt to understand the sources that drive expressions. Much of expression research to date has focused on understanding how underlying muscles move to create expressions. For example, studies have shown that movement of the eyes and eyebrows and mouth of a person are primary indicators of almost all the emotions.
Much of previous work has used FACS as a frame-work for classification. In addition to this, previous studies have traditionally taken two approaches to emotion classification according to Fasel and Luettin.

- a judgment based approach
- a sign-based approach.

The judgment approach develops the categories of emotion in advance such as the traditional six universal emotions.
The sign-based approach uses a FACS system, encoding action
Units in order to categorize an expression based on its characteristics.

This approach assigns an emotional value to a face using a combination of the key action units that create the expression. A neural-network is used to recognize action units from the coordinates of facial features like lip corners or the curve of eye brows.

For self-organized learning method**, principle component analysis** (PCA) is widely used in the field of data compression and feature extraction. There are two basic approaches to the computation of principal components: batch and adaptive methods. The batch methods include the method of Eigen decomposition and the method of singular value decomposition (SVD), while the adaptive methods are mainly done by neural networks. The main target of PCA is to explain the variance–covariance structure of the data through a few linear combinations of the original variables.

The main concerning thing about PCA is that it utilize only the global information of face images, this method is not very effective for different facial expressions.

**Aw-SpPCA** algorithm is another promising mechanism that has been used to detect emotion from image. This algorithm is based on the concepts of impound illumination conditions, facial expressions variations to local areas dividing a face image into several sub-images, and carry out PCA computation on each local area independently.

Another Approach is to make Appearance based Models. These rely on techniques from statistical analysis and machine learning to find the relevant characteristics of face images. Some appearance-based methods work in a probabilistic network. An image or feature vector is a random variable with some probability of belonging to a face or not.

**Neural Networks** is another key tool of extracting feature from an image. Many pattern recognition problems like object recognition, character recognition, etc.

have been faced successfully by neural networks. These systems can be used in face detection in different ways.

**Support Vector Machines**. SVMs are linear classifiers that maximize the margin between the decision hyperplane and the examples in the training set. So, an optimal hyperplane should minimize the classification error of the unseen test patterns. This classifier was first applied to face detection by Osuna et al.

**Hidden Markov Model** is another statistical model that has been used for face detection. The challenge is to build a proper HMM, so that the output Probability can be trusted. The states of the model would be the facial features which are often defined as strips of pixels. The probabilistic transition between states is usually the boundaries between these pixel strips. As in the case of Bayesians, HMMs are commonly used along with other methods to build detection algorithms.

**Linear discriminant analysis (LDA)** method is used in statistics and pattern recognition to find a linear combination of features. The resulting combination may be used as a linear classifier or, more commonly, for dimensionality reduction before later classification. LDA explicitly attempts to model the difference between the classes of data. PCA on the other hand does not take into account any difference in class, and factor analysis builds the feature combinations based on differences rather than similarities.

# 4.Color Models:

Color models Plays a very important role in Detecting face form an image and Feature Recognition. Research in color modeling for computational purposes has concentrated on finding numerical representations of colors which are convenient for use in image processing. Among many models of colors, these representation schemes use a three dimensional color space (RGB, CMY, YIQ, HSV, and HSL).

Some Details about Different color models:

**RGB:** The **RGB color model** is an additive color model in which red, green, and blue light are added together in various ways to reproduce a broad array of colors. RGB is a *device-dependent* color model. Different devices detect or reproduce a given RGB value differently; it depends on manufacture to manufacture how the color will be taken. Thus an RGB value does not define the same *color* across devices without some kind of color management.

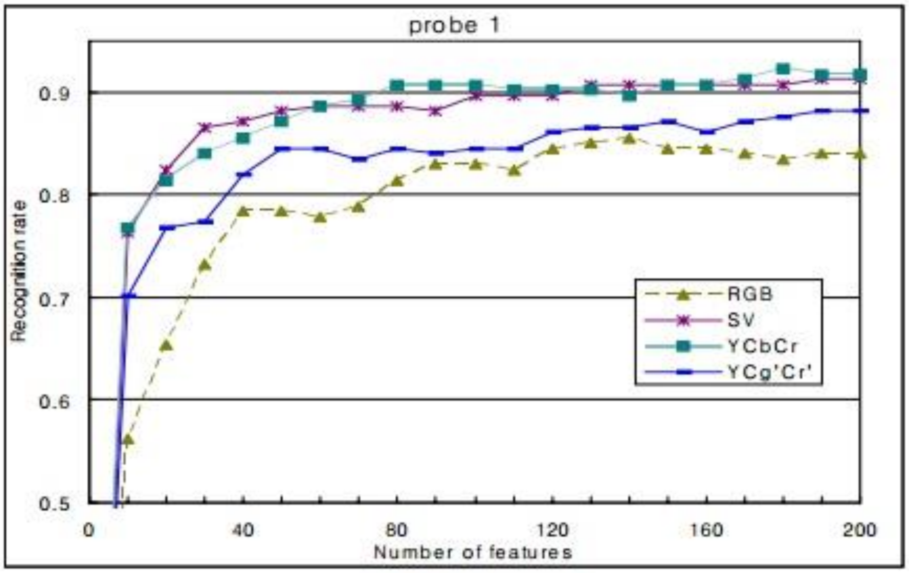
**HSV and HSL:** To make the RGB Color model more intuitive HSV and HSL color model was developed. HSL and HSV are used today in color pickers, in image editing software and in image analysis. HSL stands for hue, saturation, and lightness, and HSV stands for hue, saturation, and value.

**CMYK:** This Color Model is mainly used for printing process. **CMYK** refers to the four inks used in some color printing: **c**yan, **m**agenta, **y**ellow, and **k**ey (black). This Model is Rarely Used for Image Processing.

**YCbCr:** YCbCr is not an absolute color space; rather, it is a *way of encoding* RGB information. The actual color displayed depends on the actual RGB primaries used to display the signal. The YCbCr color domain was developed for efficient image compression by separating luminance (Y) and chrominance (Cb, Cr) components. This model is also known as an effective model for skin color segmentation.

The RGB displays are made to match our color-perception system. They have a computer counter-part, the (R,G,B) "coordinates". Since these coordinates map to implementation rather to the physical, "real nature" properties of color, they are not suited to perform some mathematical processing, e.g. perceptually linear gradient interpolation, color correction, brightness and saturation ops, etc.

Even though most of digital image acquisition devices produce R, G, and B components, the RGB color space is converted into different color spaces depending on applications. For face recognition, the eigenface analysis in the RGB domain may not be effective, because R, G, and B components are largely correlated with each other. Therefore, we need to find the color space that is less correlated between its components for improvement of face classification performance. Here, we will look into effective color spaces for face recognition. Diverse color spaces including RGB, HSV, YCbCr, and YCgCr were investigated in the PCA-based color face recognition system.




(b) Probe set 1

As we can see from here that YCbCr and HSV color model are very effective for face recognition and facial expression variation.

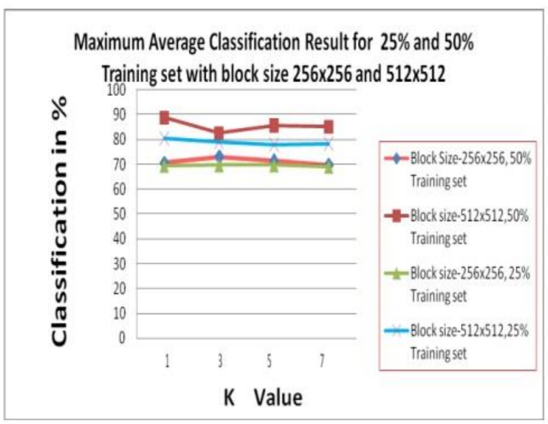



Fig 5.1. Maximum average clasification result for HSV color model

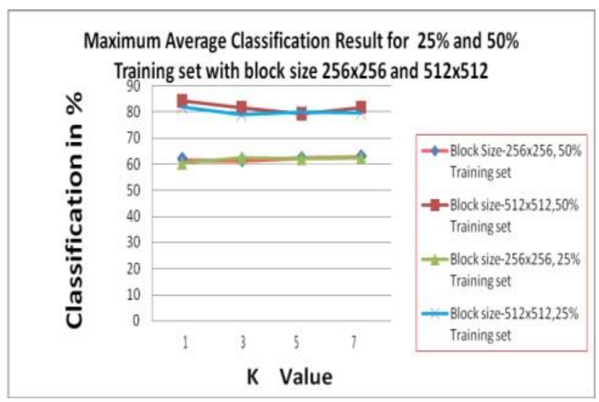



Fig 5.2. Maximum average clasification result for YCbCr color model

But HSV is also very popular model that is used in Face Recognition and Feature Extraction. In terms of Shadow in a given Image, HSV works Better than other models because of its handling of saturation of that shadowed portion.

One of the Main Reason of HSV being so popular is the Ease of implementation. And various Researches showed that in terms of Extraction of features HSV gives a Constant High Performance where YCbCr is not that Constant in Case of Small size images.

## **<u>My Approach :</u>**

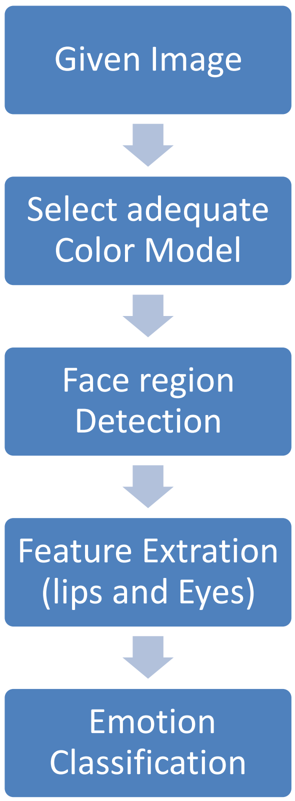



Fig: General Workflow

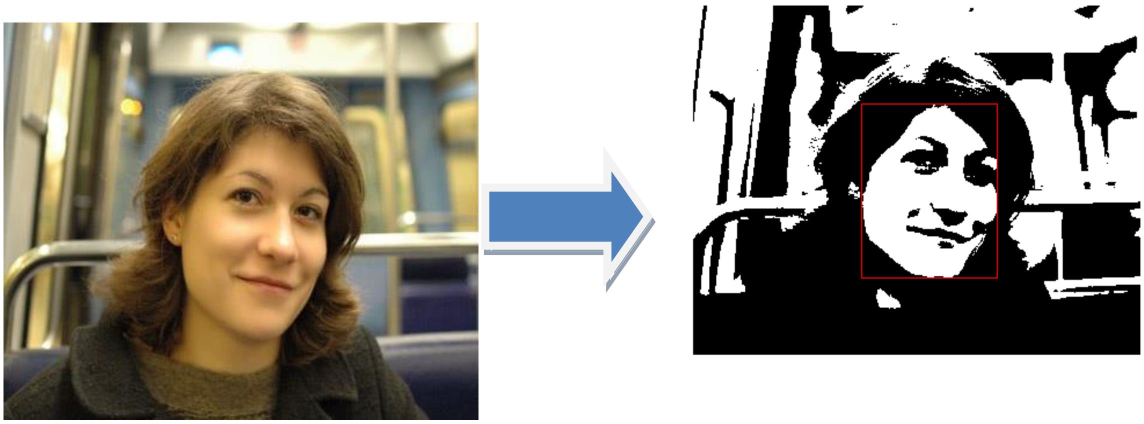
To make an efficient system that will be able to determine emotion from frontal face image is the main goal here and to reach that I have followed a certain workflow.

For a given Image I have selected to use HSV Image of the actual Image to Determine the Facial Region. When the image is converted to HSV image, detecting the larger portion of the image with a certain HSV Value for Human Face can

provide the Required Face Region from the image.

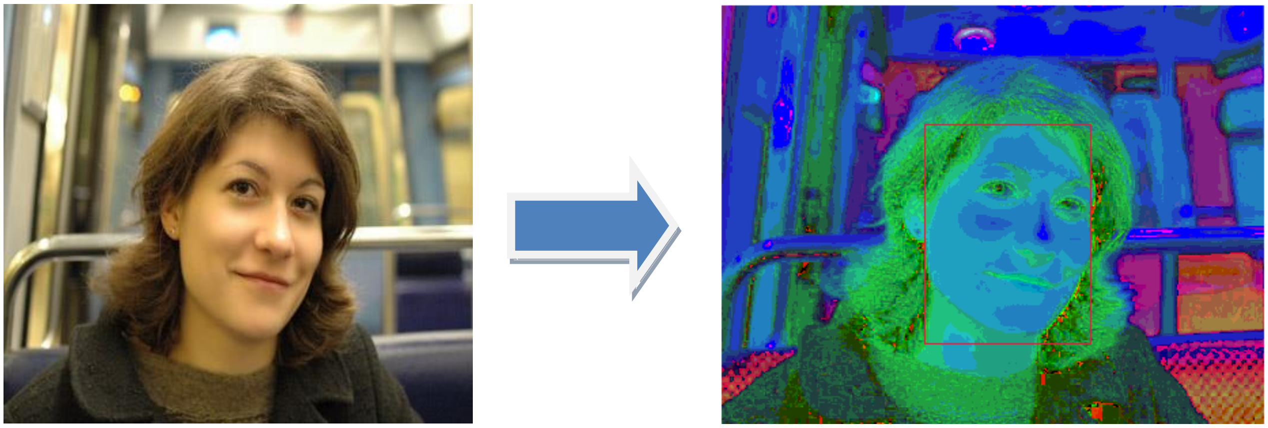
HSV are used today in color pickers, in image editing software and in image analysis. HSL stands for hue, saturation, and lightness, and HSV stands for hue, saturation, and value.

The Image below Shows the Conversion of image from RGB to HSV image of it. This detects the face from an image. As we can see that there are many white or 0 portions in image but the Face on the image is the only part where the white is connected and it is the biggest region of the image.



In such Scenario this binary image is giving us face region very accurately. But we face some problem when the background is very bright such as White Background. This system works for only a certain color region.

So in this case if we convert the given image to HSV first then try to detect it we can have more accurate result. From a HSV Image using RGB Range from R= 0.0488, G= 0.364, B= 0.882 to RGB value of R= 0.468, G = 0.546, B = 0.639 taken as accepting Range we can Detect Face Region From a Given Image as Input.



Next Step is to Crop that Portion and process of Feature Extraction. After Cropping we can see we have,

Fig : Face Region Detection and Cropped Version in YCbCR and HSV Color model.

## Face Feature Extraction:

Now for Feature extraction there are many methods to apply. They can be categorized according to whether they focus on motion or deformation of faces and facial features, respectively, whether they act locally or holistically. In our case we need deformation of faces and facial features. There are many techniques of feature extraction from an image. Here is a list of the methods:

| Method | Notes |
|---|---|
| Principal Component Analysis (PCA) | Eigenvector-based, linear map |
| Kernel PCA | Eigenvector-based , non-linear map, uses kernel methods |
| Weighted PCA | PCA using weighted coefficients |
| Linear Discriminant Analysis (LDA) | Eigenvector-based, supervised linear map |
| Kernel LDA | LDA-based, uses kernel methods |
| Semi-supervised Discriminant Analysis (SDA) | Semi-supervised adaptation of LDA |
| Independent Component Analysis (ICA) | Linear map, separates non-Gaussian distributed features |
| Neural Network based methods | Diverse neural networks using PCA, etc. |
| Multidimensional Scaling (MDS) | Nonlinear map, sample size limited, noise sensitive. |
| Self-organizing map (SOM) | Nonlinear, based on a grid of neurons in the feature space |
| Active Shape Models (ASM) | Statistical method, searches boundaries |
| Active Appearance Models (AAM) | Evolution of ASM, uses shape and texture |
| Gavor wavelet transforms | Biologically motivated, linear filter |
| Discrete Cosine Transform (DCT) | Linear function, Fourier-related transform, usually used 2D-DCT |
| MMSD, SMSD | Methods using maximum scatter difference criterion. |

Table : Feature extraction algorithms

Among all these Algorithms I have tried to Work with Neural Network based methods, Gavor Wavelet Transforms, and Viola Jones Algorithms to find out the one that provide the most accurate face feature extraction and implement the System which will detect the emotion by reading those features. Here are some of the Performance evaluations of these Methods of Feature Extraction and Emotion Recognition using these.

PERFORMANCE ANALYSIS

| No. | Type of Gesture | No. of Input Images | Recognized | Result (%) |
|---|---|---|---|---|
| 1 | Happy | 13 | 12 | 92.3 |
| 2 | Disgust | 11 | 10 | 90.9 |
| 3 | Anger | 10 | 9 | 90 |
| 4 | Neutral | 7 | 7 | 100 |

Fig: performance analysis for Weighted PCA approach

| | |
|---|---|
| Happy | 79.7% |
| Sad | 69.9% |
| Angry | 72.3% |
| Disgust | 69.9% |
| Surprise | 78.5% |

Fig: Performance analysis of gavor Wavelet Method

Despite there are these approaches which provides quite accurate output for the system, But I have used Viola Jones Algorithm to Extract Feature from the Image.

Viola Jones object detection Framework is one of the modern algorithm which is based on Haar Cashcades which is an appearance based model. The **Viola–Jones object detection framework** is the first object detection framework to provide competitive object detection rates in real-time proposed in 2001 by Paul Viola and

Michael Jones. Although it can be trained to detect a variety of object classes, it was motivated primarily by the problem of face detection.

This approach to detecting objects in images combines four key concepts:

- Simple rectangular features, called Haar features
- An Integral Image for rapid feature detection
- The AdaBoost machine-learning method
- A cascaded classifier to combine many features efficiently

The features that Viola and Jones used are based on Haar wavelets. Haar wavelets are single wavelength square waves (one high interval and one low interval). In two dimensions, a square wave is a pair of adjacent rectangles - one light and one dark.

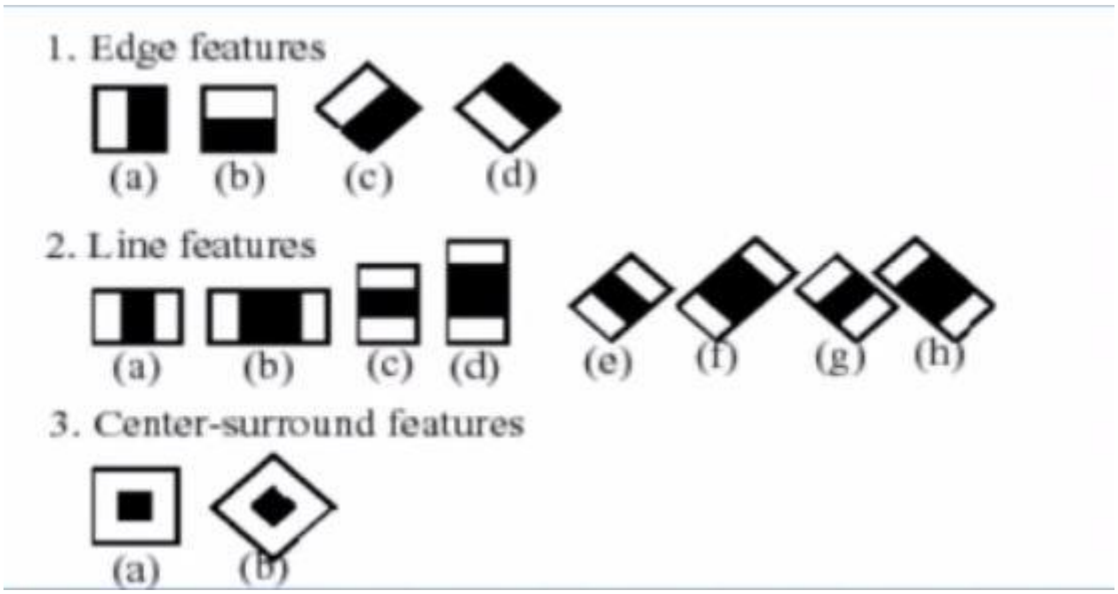


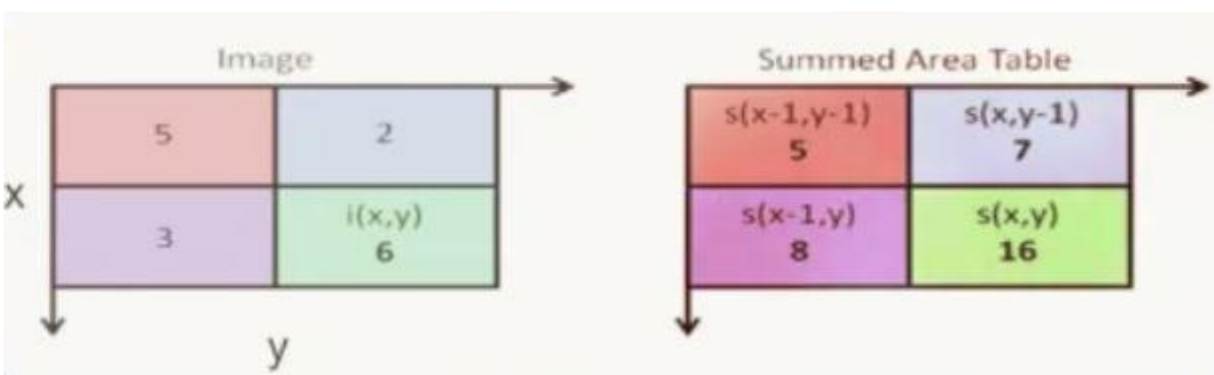

Fig: Haar-Like Feature

These are few types of Haar Classifier that were developed for detecting different

type of features and for different environment.
The actual rectangle combinations used for visual object detection are not true Haar wavlets. Instead, they contain rectangle combinations better suited to visual recognition tasks. Because of that difference, these features are called Haar features, or Haarlike features, rather than Haar wavelets. Figure above shows the features that OpenCV uses.

The simple rectangular features of an image are calculated using an intermediate representation of an image, called the integral image. The integral image is an array containing the sums of the pixels' intensity values located directly to the left of a pixel and directly above the pixel at location (x, y) inclusive. So if A[x,y] is the original image and AI[x,y] is the integral image then the integral image is computed as shown in equation 1 and illustrated in Figure below.

$$AI[x,y] = \sum_{x' \leq x, y' \leq y} A(x',y') \qquad (1)$$




As above Figure shows, after integration, the value at each pixel location, (x,y), contains the sum of all pixel values within a rectangular region that has one corner at the top left of the image and the other at location (x,y). To find the average pixel value in this rectangle, you'd only need to divide the value at (x,y) by the rectangle's area.

But what if you want to know the summed values for some other rectangle, one that doesn't have one corner at the upper left of the image? Figure on the right shows the solution to that problem. Suppose you want the summed values in D. You can think of that as being the sum of pixel values in the combined rectangle, A+B+C+D, minus the sums in rectangles A+B and A+C, plus the sum of pixel values in A. In other words,

$$D = A+B+C+D - (A+B) - (A+C) + A.$$

It only takes two passes to compute both integral image arrays, one for each array. using the appropriate integral image and taking the difference between six to eight array elements forming two or three connected rectangles, a feature of any scale can be computed. Thus calculating a feature is extremely fast and efficient. It also means calculating features of various sizes requires the same effort as a feature of only two or three pixels. The detection of various sizesof the same object requires the same amount of effort and time as objects of similar sizes since scaling requires no additional effort.

To select the specific Haar features to use, and to set threshold levels, Viola and Jones use a machine-learning method called AdaBoost. AdaBoost combines many "weak" classifiers to create one "strong" classifier. "Weak" here means the classifier only gets the right answer a little more often than random guessing would. That's not very good. But if you had a whole lot of these weak classifiers, and each one "pushed" the final answer a little bit in the right direction, you'd have a strong, combined force for arriving at the correct solution. AdaBoost selects a set of weak classifiers to combine and assigns a weight to each. This weighted combination is the strong classifier.

Viola and Jones combined a series of AdaBoost classifiers as a filter chain, shown in Figure below, that's especially efficient for classifying image regions. Each filter is a separate AdaBoost classifier with a fairly small number of weak classifiers.

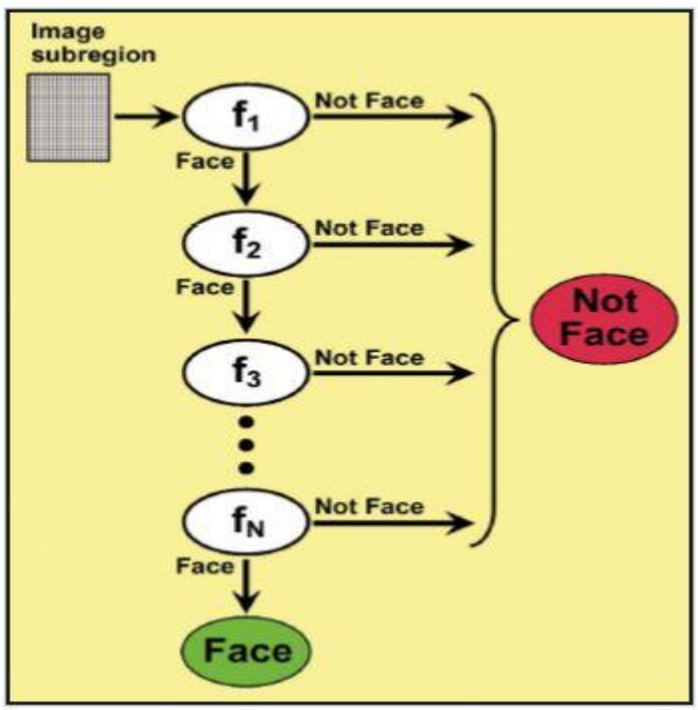



Figure 3. The classifier cascade is a chain of filters. Image subregions that make it through the entire cascade are classified as "Face." All others are classified as "Not Face."

Here are some of the images where face features were detected by the System.

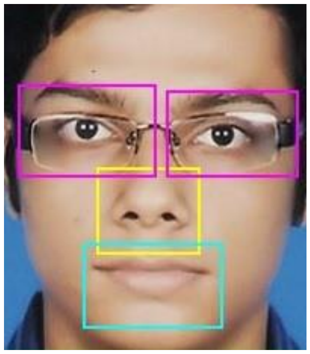
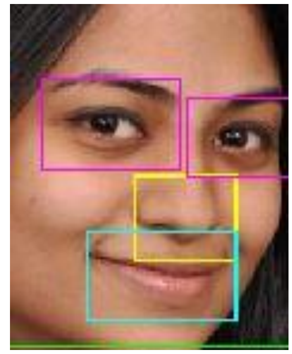
 

Fig: Detection of face Features Such as Eyes Nose and Lips.

## Use of Neural Network to Detect Emotion from the Extracted Feature:

From the Extracted Lips and Eyes Region and from reading them we can detect the emotion of a Human Face. I have used neural network to detect the emotion from the lips and eye region. And for that knowing neural network is a vital step.

Neural Network is a powerful and efficient way of getting a solution using pattern recognition. It is a widely used method to recognize pattern where in my research I have used it to determine emotion by remembering the pattern of lips region. Neural Network is an efficient way of solving complex problems is following the lemma “divide and conquer”. A complex system may be divided into simpler and smaller systems, in order to be able to understand it. Networks are one approach for achieving this. There are a large number of different types of networks, but they all are characterized by the following components: a set of nodes, and connections between nodes. Nodes can be seen as computational units. They receive inputs, and process them to obtain an output. This processing might be very simple (such as summing the inputs), or quite complex.

The connections determine the information flow between nodes. They can be unidirectional, when the information flows only in one direction, and bidirectional, when the information flows in either direction.

Similarly we are also using a kind network known as “Artificial Neural Network” in short (ANN). Biological human brain neural structure is more similar to this network. They are powerful tools for modeling, especially when the underlying data relationship is unknown. ANN can identify and learn similar patterns between input data sets and corresponding target values. After training ANN can be used to predict the outcome of new independent input data. As we mentioned ANN follows the learning process of the human brain and can process problems involving non-linear and complex data even if the data are imprecise and noisy. It consists of simple computational units called neurons, which are highly interconnected. A very important feature of these networks is there adaptive nature where, “learning by example” replaces “programming” in solving problems. This feature makes such computational models very appealing in application domains.

## Structure of the Network:

The network we have talked about so far must have a structure or model that would help all the learning and computational processes. The kind of model we are implementing is called Multilayer Perceptron (MLP) or sometimes called Multilayer Feed Forward neural network. The name itself defines the structure that is a model that has multiple layers of neurons or nodes. MLP neural network learned by back propagation algorithm is based on supervised procedure, i.e. the network constructs a model based on examples of data with known output. As like any network models this network also contains two basic layers called input layer and output layer. The number of neurons in the input layer depends on the input image size that is each pixel represents each node respectively. The output layer may contain one or more neurons depending on the developer and the system. In our system we kept 4 output neurons which will resembles emotions such as HAPPY, NEUTRAL, SAD and SURPRISED.

In between these two layers there may be one or more additional layers called the hidden layers. We have added one hidden layer in our system because it increases accuracy while the learning process proceeds. There is no fixed rule for the number of neurons that would be in the hidden layer. These bunches of layers are interconnected and as part of MLP the information flows unidirectional from input layer to output layer through hidden layer.

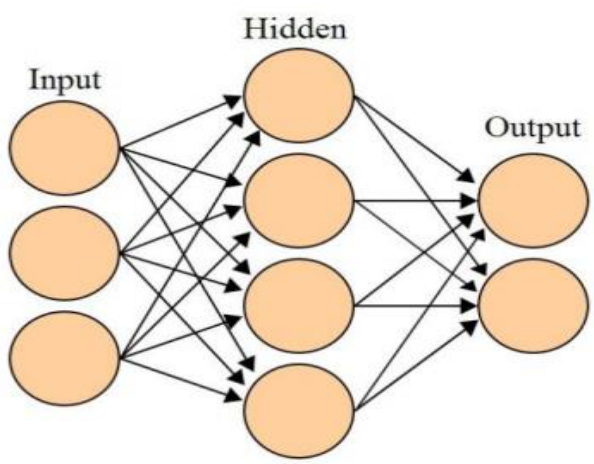
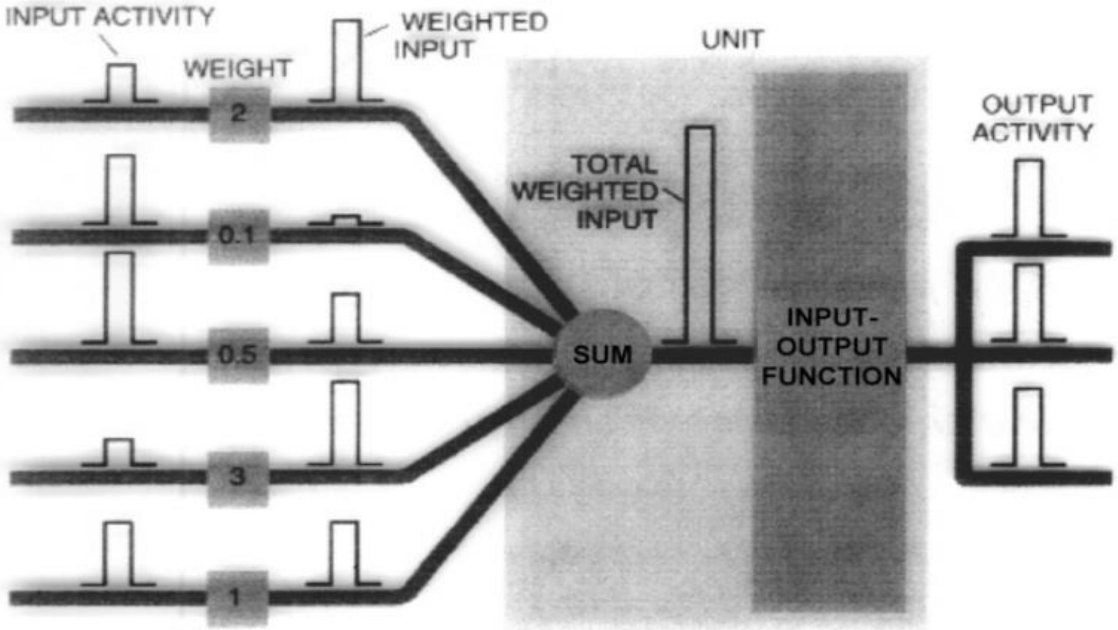



Fig1: Artificial Neural Network with input, hidden and output layers.

In each node there are assigned weight depending on the nodes type. And idealization of a NEURON processes activities or signals. Each input activity is multiplied by a number called weight. The unit adds together the weighted inputs. Then it computes the output activity using and input- output function. The process can be viewed in detail from the following figure.




## Training the Network:

To train a neural network to perform some task, we must adjust the weights of each unit in such a way that the error between the desired output and the actual output is reduced. This process requires that the neural network compute the error derivative of the weights (EW). In other words, it must calculate how the error changes as each weight is increased or decreased slightly. The back-propagation algorithm is the most widely used method for determining EW.

Also in term of implementation, I had to Tell Matlab what optimization (or training) routine to use. I have used use Sigmoid Activation Function (transig), which is gradient descent, Secondary as trainlm (for Levenburg-Marquardt, which is a combination of gradient descent and Newton's Method).

Here is a Portion of Training set of input that was used to train the Network. There were 100 input data used to train the network.


**FIG : a Portion of Trainisg Set**

The Back Propagation Algorithm works the Following way.

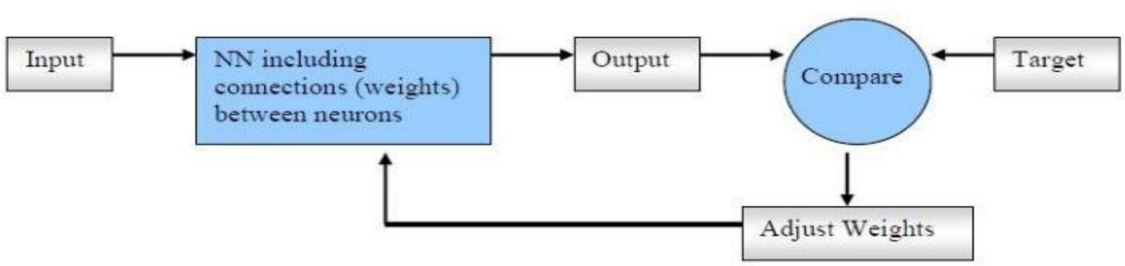



Fig 6: Training with backpropagation algorithm

After our training is successful then we will see if out network able to recognize any given pattern.

Fig: Input for testing

Fig: Output Recognised by System

This shows that the System is perfectly recognizing the Emotion of the given input.

By this Technique I have tested 50 times with different Images with Different Emotion and the Performance that the method showed are given below.

| Emotion | % of Detection |
| --- | --- |
| HAPPY | 100% |
| NEUTRAL | 98% |
| SAD | 96% |
| SURPRISED | 100% |

Fig: Accuracy measurement

# **The Drawback of this approach:**

This work has presented the face recognition area, explaining different approaches, methods, tools and algorithms used to determine Emotion from Images. Some algorithms are better, some are less accurate, some of them are more versatile and others are too computationally costly. Despite this variety, face recognition faces some issues inherent to the problem definition, environmental conditions and hardware constraints. In terms of side Face or where the image is not providing proper frontal face view these algorithms and methods give very less accurate recognition of emotion.

Some of the Drawback of this System:

- In Case of a Dark person with a Bright Background, this System Won't be able to detect face.
- Side Faced Images will fail to detect emotion from them as it will not be able to extract face feature.
- I have only used Lips as Neuron to detect emotion. Some of the mixed emotion will be failed to detect;

# Future Work:

The System that I have implemented works quite well with normal background but if the background is too bright or matches with skin color of the person or people with dark skin, the system fails to deliver properly, so I will work on how to make the system more efficient so that it works on bright background or for people with darker skin. Eyes also help to detect emotions. So I will use eyes to detect emotion more accurately. Adding more emotions to detect is one of my future plans as I have only detected four emotions for this system. Another plan is to detect emotions from live video footage as it can help on many sectors of daily usage such as medical or investigation or security purpose and many more.

I will try to make a better system in future as Emotion Detection can help us to decide many problems that we face in our daily life and it will help us to make the society a better place to live in.

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  Morphological Edge Detection and Localization for Fast Iris Recognition

Suganthy, M. and P. Ramamoorthy

- Face Detection Using Gabor Feature Extraction and Artificial Neural Network -Bhaskar Gupta , Sushant Gupta , Arun Kumar Tiwari(ABES Engineering College, Ghaziabad)
- Speed limit sign board detection & extraction of digits in different weather conditions- Khan Hafizur Rahman & MD. Zubair Alam
- ArtificialNeural Networksfor Beginners-Carlos Gershenson (C.Gershenson@sussex.ac.uk)

- Artificial neural networks:Training with backpropagation-Juan Rojo (INFN, Sezione di Milano)
- http://www.doc.ic.ac.uk/~nd/surprise_96/journal/vol4/cs11/report.html
- http://www.dacs.dtic.mil/techs/neural/neural_ToC.html
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- http://www.cognotics.com/opencv/servo_2007_series/part_2/sidebar.html
- FACIAL FEATURE DETECTION USING HAAR CLASSIFIERS - Phillip Ian Wilson & Dr. John Fernandez