

# **An Efficient Facial Expression Recognition Method**

## **Using Mean And Standard Deviation**



Thesis submitted in partial fulfillment of the requirement for the degree of

**Bachelor of Computer Science and Engineering**

Under the Supervision of

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# Declaration

We hereby declare that this thesis is based on results obtained from our own work. Due acknowledgement has been made in the text to all other material used. This thesis, neither in whole nor in part, has been previously submitted to any other University or Institute for the award of any degree or diploma.

**Signature of Supervisor:**

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Dr. Jia Uddin

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# Abstract

Facial Expression gives vital information about emotion of human being. It is really a speedily growing and an ever green research field in the sector of computer vision, artificial intelligence and automation. If we talk about a fully automated system, it might be used to have an interaction between a human being and a computer. Here a user without using his hands can give command to system with the help of facial expression. We are proposing a facial expression recognition model analyzes an image of a face and detects alignments to six different emotions which are disgust, annoy, surprise, crying, happiness and neutral. In this research we choosed JAFFE dataset and we used mean and standard deviation method to classify the images into categories. A new algorithm based on a set of images to face recognition is proposed here.

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# List of Abbreviations

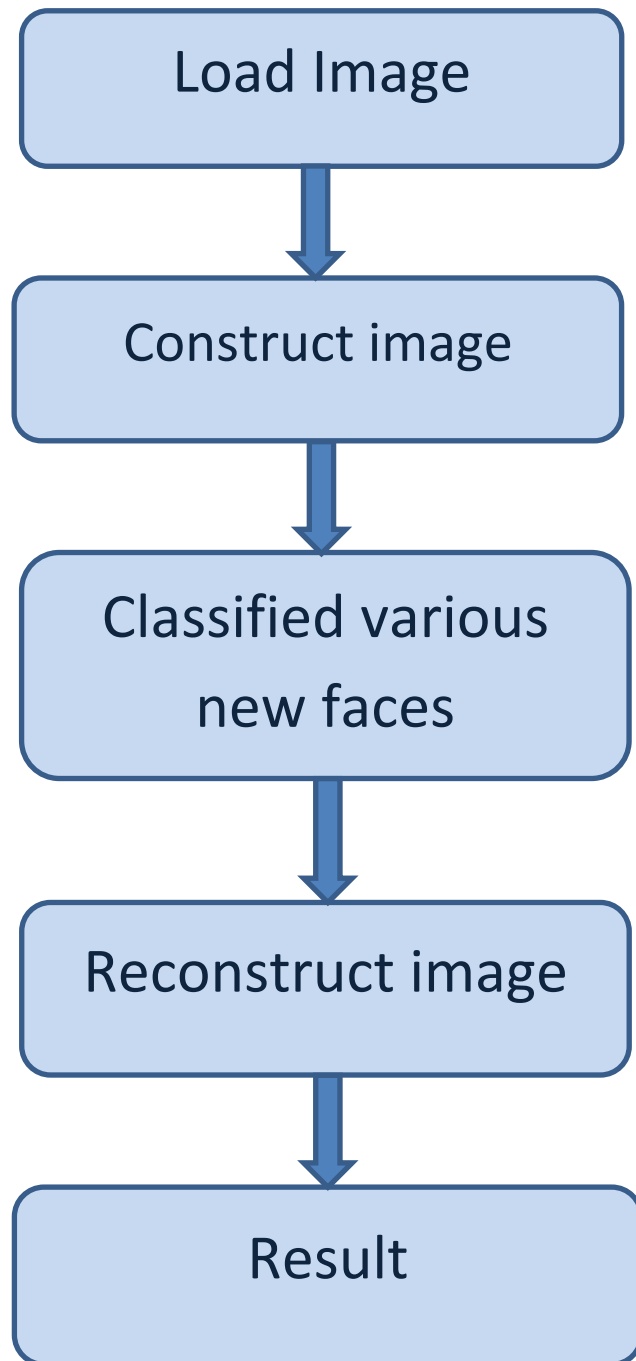
**RMS** : Root Mean Square

**SD** : Standard Deviation

# CHAPTER 01

## Introduction

Emotion recognition through facial expression recognition is one of the significant grounds of study for human-computer interaction. To distinguish a facial expression one system need to come across a various changeability of human faces such as color, posture, expression, orientation, etc. To detect the expression of a human face first it is required to distinguish the different facial features such as the activities of eye, nose, lips, etc. and then categorize them comparing with trained data using an appropriate classifier for expression recognition. In this research, we first take the image input for which the image is needed to be pre-processed. Then we need to classify the images. After classifying we need to send it to the face database and allocate into the different classes. After pre-processing and train the dataset using feature extraction we get our desired output. A dataset is used for training purpose. The gray scale images of the face is used by the system to classify six basic emotions such as surprise, annoy, disgust, sad,neutral and happiness. Every Facial expression recognition system has some basic operations. The following flow chart in Figure 1 can represent a simple system.



**Figure 1:** Basic flow chart

## 1.1 Motivation

The most significant part of human body which helps to distinguish the individuals as well as delivers the important information is the face. It also expresses present state of user behavior through their different expressions. Facial expressions have the aptitude to communicate emotion and regulate personal behavior. In human-to-human conversation, the expression and observation of facial expressions form a communication network in addition to voice which carries dynamic information about the mental, emotional, and even physical state of the persons in conversation. Over the past 30 years, Scientists have established human-observer based systems that can be used to identify and compare facial expressions with human emotion. Facial Action Coding System (FACS) developed by Paul Ekman and Wallace V. Friesen is the most widely used and validated for measuring and describing facial behaviors [1].

## 1.2 Contribution Summary

- The first approach is to use the facial expression recognition system is to provide a dataset for which we choose JAFFE dataset. This dataset is relatively small and appropriate for our project.
- Then in the pre-process part the images get to be prepared for feature extraction if needed. After that in the feature extraction part we used mean and standard deviation method from which we classify the images into categories.
- In the last part after comparison we get the expected result from the system.

## 1.3 Thesis Orientation

The thesis paper is structured in total five chapters. Here, Chapter 2 includes the background study of facial expression recognition technology. Chapter 3 discusses the literature review of related works and proposed methodology. Chapter 4 demonstrates the implementation and results of the experiment with the performance analysis, comparison and some challenges observed. Chapter 5 concludes the thesis.

# CHAPTER 02

## Background Analysis

### 2.1 Facial expression Recognition

Facial expression is having an important role in interconnecting human emotions, finds its applications in human-computer interaction (HCI), health-care, surveillance, driver safety, deceit detection etc. Tremendous success being accomplished in the fields of face detection and face recognition, affective computing has received substantial attention among the researchers in the edomain of computer vision. Signals, which can be used for affect recognition, include facial expression, paralinguistic features of speech, body language, physiological signals (e.g. Electromyogram (EMG), Electrocardiogram (ECG), Electrooculogram (EOG), Electroencephalography (EEG), Functional Magnetic Resonance Imaging (fMRI) etc.). Most of the research on facial expression analysis are based on detection of basic emotions which are happiness, annoy, disgust, neutral, sadness, and surprise. A number of different methods for facial expression recognition have been proposed over the last decade [2].

#### 2.1.1 Tools and Training

There have been many modifications in technology over years as well as in image processing. If we consider now, OpenCV, MATLAB has been one creator of image processing. However we select MATLAB for our thesis in respect of programming efficiency and usefulness. MATLAB libraries have been a great advantage in our work

#### 2.1.2 MATLAB

MATLAB is a multi-paradigm numerical computing environment and programming language. It was developed by MathWorks in 1984. It can be operated in Windows, macOS and Linux operating systems. It has many functions and allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing

with programs which are written in other languages including C, C++, C#, Java, Fortran and Python. Though initially MATLAB was built for numerical computing, later it added some new dimensions such as symbolic computing abilities, graphical multi-domain simulation and model based designs for dynamic and embedded systems [3].

## 2.2 Previous Works and Technical Overview

Facial expression recognition has been a vast research field although still now it is considered a complex problem. There are some reasons for that. First of all, the ambience around an individual differs significantly. Moreover a person can experience similar emotion at different time and can have different external effects. Identify ones correct emotional state from that external is a difficult task. The task turns out to be more complex when an individual gives some kind of mixed emotional expression.

There has been many works on facial expression recognition. However the pioneer in the study of emotion is an American psychologist Paul Ekman. Ekman and Friesen developed a scheme for recognition of facial expression from different parts of face (chin, cheek, wrinkles etc.) [4,5].

Then many used neural networks for detecting facial expression such as Saudagare and D.S Chaudhari. Using MATLAB (neural network toolbox) their system reviews several methods of facial expression detection [6].

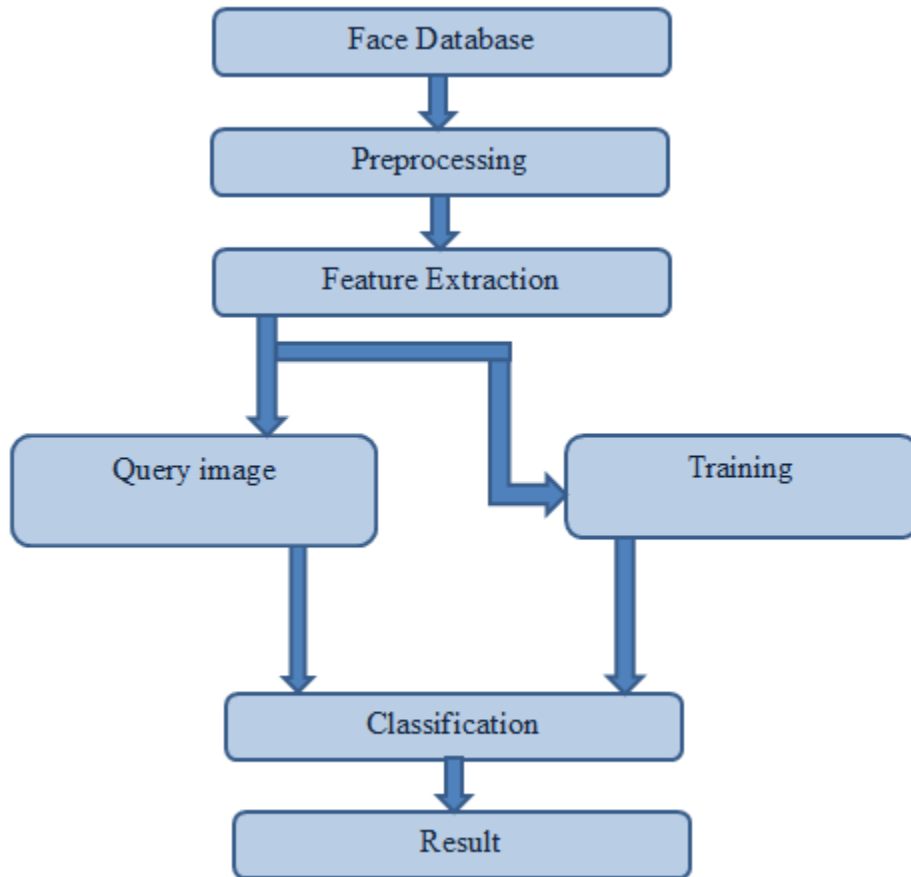
Mandeep Kaur, Rajeev Vashisht and Nirvair Neeru established a facial expression recognition system using Principal Component Analysis and Singular Value Decomposition techniques [7].

Anurag De, Ashim Saha, Dr. M. C. Pal In their research, modeled a human facial expression recognition system using eigenface approach. The proposed method uses the HSV (Hue-Saturation-Value) color model to detect the face in an image and PCA has been used for reducing the high dimensionality of the eigen space [8]. Xiaoming CHEN and Wushan CHENG build a system based on Edge detection algorithm [9].

# CHAPTER 03

## Proposed Model

The proposed methodology is being explained in Figure 2. In this whole research we first take the image input for which the image is need to be pre-processed. Then we have to classify the images. After classifying we need to send it to the face database and allocate into the different classes. After pre-processing and train the dataset using feature extraction we get our desired output.



**Figure 2:** Workflow

There are five main functional blocks, whose responsibilities are given below:

### **3.1 The acquisition part**

The acquisition part is the starting point of the process of facial expression recognition process. Here we will start our work with the input image collected from the dataset. In another way, the user need to give a face image as input in this part. The face image dataset has to be placed somewhere easily accesable from the system.

### **3.2 The pre-processing part**

Pre-processing is applying some sort of processing to images before they are analyzed to increase success. In this part, face images need to be normalized and to get desired output, we collect dataset consisting pictures of same person's expressions which must have the following features:

- a. 256 x 256 pixels
- b. 1200 dpi
- c. bit depth 8
- d. gray scale photo

### **3.3 The feature extraction part**

After performing some pre-processing (if necessary), the normalized face image is presented to the feature extraction part in order to find the key features that are going to be used for classification. Another word, this module is responsible for composing a feature vector that is well enough to represent the face image.

### **3.4 The classification part**

In this part, we used mean and standard deviation process to extract features of the face image and then it is compared with the images kept in the face dataset. After doing this comparison,



face image is classified into one of the six expressions (happy, sad, surprise, neutral, cry, annoyed).

### 3.5 The Training part

The project is conducted on the input 190 images using MATLAB software. At first we take 3 or 4 pictures of one specific person of each expression. Then put them in the inputentry code. So the picture is in the db.mat file now. This is how we will train our system. Now we run the test code and test the other images which we have not put in the inputentry code. Then we check how many times we get the authentic result. Then at last we calculate the percentage error with the following equation (1):

$$\text{Percentage of Error: } \frac{\text{Number of input} - \text{Number of Incorrect Output}}{\text{Number of Input}} \times 100 \quad (1)$$

# CHAPTER 04

## Experimental Setup and Result Analysis

In this research a new approach is proposed based in mean and standard deviation for authentication system of face. The feature which we are evaluated in this research is as follows.

### 4.1 Mean

Mean filtering is a simple, spontaneous and easy to implement method of smoothing images, i.e. reducing the amount of intensity variation between one pixel and the next. It is often used to reduce noise in images.

Mean [10, 11] is most fundamental of all statistical measure. Means are frequently used in geometry and analysis; an extensive range of means have been established for these purposes. In the field of image processing mean is classified as spatial filtering and used for noise reduction. Mathematically mean is given by

$$\bar{X} = \frac{\sum_{i=1}^n X_i}{n} \quad (2)$$

### 4.2 Standard Deviation

Standard deviation is a most commonly used measure of variability or diversity used in statistics. In the field of image processing it displays how much variation or "dispersion" occurs from the average (mean, or expected value). A low standard deviation states that the data points tend to be very close to the mean, where high standard deviation specifies that the data points are spread out over a large range of values.

Standard deviation is a measure of how spread out the data set from the mean; it is denoted by  $\sigma$  [12]. A standard deviation filter computes the standard deviation and allocates this value to the center pixel in the output map. It can be used in edge sharpening, as intensity level get changes at the edge of image by large value as it has ability to measure the variability .

Standard deviation filters [13] can be valuable for radar images. The explanation of radar images is often tough: we cannot rely on spectral values because of back scatter (return of the pulse sent by the radar). This often causes a lot of 'noise'. By using a standard deviation filter, we may be able to recognize some patterns.

Mathematically standard deviation is given by

$$\sigma = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}} \quad (3)$$

### 4.3 Dataset Collection

A database containing images of facial expression was accumulated. Ten expressers posed 3 or 4 examples of each of the six basic facial expressions (happiness, sadness, surprise, anger, disgust, fear) [5, 19] and a neutral face for a total of 213 images of facial expressions. For simplicity of experimental design only Japanese female expressers and subjects were employed. The Japanese Female Facial Expressions (Lyons, Akamatsu, Kamachi, & Gyoba, 1998) dataset in which the expressions were posed without instruction by Japanese participants in Japan, and they were not screened against any standards for emotional facial expressions. We therefore call the JAFFE expressions “Japanese” expressions [20].

For this analysis we will be using 190 selected images from JAFFE dataset since it already has been established over its state and has 6 different expressions mentioned over as sample. The database contains 213 images of 7 facial expressions (6 basic facial expressions + 1 neutral) posed by 10 Japanese female models. Each image has been evaluated on 6 emotion adjectives by 60 Japanese subjects [14]. We selected the JAFFE faces according to the requirements of the system. We collect dataset consisting pictures of persons' expressions which must have the following features:

- a. 256 x 256 pixels
- b. 1200 dpi

c. bit depth 8

d. gray scale photo



**Figure 3: JAFFE Dataset**

Figure.3 shows the apparatus used to photograph the expressers. Each expresser took pictures of herself while looking through a semi-reflective plastic sheet towards the camera. Hair was tied away from the face to expose all expressive zones of the face. Tungsten lights were positioned to create even illumination on the face. A box enclosed the region between camera and plastic sheet to reduce back reflection. The images were printed in monochrome and digitized using a flatbed scanner.

In this part we are going to focus on the implementation of the system. The basic parts will be described in general.

## 4.4 Implementation

### 4.4.1 Train input and input entry

In this part we have to provide an image from face dataset at first. Here in Figure 4 and 5 it

shows that we have allocated each expression with a number and the system will ask for an expression number when an image will be provided. The user has to give a number according to the image he /she is selecting from dataset. We are calling this phase Train Input.

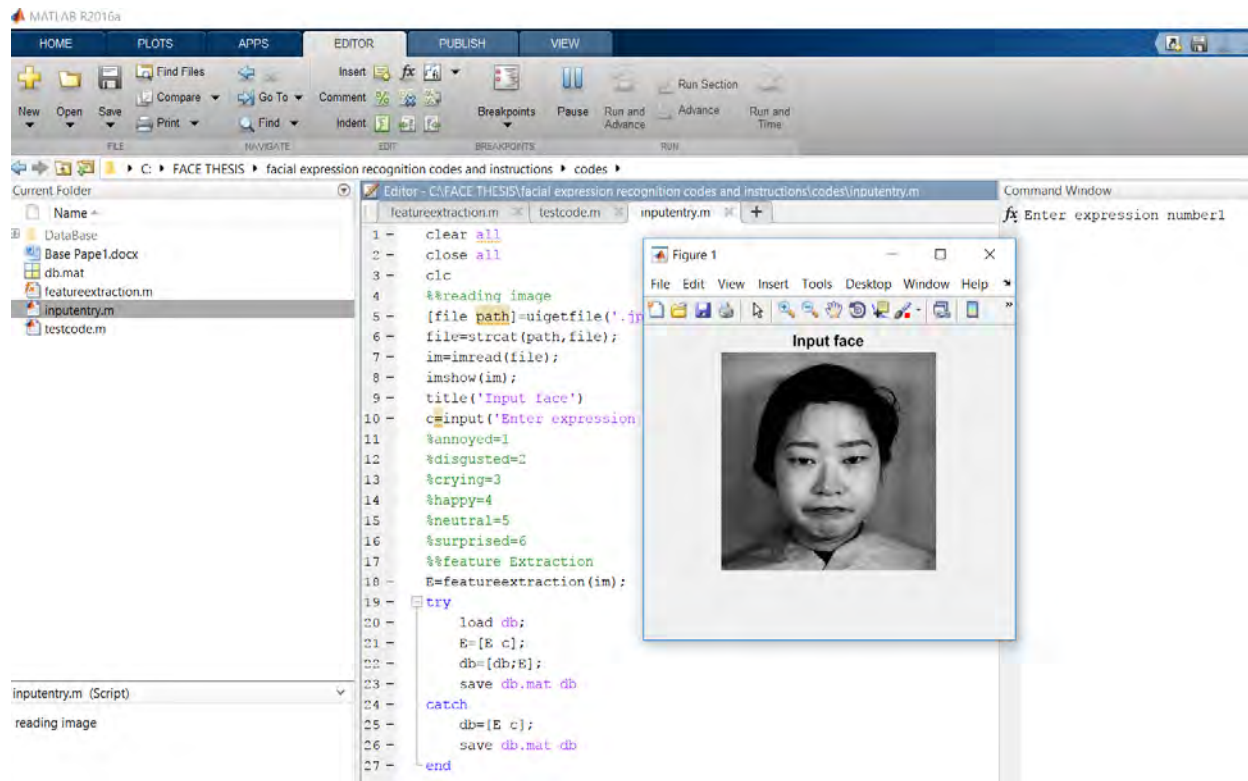
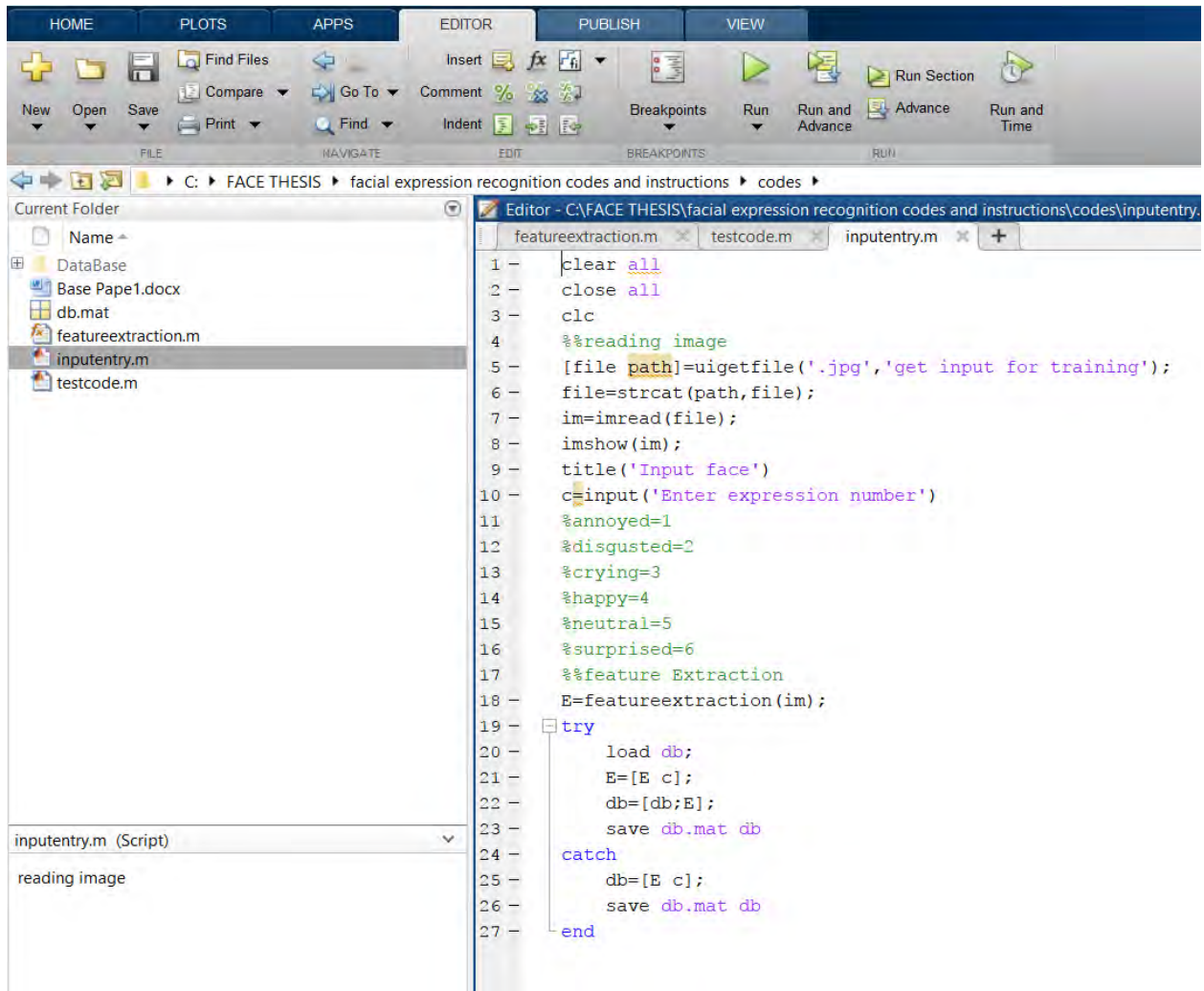


Figure 4: Train Input



**Figure 5:** Input Entry

## 4.4.2 Test code and output

After the training of input image we will test the system. If we wish to test a particular expression we have to train that expression first in the input image section first. Then we have to select one from database. After running the comparison it will give the result. The result output is shown in Figure 6.

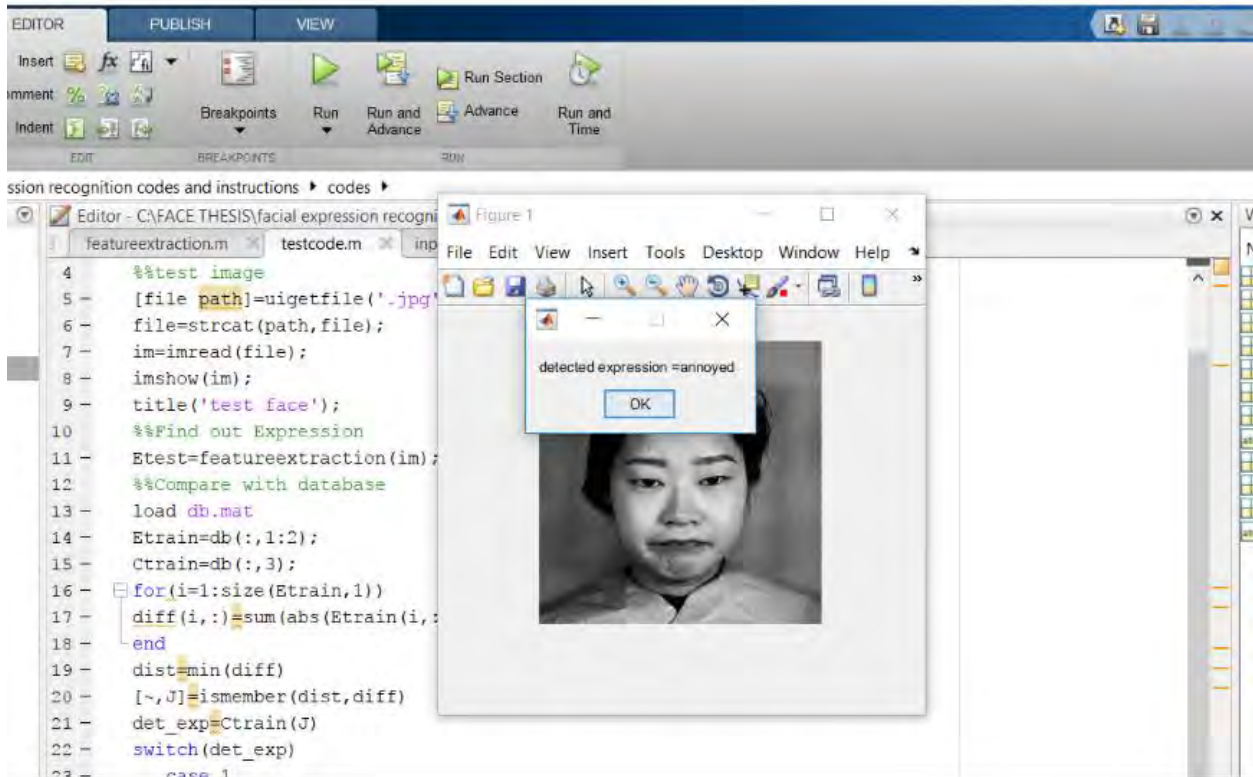


Figure 6: Output

### 4.4.3 Feature Extraction Method

This is where the main functions of our program are defined. Figure 7 shows how the function works.

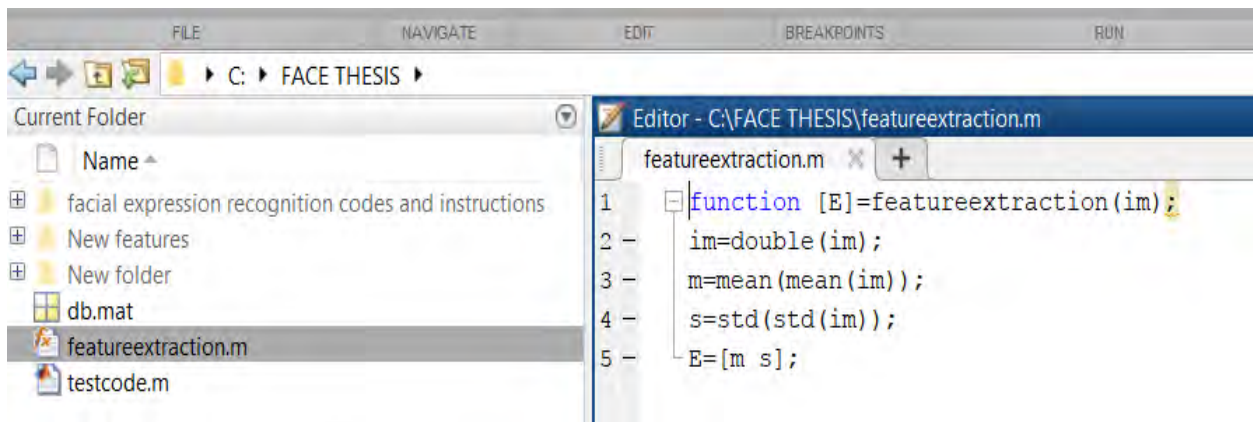


Figure 7: Feature Extraction Method

## 4.5 Result Analysis

The algorithm has been implemented and tested and it works well with emotions such as Surprise, Sad, Cry, Annoy, Disgust and Happiness. It is tested upon JAFFE dataset and gives the result as shown in Table 1. The result matrix is created based on Mean and Standard deviation approach. It is seen here that Annoy and Neutral has a recognition rate of 50%, Surprise, Happy and Cry also has an error of 33.33% and Disgust has an error rate of 25%. Cry, Annoy, Disgust are some close emotions. So machine mixes them up sometimes. On the other hand, Surprised is a combination of happy and disgust emotions as surprise can be pleasant or unpleasant. So machine mixes them up pretty frequently.

To avoid such error, more data is to be collected by machine. The bigger the database is, the accuracy of the system rises which can be considered as a point of concern for the model and can be improvised by a much stronger training process.

**Table 1:** Output Analysis

<b>Input</b>	<b>Test Face</b>	<b>Output</b>	<b>Correct/Incorrect</b>
Happy	Happy	Happy	Correct
Happy	Annoy	Happy	Incorrect
Happy	Cry	Happy	Incorrect
Annoy	Annoy	Annoy	Correct
Annoy	Happy	Annoy	Incorrect
Cry	Cry	Cry	Correct
Cry	Annoy	Cry	Incorrect
Cry	Happy	Cry	Incorrect
Depressed	Depressed	Depressed	Correct
Depressed	Annoy	Depressed	Incorrect
Depressed	Happy	Depressed	Incorrect
Depressed	Surprised	Depressed	Incorrect
Neutral	Neutral	Neutral	Correct
Neutral	Annoy	Neutral	Incorrect
Surprised	Surprised	Surprised	Correct
Surprised	Happy	Surprised	Incorrect
Surprised	Annoy	Surprised	Incorrect



Percentage of Error:  $\frac{\text{Number of input} - \text{Number of Incorrect Output}}{\text{Number of Input}} \times 100\%$

$$\text{Annoy} = \frac{2-1}{2} \times 100\% = 50\%$$

$$\text{Cry} = \frac{3-2}{3} \times 100\% = 33.33\%$$

$$\text{Disgust} = \frac{4-3}{4} \times 100\% = 25\%$$

$$\text{Happy} = \frac{3-2}{3} \times 100\% = 33.33\%$$

$$\text{Neutral} = \frac{2-1}{2} \times 100\% = 50\%$$

$$\text{Surprised} = \frac{3-2}{3} \times 100\% = 33.33\%$$

Plotting a graph of the Output

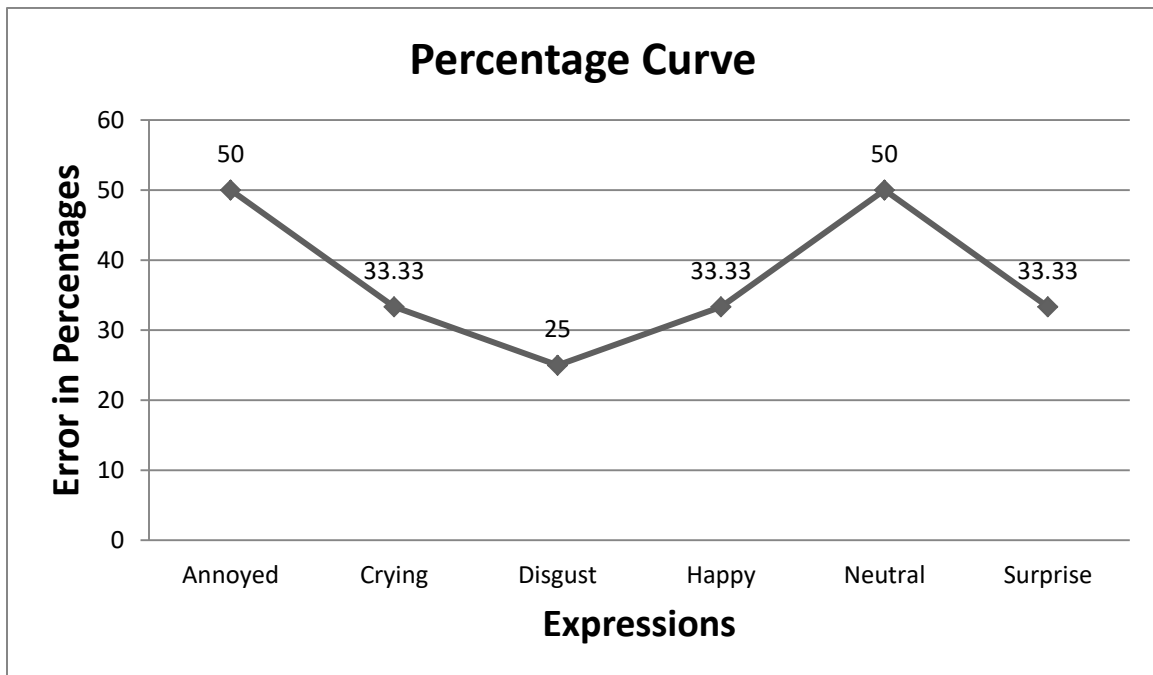


Figure 8: Output Graph

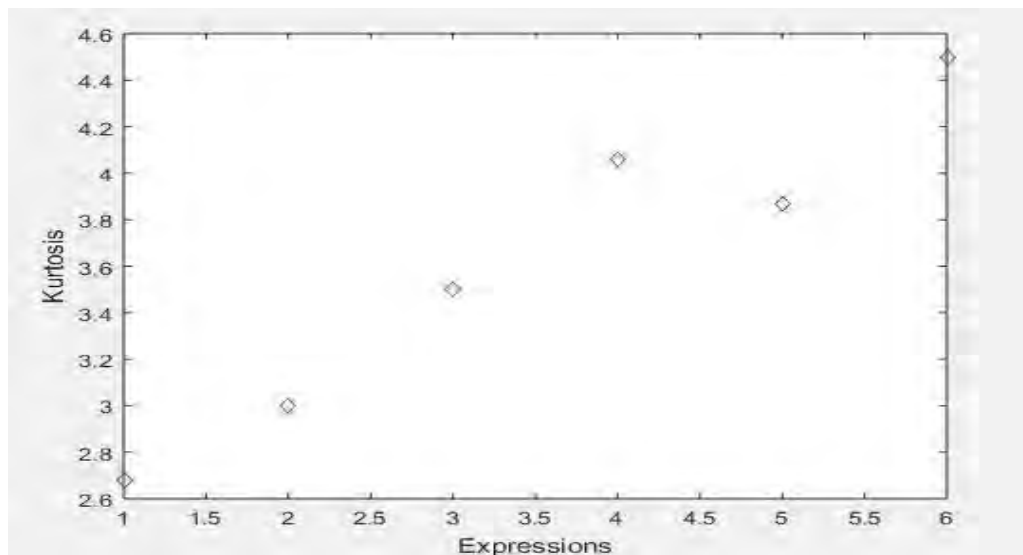
## 4.6 Comparison with other Statistical features

The algorithms we chose for our system are Mean and Standard deviation. However we had to do some research for selecting them. Initially, we focused on the comparison between the classification performances by using different well known time-domain feature extraction methods. This work is carried out by revealing that, Mean and Standard Deviation gives the most significant result. The results which we obtained from our reseach are plotted in Figure 15 which describes that Mean and Standard Deviation are better choice for feature extraction. We compared them with the terms of kurtosis, root, root mean square and skewness.

### 4.6.1 Kurtosis

Kurtosis is a measure of whether the data are peaked or flat relative to a normal distribution, that is, data sets with high kurtosis tend to have a distinct peak near the mean, decline rather rapidly, and have heavy tails [15]. Data sets with low kurtosis tend to have top near mean rather than a sharp peak. The following Figure 9 shows the Kurtosis value of our dataset for each expression. Mathematically kurtosis is given by

$$Kurtosis = \frac{1}{n} \sum_{i=1}^n \left( \frac{x_i - \bar{x}}{SD(n-1)} \right)^4 \quad (4)$$



**Figure 9:** Plot for Kurtosis

## 4.6.2 Skewness

Skewness is a measure of symmetry, or more precisely, the lack of symmetry. A distribution, or data set, is symmetric if it looks the same the left and right of the center point [16]. The following Figure 10 shows the skewness value of our dataset for each expression. Mathematically skewness is given by

$$\text{Skewness} = \frac{1}{n} \sum_{i=1}^n \left( \frac{x_i - \bar{x}}{SD(n-1)} \right)^3 \quad (5)$$

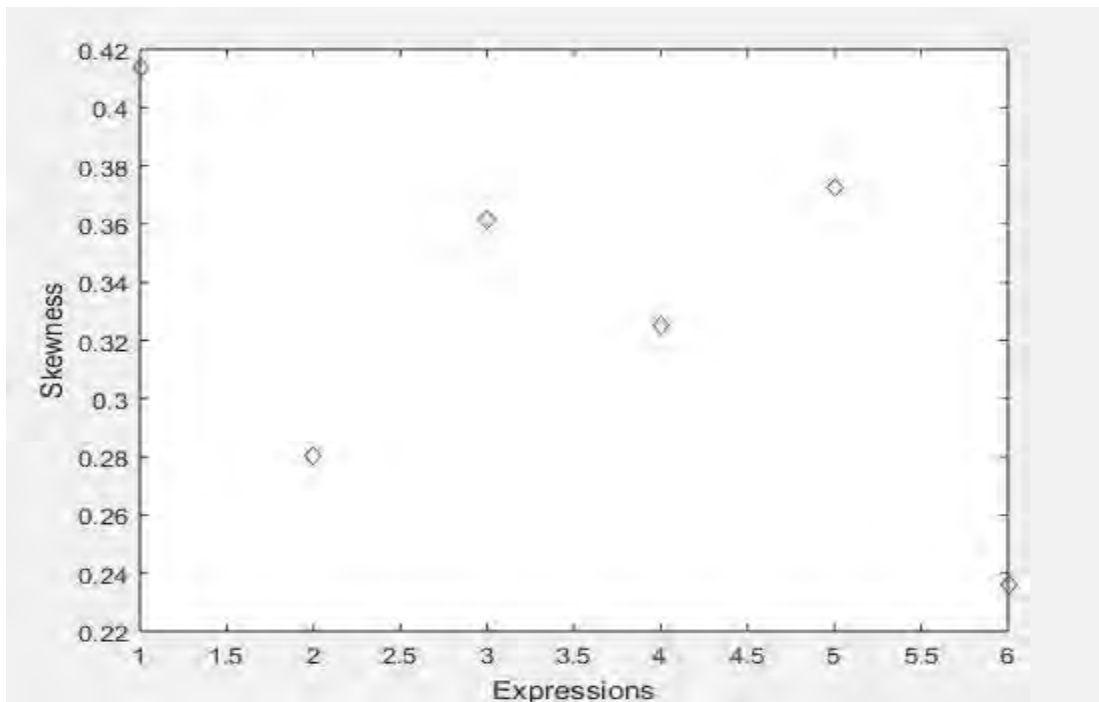
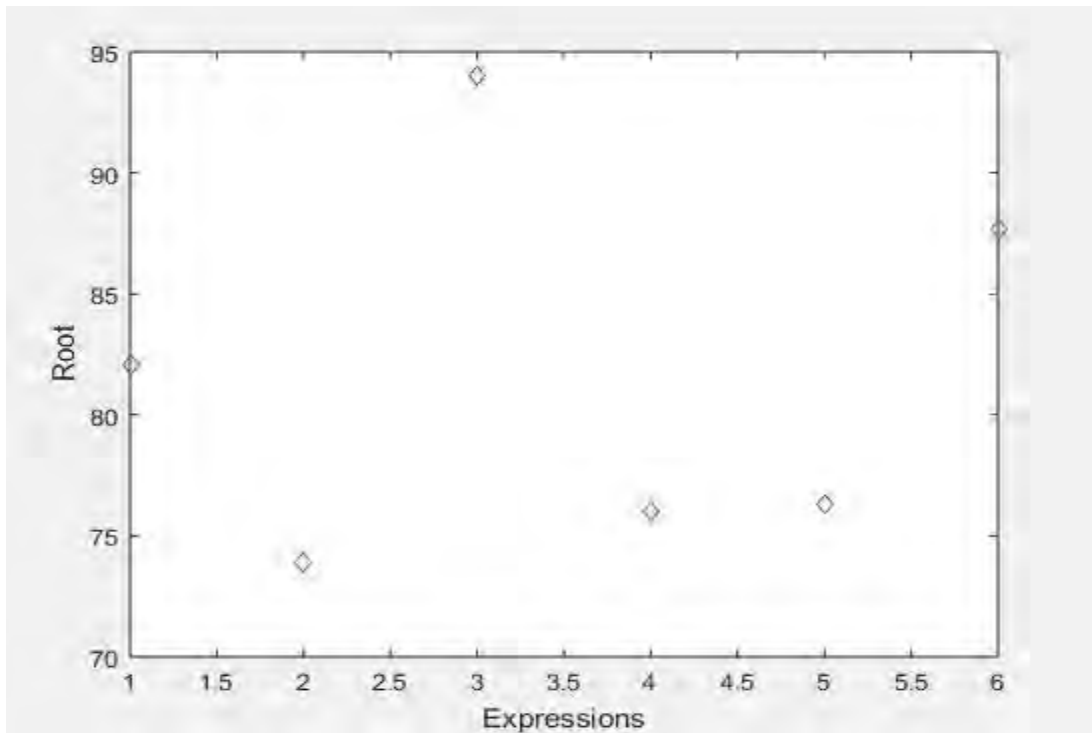


Figure 10: Plot of Skewness

### 4.6.3 Root

Mathematically skewness is given by the Equation (6) where  $x_i$  is a signal time series for  $i=1,2,\dots,n$ ,  $n$  is the number of data points  $\bar{x} = \frac{1}{n} \sum_{i=1}^n |x_i|$  is the Absolute mean value. The following Figure 11 shows the Root value of our dataset for each expression.

$$\mathbf{Root, T} = \left[ \frac{1}{n} \sum_{i=1}^n |x_i|^{\frac{1}{2}} \right]^2 \quad (6)$$



**Figure 11:** Plot for Root

## 4.6.4 RMS

The root mean square is a measure of the magnitude of a set of numbers. It gives a sense for the typical size of the numbers [17]. The following Figure 12 shows the RMS value of our dataset for each expression. The equation is below;

$$RMS = \left[ \frac{1}{n} \sum_{i=1}^n x_i^2 \right]^{\frac{1}{2}} \quad (7)$$

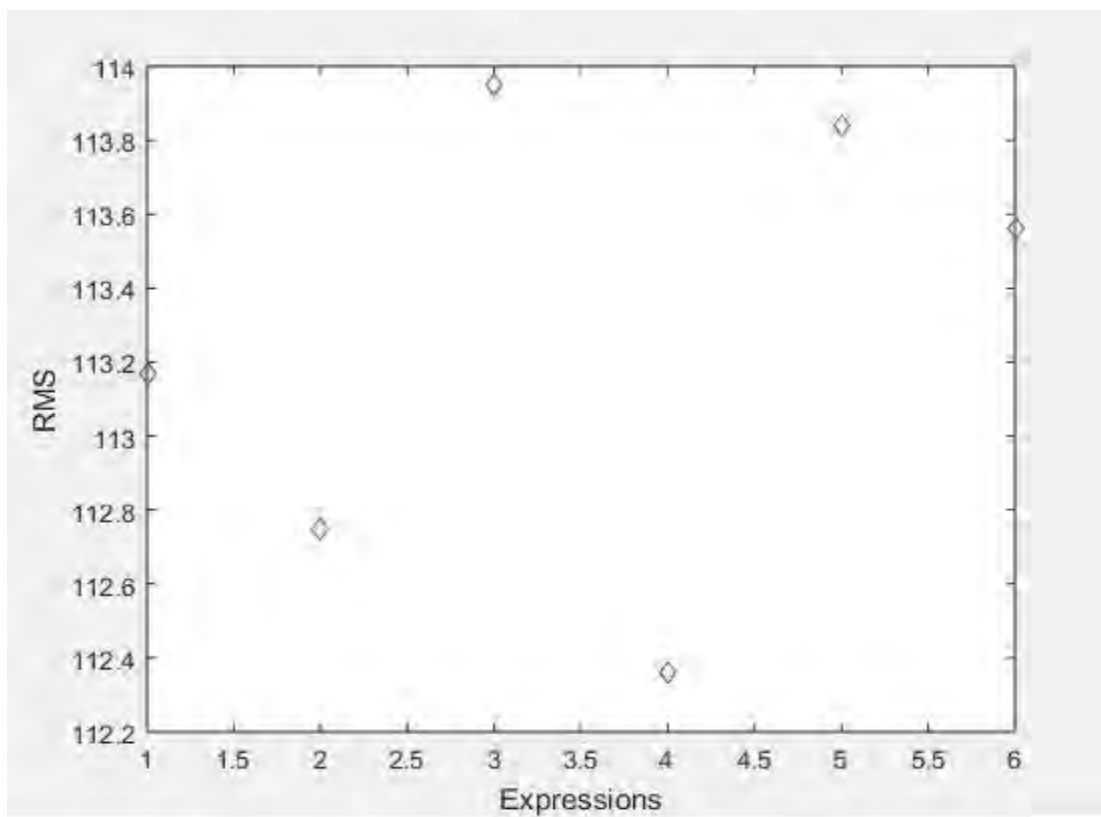


Figure 12: Plot for RMS

## 4.6.5 Mean

Mean is the sum of the values divided by the number of values. The mean of a set of numbers  $x_1, x_2, x_3, \dots, x_n$  is typically denoted by  $\bar{x}$  [18]. The following Figure 13 shows the Mean value of our dataset for each expression.

$$\bar{X} = \frac{\sum_{i=1}^n X_i}{n} \quad (2)$$

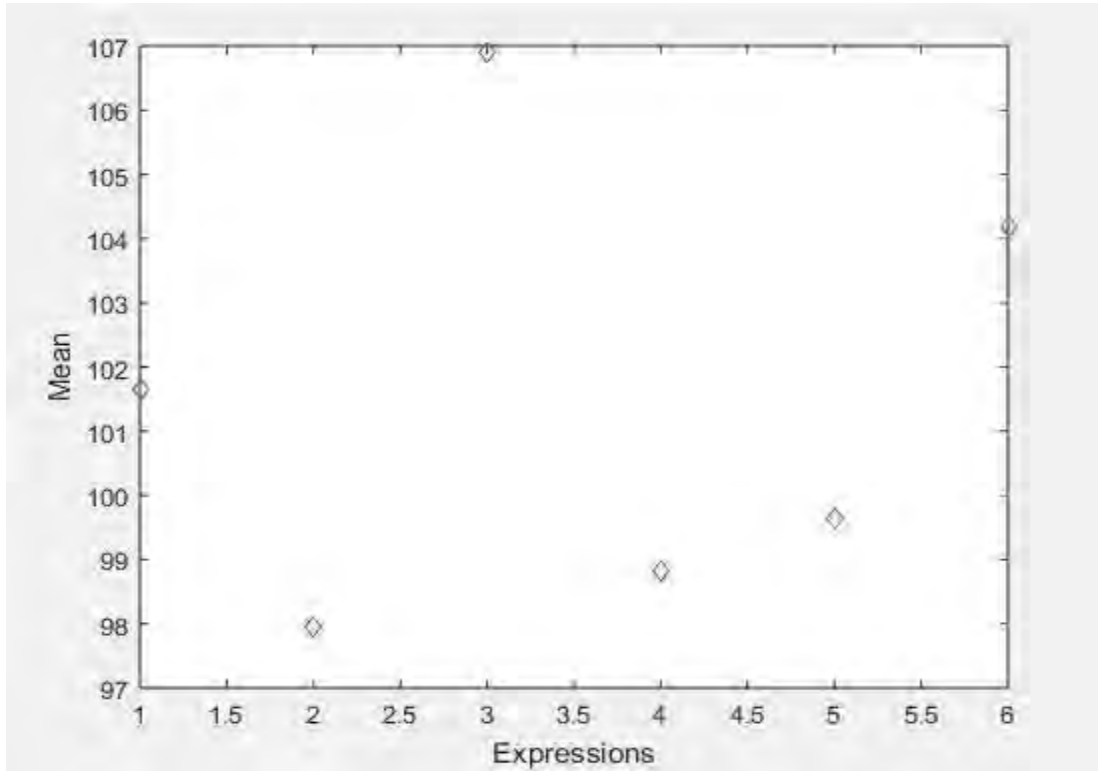
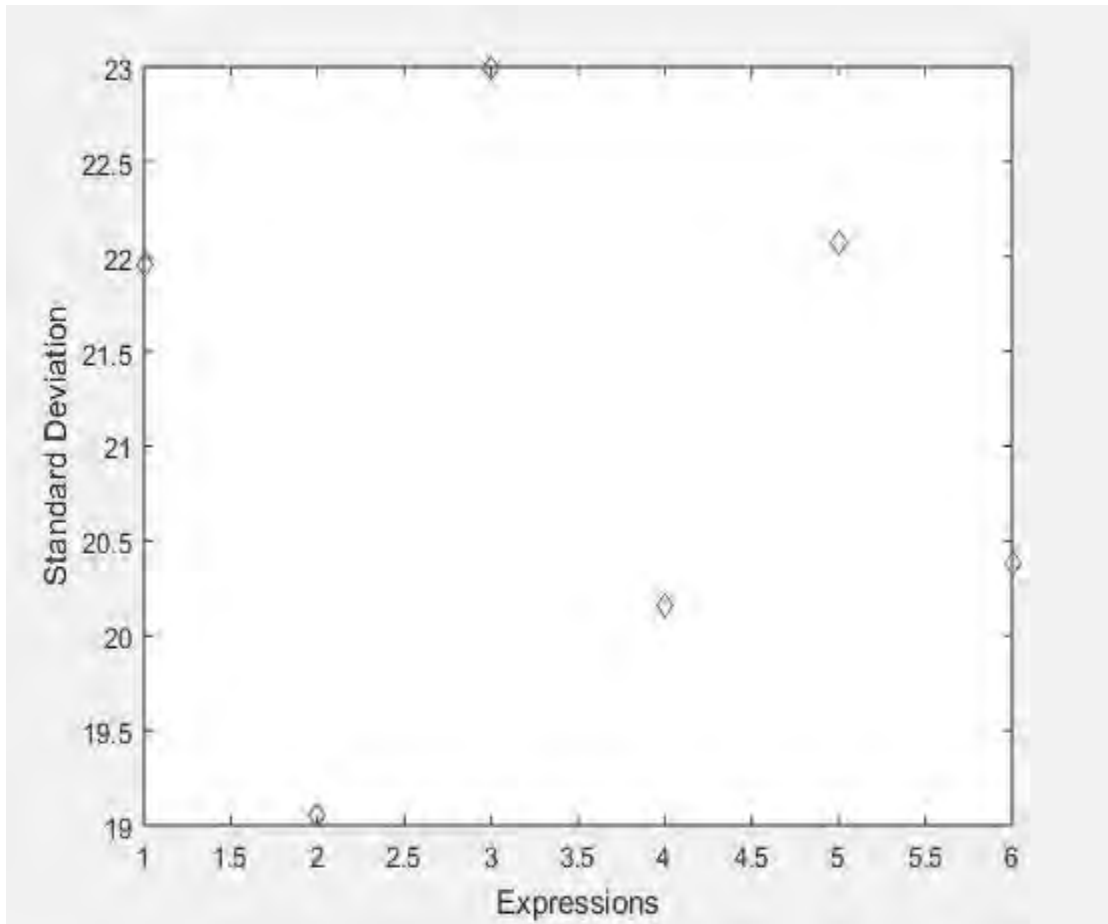


Figure 13: Plot for Mean

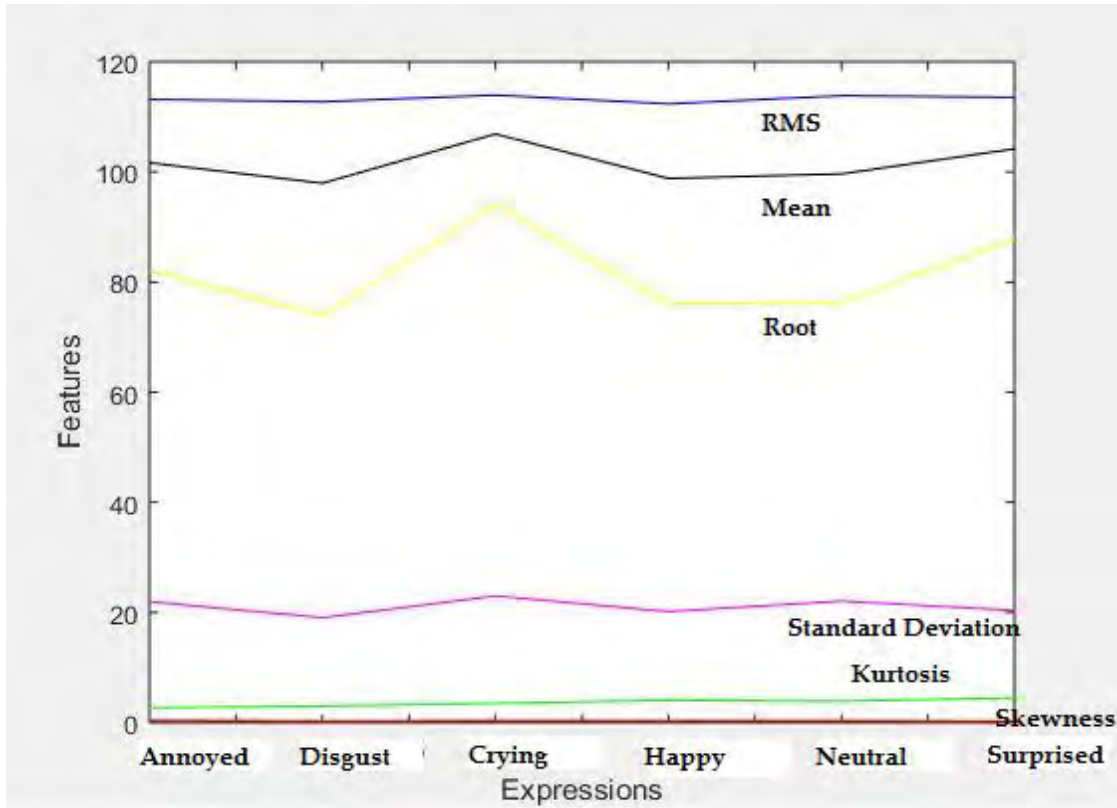
### 4.6.6 Standard Deviation

Standard deviation is a measure of how spread out the data set from the mean; it is denoted by  $\sigma$ . The following Figure 14 shows the standard deviation value of our dataset for each expression.

$$\sigma = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}} \quad (3)$$



**Figure 14:** Plot for Standard Deviation



Figure

**15:** Plot of Experimented Expressions Features with Mean, Standard Deviation, Roots, Kurtosis, Skewness

Figure 15 shows that, the plot lines have distinctive values in terms of Mean and Standard Deviation. Therefore every expression will be easily identified.

On the other hand, in terms of Roots, RMS, Skewness and Kurtosis, the values are almost same for every expression. As a result, the plot line is straight and differences between different expressions are hard to find. So the values of the features are concentrated in one point.

That is why we suggest that Mean and Standard Deviation are better choice for feature extraction.

## 4.7 Challenges observed and possible reasons

The data consists of 256x256 pixels grayscale images of faces. The faces have been automatically listed so that the face is more or less concentrated and occupies about the same



amount of space in each image [10]. The task is to categorize each face based on the emotion shown in the facial expression in to one of six categories (1=Annoyed, 2=Disgusted, 3=Crying, 4=Happy, 5=Neutral, 6=Surprised). We need to take 3 or 4 pictures of one specific person of each expression [8].

The main drawback of our system is every time we need to train our system unless it wont give us correct output as our system is still now user defined not automated. The input images need to have some significant properties which are 256 x 256 pixels, 1200 dpi, bit depth 8 and grayscale photo. Otherwise Program cannot be executed.

# CHAPTER 05

## Conclusion and Future Work

Facial expression recognition is now a challenging problem in the field of image analysis and computer vision. Because of its many applications in various fields it has received a great deal of attention over the last few years. This paper proposes a human facial expression recognition model based on mean and standard deviation approach in which the six emotions are recognized from JAFFE dataset. The training dataset consists of images of different expression of same person and when we tested it gives satisfactory results but our system is still now user defined not automated for which we have to use some filters and AI. It can be thought of as a future work and can be improved by more extensive training. In future, more features can be added to the system and we want to upgrade it to a fully functional automatic facial expression recognition system which can have a user friendly interface. As the arena of research in expression recognition is a part which can be further discovered and upgraded.

## References

- [1] Ryan A., Cohn J. F., Lucey S., Saragih J., Lucey P., la Torre F. D. and Rossi A., *Automated Facial Expression Recognition System*, 978-1-4244-4170-9/09/\$25.00 ©2009 IEEE
- [2] Happy, S. L., & Routray, A. (2014). *Automatic facial expression recognition using features of salient facial patches*.
- [3] "MATLAB." *Wikipedia*, Wikimedia Foundation, en.wikipedia.org/wiki/MATLAB.
- [4] "Paul Ekman." *Wikipedia*, Wikimedia Foundation, 2017, en.wikipedia.org/wiki/Paul\_Ekman.
- [5] Ekman, P. and Friesen, W. V. (1975). *Unmasking the Face: A Guide to Recognizing Emotions From Facial Clues*; Englewood Cliffs, NJ: Prentice-Hall.
- [6] Saudagare, P.V., Chaudhari, D.S.(2012). *Facial Expression Recognition using Neural Network –An Overview*, International Journal of SoftComputing and Engineering (IJSCE); ISSN: 2231-2307, Volume-2, Issue-1.
- [7] Kaur, M., Vashisht, V., & Neeru, N.(2012). *Recognition of Facial Expressions with Principal Component Analysis and Singular Value Decomposition*, International Journal of Computer Applications (0975 – 8887) Volume 9–36 No.12.
- [8] De, Anurag., Saha, Ashim., Pal, M.C.Dr.,(2015). *A Human Facial Expression Recognition Model Based on Eigen Face Approach*; volume 45, pp. 282-289
- [9] Chen, Xiaomin. & Cheng, Wushan. (2015). *Facial expression recognition based on edge detection*, International Journal of Computer Science & Engineering Survey (IJCSES) Vol.6, No.2.
- [10] E. Kreyszig *Advanced Engineering Mathematics*, J. Willey & Sons Inc. 2011.
- [11] Gonzalez, R. & Woods, R.E. (2002). *Digital Image Processing*; Upper Saddle River, NJ, Prentice Hall.
- [12] "Standard Deviation." From *Wolfram MathWorld*, [www.mathworld.wolfram.com/StandardDeviation.html](http://www.mathworld.wolfram.com/StandardDeviation.html).
- [13] M. Mastriani and A. Giraldez, *Enhanced Directional Smoothing Algorithm for Edge-Preserving Smoothing of Synthetic-Aperture Radar Images*, Journal of Measurement Science Review, 2004, vol 4, no.3, pp.1-11.

- [14] “Facial Expression Database: Japanese Female Facial Expression (JAFFE) Database.” *Facial Expression Database: Japanese Female Facial Expression (JAFFE) Database*, [www.kasrl.org/jaffe.html](http://www.kasrl.org/jaffe.html).
- [15] “Kurtosis.” From *Wolfram MathWorld*, [www.mathworld.wolfram.com/Kurtosis.html](http://www.mathworld.wolfram.com/Kurtosis.html).
- [16] “Skewness.” From *Wolfram MathWorld*, [www.mathworld.wolfram.com/Skewness.html](http://www.mathworld.wolfram.com/Skewness.html).
- [17] “Mean.” *Root-Mean-Square level - MATLAB rms*, [www.mathworks.com/help/signal/ref/rms.html?s\\_tid=srchtitle&requestedDomain=www.mathworks.com](http://www.mathworks.com/help/signal/ref/rms.html?s_tid=srchtitle&requestedDomain=www.mathworks.com).
- [18] “Mean value.” *Wikipedia*, Wikimedia Foundation, 2017, [en.wikipedia.org/wiki/Mean\\_value](http://en.wikipedia.org/wiki/Mean_value).
- [19] Lyons, M., Akamatsu, S., Kamachi, M. & Gyoba, J. (2002). *Coding facial expressions with Gabor wavelets, Automatic Face and Gesture Recognition, 1998. Proceedings*. Third IEEE International Conference.
- [20] Dailey, M.N., Joyce, C., Lyons, M.J., Kamachi, M., Ishi, H., Gyoba, J. & Cottrell, G.W. (2010). *Evidence and a computational explanation of cultural differences in facial expression recognition*.