IJRAR.ORG E-ISSN: 2348-1269, P-ISSN: 2349-5138

INTERNATIONAL JOURNAL OF RESEARCH AND ANALYTICAL REVIEWS (IJRAR) | IJRAR.ORG

An International Open Access, Peer-reviewed, Refereed Journal

# FACIAL EXPRESSION (EMOTION) DETECTION USING MATLAB

**[1]Gulrukh Shahab, [2]Neha MAtathur, [3]Akanksha Kulshreshtha**

[1]M.Tech (ECE)- Fourth Semester, [2]Astt Professor, [3]Astt Professor

[1]Electronics and Communications

[1]DPGITM, Gurgaon, India

*Abstract :* Today's world is moving towards AI (Artificial Intelligence) and ML (Machine Learning) and it has many applications, and face emotion recognition is one of its applications. In current times, quick face emotion detection is in demand. There are many applications where quick emotion recognition is needed, like Medical emergencies. And when quickness, as well as accuracy, is concerned, there is no option as efficient as Artificial Intelligence. So, I try to use MATLAB for implementing Face emotion recognition. Face recognition and feature extraction algorithms and classifier algorithms have been used to detect the emotion in the given image. Various parameters like body language, facial expressions, biological similarities, voice, etc, are utilized for the process of Emotion recognition. As this world is moving to modernization, it is very difficult to recognize every individual's emotions manually. Here I am presenting "Facial emotion detection using MATLAB", the most expected work in the field of facial expression detection through the use of deep convolutional neural networks with concepts that will force us to think more in this field.

*IndexTerms* - **Matlab, Facial Emotion detection, Facial Expression detection, Feature extraction, Deep Learning, Machine Learning, Image processing using Matlab, Supervised methods, Pre trained networks used in Matlab, free pik datasets for facial images.**

## I. INTRODUCTION

### 1. PROCESSING OF EMOTIONS

Emotion is a high-intensity process of the mind which involves a combination of muscles. The type of a particular emotion decides a specific combination of different muscles. These different combinations of muscles undergo a varied number of contractions and also varied patterns of contractions.

These varied numbers and/ or varied patterns of contractions depend on the type of emotions viz, sadness, horror, anger, surprise, happiness, etc. Human beings as well as several other living beings are built naturally to recognize and distinguish these and various other emotions not mentioned here.

In certain critical situations, there is a requirement that the different emotions can be recognized quickly and effectively many times faster than humans. Here comes the solution in the form of Artificial Intelligent. Some techniques like Support Vector Machine (SVM), and Convolution Neural Networks (CNN) are used to categorize emotions viz verbal, non-verbal, speech and various facial expressions, etc.

Emotion Recognition refers to the procedure of recognizing emotions from speech, facial expressions, etc. Although human beings can interpret most of the types of emotions, well in some conditions, humans can't act instantaneously after observing various emotions like in medical conditions. Like various other fields, emotion recognition is also a current field where various research and studies are going on for utilizing Artificial Intelligence.

### 2. OCCURRENCE OF EMOTIONS

As can be inferred from the above paragraph that it needs various changes to express different emotions. A very typical way of contraction of seven muscle groups is utilized for expressing anger. Greater zygomatic muscle will be utilized if happiness is to be expressed. You will require Levator Labii Superiosis if you have to show that you are sad. Expression of grief requires Anguli Oris. If you have to frown at someone Corrugator Supercilli and Procerus will be involved for it.The platysma is used for showing

the emotion of horror. Mentallis expresses doubt. Without using Risorius, you can't grin. The emotion of contempt by Zygomaticus minor.

Artificial intelligent machines use audio-visual techniques for the analysis and storage of varied numbers, types, and patterns of contractions of different muscles groups.

In the present times, multiple types of research in computer vision are going on. Emotion recognition using Artificial Intelligence is one of the most active areas here. Detection, assessment, and interpretation of visually fed inputs are done automatically.

The architecture of Artificial Neural Network, ANN, has got its inspiration from the brain of animals and/or human beings. A network where convolution, which is a mathematical operation is used, is referred to as a Convolution Network. Hence a neural network that has got a number of convolution layers is called a Convolutional Neural Network, CNN. The significance of these convolution layers is that they are utilized for functions such as processing the image, segmenting, and classifying purposes. These convolution layers are also utilized for various other types of data which are automatically related. If there is a requirement of recognizing data having some images, than a two-dimensional CNN network is used.

DCNN, i.e. Deep Convolution Neural Network is also a famous neural network where video and images with different patterns can be recognized. DCNN is a highly trained network to classify different facial expressions with high accuracy. This training is performed through the set of data collected with the help of the camera of a cell phone.

Several CNNs for facial expression recognition purposes were developed.Their performance by utilizing various visualization and post-processing techniques was evaluated. Hence, it can be concluded that deep CNNs can efficiently learn facial features, and using these can improve the detection of facial emotions. Model accuracy couldn't be improved with Hybrid feature sets. So we can infer from this that utilizing raw pixel data can lead convolutional networks to learn facial features.

## II. CONTRIBUTION TOWARD SOCIETY

If we employ a deep convolution neural network for the detection of facial expressions, we can hope for wonderful outcomes exceeding our expectations. This paper deals with everything related to this technique. This article is filled with a summary of firm points related to emotion recognition. Now we have to adopt a mindset for going with this project. Different emotions are the feeling of living beings for their different states of mind and body. Expressing these different emotions is done through various sources like body language, voice, etc. And our face is the most important source of expressing different emotions. Our emotions can easily be found through our faces. So we have developed a project to find the facial expression of a given image using CNN and the feed forward algorithm. Face expression recognition system has many applications in healthcare, security, and many other sectors. In healthcare, it can be used by doctors to study the emotions of patients while treatment. It can be also used in monitoring systems to monitor personal activities. Based on his expression we can find out a criminal too. In this paper, we present the results using MATLAB. In MATLAB we use Haar features for face detection, the Gabor filter for feature extraction, and a classifier to find the facial expression which has been found.

## III. OBJECTIVE OF FACE EMOTION DETECTION

The objectives behind emotion detection are to aid medical facilities, and to improve social relationships among people and various others. Emotions can be replicated in various forms such as voice (tones), video, image, body gestures & even facial expressions.

When computerizing emotion detection, it needs huge interactions between intellectual machines & human beings.

## IV. LITERATURE REVIEW

### IV(a). EMOTIONS AND FEATURE CONDITIONS

For a better understanding, the following is a list of various emotions of an individual with their feature conditions

**Joy**

- Zygomatic
- Orbicularis
- Nose Labial Fold Formed
- Raised Upper Lips

**Sad**

- Raised Eyebrow's Inner Corners
- Depressed Mouth Corners

**Surprise**

- Lips Swollen
- Raised Eyebrows
- Opened Mouth
- Widen Eyes

**Happy**

- Under Eye Skin Wrinkles
- Wider Mouth Corners (Big Smile)

**Contempt**

- Wrinkled Nose
- Lip Projections
- Raised Upper Lips
- Gazing Away

**Disgust**

- Raised Upper Lips
- Downed Lower Lips
- Opened Mouth

**Anger**

- Raised Nostrils
- Wider Eyes
- Reduced Mouth Corners

**Fear**

- Raised Eyebrows
- Lips Compression
- Opened Mouth
- Widen Eyes

The above listed are the various emotions and the facial feature conditions according to the emotion expressed by an individual. As you know very well, corporate and IT companies are investing a vast amount in review management.

However, the companies are not getting the appropriate state of mind (users). So emotion recognition techniques are introduced and help them a lot to detect the person's behavior under various circumstances with their emotions.

AI analyses the written language. It assigns a weighted "sentiment" score to text phrases written by a customer. Sentiment analysis uses a classification algorithm to identify the key excerpts from the text. It then grades them as positive, neutral, or negative.

IV. (b) **Different Features for Extraction**

❖ ***Shape-based Features***

- *Index Shapes*
- *Irregularity*
- *Circularity*
- *Perimeter*
- *Area*

❖ **Texture oriented Features**

- Local Binary Pattern
- Homogeneity
- Entropy & Energy
- Dissimilarity
- Cluster Shades
- Cluster Prominence
- Contrast & Correlation
- Auto Correlations

❖ **Intensity oriented Features**

- Pixel Angles
- Kurtosis
- Skewness
- Variance
- Average / Mean

The above listed are the various features used for the feature extraction processes according to several methods. For example, these features are extracted by deep learning-based convolutional neural networks.

As they extract features ranging from simple to high-level complex features automatically, it is widely preferred by many of the top engineers in the world. Come let us look into the feature extraction & selection methods for the ease of our understanding

**IV (c) ARTIFICIAL INTELLIGENC AND EMOTION DETECTION**

Artificial intelligence is widely used in emotion recognition or detection techniques and it is also known as 'affective computing. Humans use both nonverbal & verbal cues in communication to express their emotions.

An intellectual machine with emotional intelligence is highly capable of reasoning (cognitive) the inputs given to it. Along with this, they are interpreting that image recognizing the emotions of a person by their facial expressions and, giving effective responses.

Intelligent machines are being inputted with a larger amount of inputs for detecting human emotions. Deep learning & machine learning are the sub-branches of artificial intelligence technology. In these (ML & DL) technologies, inputs are given as speech (voice) & images for interpreting with the same.

They effectively recognize the tone changes and expression changes. For example, if a person is screaming loud it may be considered as he is neither angry nor happy and even assumes the current state of the mind.

On the other hand, researchers are aimed to develop wearable technologies which have much intimacy with the users to detect the heartbeat rates & some other parameters to detect the emotion of a person. There are many biological signals being used for emotion recognition in the form of solutions. Come, let us learn them. let us discuss how the inputs get processed under **2 of these techniques** for our better understanding.

### IV.(C).1 SUBSETS OF AI

We know that **deep learning** & **machine learning** are the subsets of AI. In this manner, Sentiment analysis also avoids any of the biases associated with human analysis and review. The major idea behind this technique is to detect and measure the reviews from customers in an e-commerce platform broadly.

Now we can also learn how artificial intelligence detects emotions with brief explanations.

(a). **Deep Learning**

- Step 1: Input (image or text)
- Step 2: Simplest feature extraction
- Step 3: Multi-layers of abstract features
- Step 4: Mapping
- Step 5: Output

**(b). Machine learning**

- Step 1: Inputs (image or text)
- Step 2: Manually crafted features
- Step 3: Automated feature extraction
- Step 4: Mapping
- Step 5: Output

### 3.1 METHODOLOGIES

Here we propose the technique for facial expression recognition using a classifier in MATLAB

**What are the Steps in Emotion Recognition?**

- **Image Processing**

Facial features and regions are extracted in the image processing stage with the help of histograms, virtual or digital face model & fuzzy algorithms.

- **Feature Extraction**

Here, various facial features such as temporal and spatial features are extracted for the emotion detection process.

- **Emotion Detection**

Classifier techniques are proposed to detect or recognize human facial expression-based emotions in the extracted features.

Itemized above are the 3 major indispensable steps involved in the process of emotion recognition or detection. Our researchers in the concern are accustomed to the emotion detection processes. This is becoming possible by conducting habitual research in the same areas.

### 3.2 STEPS FOR EMOTION RECOGNITION

**3.2 (a). Selection and processing of the images**

- Step 1: Image Selection
- Step 2: Face Detection using transfer learning.
  - Face / Image Edges
- Step 3: Feature Extraction
  - Grayscale Face Transformation
  - Face Resizing (224 X 224)

**3.2 (b) Using data set and pre-trained Network**

- Face Prediction
- Step 4: Emotion Classification
  - Datasets
  - Trained GoogleNet
- Step 5: Emotion Prediction

The foregoing passage has conveyed the major 5 steps involved in emotion recognition when it comes to deep convolutional neural networks. Many developers and researchers are dynamically performing in various areas of technology.

So the skillsets of the researchers are enlarged day by day.

**3.2 (c) Feature extraction and selection methods for emotion recognition**

I want to highlight the two different methods (feature extraction & selection) in emotion recognition for the ease of our understanding.

**3.2 (c) 1. Feature extraction methods**

- **Feature Learning Methods**
  - Deep Learning Methods
  - Bag of Features
  - Textons
- **Spatial Domain Methods**
  - Salient Color
  - Local Color
  - Color Histogram
  - Color Moments
  - Statistical Textures
  - Local Binary Patterns
  - Edge & Shape Features
  - Geometric Texture & Color Features
- **Frequency Domains**
  - Gabor Filter & Texture Analysis
  - LBP-based Wavelet Domains
  - Statistical Texture Features
  - Fourier Filter based Color Features
  - DWT-based Color Features
  - Geometric Color & Texture Features
  - Statistical Texture based Wavelet Domains
  - GLCM-based Color Texture
  - Gabor-based Color Texture

**3.2 (c) 2. Feature Selection Methods**

- Wrappers
- Gabor Filters

7

- Feature Subset Search Algorithms
- Search Organization
- Feature Generation
- Feature Evaluation

## 4. DEEP LEARNING METHODS FOR FACE EMOTION RECOGNITION

### 4.1 Supervised methods

- Recurrent Neural Network
- Deep Neural Network
- Convolutional Neural Network

### 4.2 Unsupervised methods

- Generative Adversarial Network
- Deep Belief Network
- Auto Encoder

The aforementioned are the irreplaceable methods used for emotion recognition and **hybrid** methods are the combination of both methods. As this article is focused on giving emotion recognition using deep convolutional neural networks, we wanted to list out the different types of DCNN for your better understanding

## 5. DIFFERENT TYPES OF DCNN FOR EMOTION RECOGNITION

### 5.1 Width-based Multi-connection CNN

- Xception
- ResNet
- Inception Family
- Pyramidal Net
- WideResNet

### 5.2 Attention-based CNN

- Concurrent Squeeze & Excitation
- Residual Attention Neural Network
- Convolutional Block Attention

### 5.3 Channel Exploitation- based CNN

- Channel Boosted CNN (TL)

### 5.4 Feature-map Exploitation-based CNN

- Competitive Squeeze & Excitation
- Squeeze & Excitation

### 5.5 Multi-path-based CNN

- DenseNet
- Highway Nets
- ResNet

### 5.6 Depth-based CNN

- Inception-ResNet
- Inception V3 & V4

### 5.7 Spatial Exploitation based CNN

- ZfNet
- GoogleNet
- VGG
- AlexNet
- LeNet

These are the various types of deep convolutional neural networks for emotion recognition. On the other hand, it is very important to evaluate the performance of the system by several metrics, and such metrics are comprised in the following passage. Here, the next section is presented to grab the performance metrics of emotion recognition.

## 6. PERFORMANCE METRICS FOR EMOTION RECOGNITION

- Emotional Response
- Recognition Accuracy

Listed above are the two major metrics, mainly used for evaluating the performance of emotion recognition. There are so many datasets, being used to recognize the emotions of human beings. Among those datasets, here we are going to illuminate some of the essential datasets for ease of our understanding

## 7. DATASETS

### 7.1 BU-3DFE

- Description: Extracts 3D Images & Consists of 6 Expressions
- Number of Sequences: 2500
- Inputs: Texts & Images
- Used for Facial Expression Recognition & Classification

### 7.2 Cohn-kanade AU-Coded expression database

- Description: Consists of Expression based Labeled Images
- Tasks: Facial Feature Tracking
- Number of Sequences:
- Inputs: Texts & Images
- Used for: Facial Expression Analysis

### 7.3 JAFFE Facial expression database

- Description: Consists of Japanese Models' 213 Images with 7 Expressions
- Tasks: Image Cropping & Semantic Rating
- No.of Sequences: 213
- Inputs: Texts & Images
- Used for: Facial Expression Cognition

These are the essential datasets being used in facial emotion recognition. So far, we have come up with all the needed areas of emotion recognition using deep convolutional neural networks.

## 8. APPLICATIONS

- Behavioral conditions such as unsociability, friendliness, nervousness
- Emotional statements about sicknesses for depression diagnosis
- Micro-expressions based on concealed (hidden) emotions analysis
- Cognitive (reasoning) to detect either attention or inattention
- State of emotional conditions such as anger, fear, happiness, etc.

The above listed are the various real-time applications of emotion recognition utilized. Apart from this, there are so many areas yet to cover and they are as you know very well. Besides, artificial intelligence is playing a huge role in detecting emotion and that is known as emotion artificial intelligence.

Some other applications are mentioned below:

### 8.1 Crime Identification

- Spots out thieves
- Detects politically aware arrogances
- Detects driver's low energy
- Fraud prevention systems
- Identifies and decreases forged insurance claims

### 8.2 Public Safety

- Inspects crime scene footage for crime motives
- Smart boundary controls and untruth detectors
- Screening of public places to detect terrorism threats

### 8.3 Education

- Identifies student's engagement in virtual learning
- Models emotional teaching system
- Responses-based learners' learning track
- Observes students' responsiveness

### 8.4 Employment

- Observes attention and mood swings of employees
- Assists in decision making
- Spots unresponsive applicants in interviews

### 8.5 Medicare

- Prevents suicides
- Patient condition monitoring
- Aged people's depression level identification
- Mental disorders prediction and assistance
- Identifies neurodegenerative and autism syndromes

### 8.6 Personalized Service Provision

- Individual reaction prediction in movies, shops, and ads.
- Facial expression tracking for marketing motives
- Analyzing customer's emotions in shopping
- Personal recommendations in e-commerce
- Analyzing the state of mind to display personalized messages

## 9. BLOCK DIAGRAM OF SYSTEM ARCHITECTURE

### 9.1 Using a classifier:

Here we are using the JAFFE dataset to recognize the expression of the input face image The block diagram below represents the "Facial Expression Recognition" architecture.

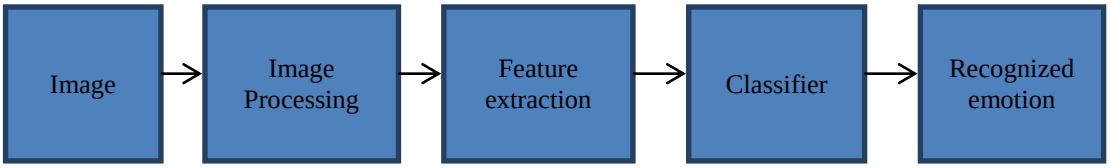



Fig 1: Face expression recognition system architecture

#### A. Image pre-processing:

The project begins with acquiring the image from a camera. This acquired image must be pre-processed and many image processing techniques have been implemented on it like scaling of the image, decreasing brightness, etc and all. Since we are using the JAFFE dataset all the pre-processing work has already been done, so there is no need for this step. We can take images directly from a dataset.

#### B. Feature Extraction:

After taking the image, it has been passed on to the feature extraction stage. We know that every expression has different types of features like: when we are happy our lips and eyes are wide, when we are surprised our mouth is wide open etc. These kinds of features have been extracted here using a Gabor filter whose purpose is for feature extraction.

#### C. Classifier:

Here we use the feedforward neural network classifier which has 30 input, 50 hidden layers, and seven outputs in which each output indicate one of the given expressions. We classify the input images into happy, angry, disgusted, neutral, sad, surprised, or fearful. The output gives the expression of the input image.

### 9.2 Using a CNN:

Face expression recognition projects can also be implemented using the CNN algorithm. The name "convolutional neural network" indicates that the network uses the convolution technique. Convolution is a linear operation. Convolutional networks are simply the

Neural networks that use the convolution in place of general matrix multiplication in at least any one of the layers. In a network, when all the neurons of a layer are connected to all the other neurons of the next layer then this becomes a multilayer perceptron. This multilayer perceptron is also known as a fully connected network. The fact to keep in mind is that CNNs are an updated version of multilayer perceptron. As compared to many other image classification algorithms, a small quantity of preprocessing is used by CNNs.

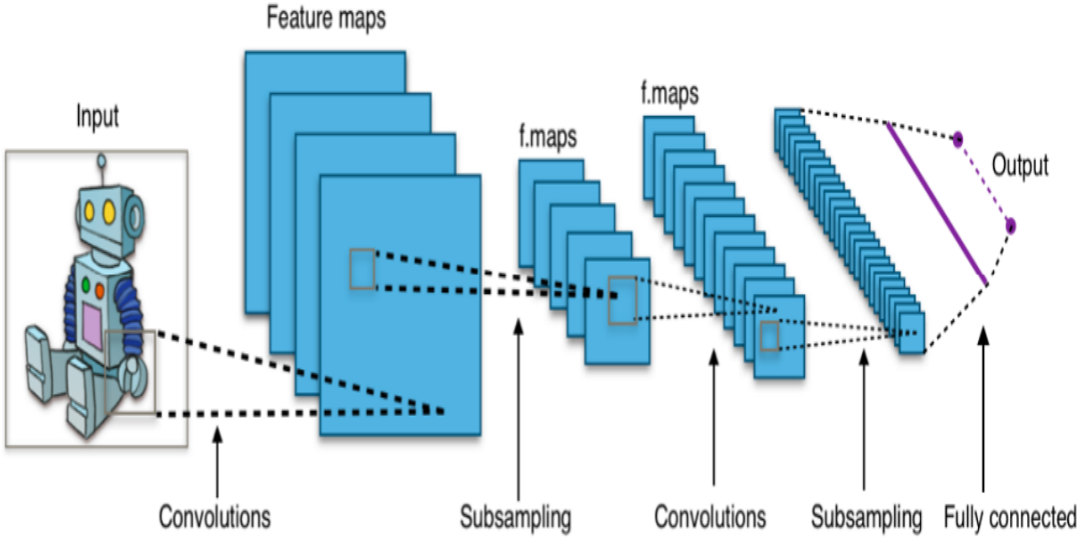



Fig 2. Typical CNN architecture

The following block diagram represents the face expression recognition architecture using CNN.

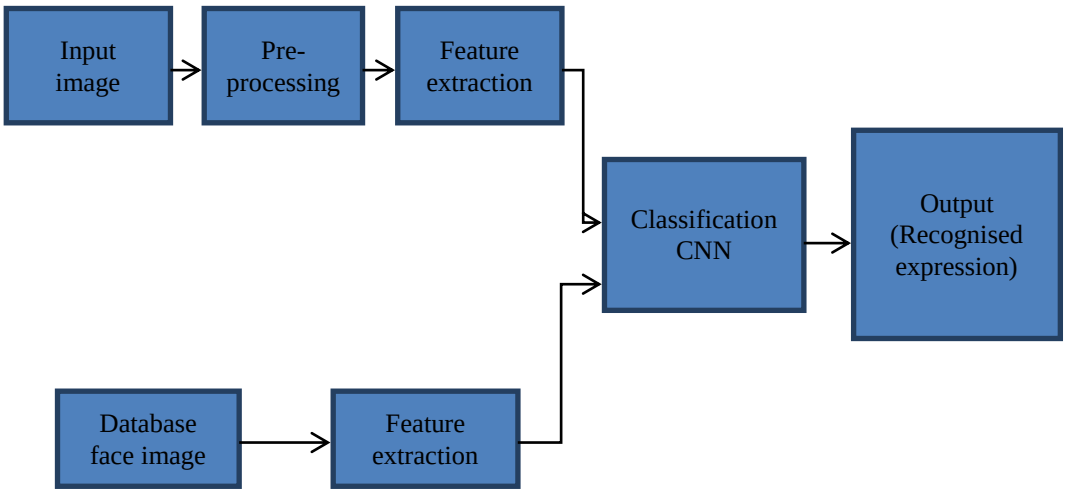



Fig 3. Face expression recognition using CNN

**9.3 Tool boxes used in Matlab**

- Toolbox used for 'Machine Learning.
- Toolbox used for 'Image Processing
- Toolbox used for 'Image Acquisition
- Toolbox used for 'Deep Learning

Above mentioned toolboxes are the most important toolboxes used by MATLAB for the detection of facial expressions

**9.4 STEPS**

- Step 1: Selection of an image.
  - Reading the input given in the form of an image
- Step 2: Selection of images and then add these to the database.
  - Training the images stored in the database.
- Step 3: Facial emotion detection.
  - The selected image is processed to recognize the expression.
- Step 4: Information of the database.
  - Illuminates the complete details of the database.
- Step 5: Removal of the database.
  - Terminates the prevailing database from the directory.
- Step 6: Program information.
  - Showcases the software information
- Step 7: Source code of the process.
  - Emphasizes the source code being used.
- Step 8: Exit
  - Exiting from the program (quit)
  - This is how the MATLAB functions process when an image is given to it.

## 10. SIMULATION WITH MATLAB

The neural network is a three-layer network with eight neurons in the first layer, seven neurons in the hidden layer, and six neurons in the output layer. The inputs of this network are the set of features listed in Table I which will be ready for the neural network after extraction and normalization. 60 test samples are used to examine the proposed algorithm. Samples are arranged at the network's input in order of 10. In various simulations, the average accuracy rate of the algorithm presented in the MATLAB environment is 91.76% which is shown in the Table shown below.

Table 1.The average accuracy rate for facial expression recognition in matlab

| | |
|---|---|
| Anger | 100% |
| Sadness | 100% |
| Happiness | 100% |
| Surprise | 100% |
| Disgust | 70% |
| Fear | 90% |
| **Average** | **91.76%** |

## 11. RESULTS AND DISCUSSIONS.

1. Results obtained using MATLAB software:


**Recognized facial expression: sad** **Recognized facial expression: Happiness**

**Fig. 4: Expression of the face has been recognized**

The above Fig 4. Shows the output obtained using MATLAB. Here the JAFFE dataset is divided into training and test dataset. The model has been trained using a training dataset and has been checked using a validation dataset to see whether the required results are obtained or not. Here few images are taken from the dataset itself and have been given as input images to check the expression of the image. The model works perfectly by giving the right expression name of the input image.

## 12. IMPLEMENTATION

Now I implemented the facial expression detection using MATLAB software again with two facial expression detection using the MATLAB code. Steps used are as follows.

(12.1). Downloading the images from the dataset.

(12.2). Resizing of the image from 48X48 pixel to 227 X 227 pixel.

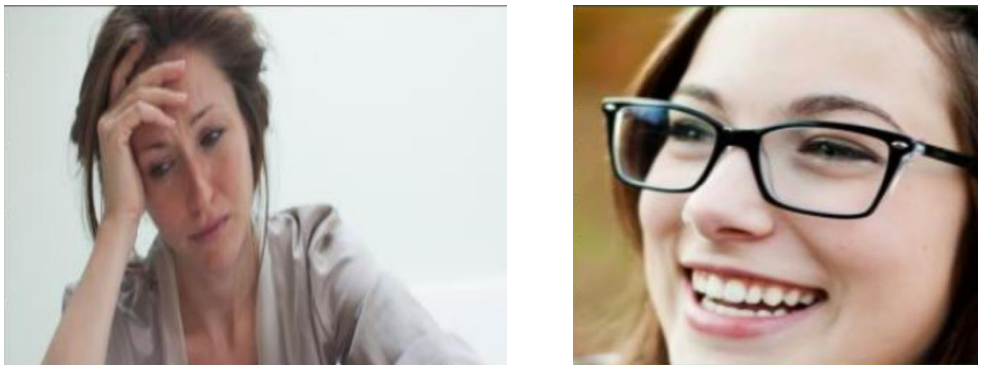
(12.3). Converting the images into RGB format.

(12.4). Pre-Processing: First I loaded the image into MATLAB software workspace and then I processed it for following purposes.

- Edge defining
- Background refining

NOTE: I have downloaded the images from image bank website, named- free pik

**12.4.1** Original images before being processed in MATLAB Image Processing.



**12.4.2** Images obtained after Image Processing using MATLAB

**(**12.5). **Using Pre-trained Network:** After passing the pre-processing of the images, I took the guidance from MATLAB documents provided within the software package itself.

(12.6). **Running the code after necessary modifications in the live script of MATLAB live editor**.

Now, when these images were given as input for the facial expression detection,
following results are achieved showing output efficiency by a bar graph generated thorough MATLAB.

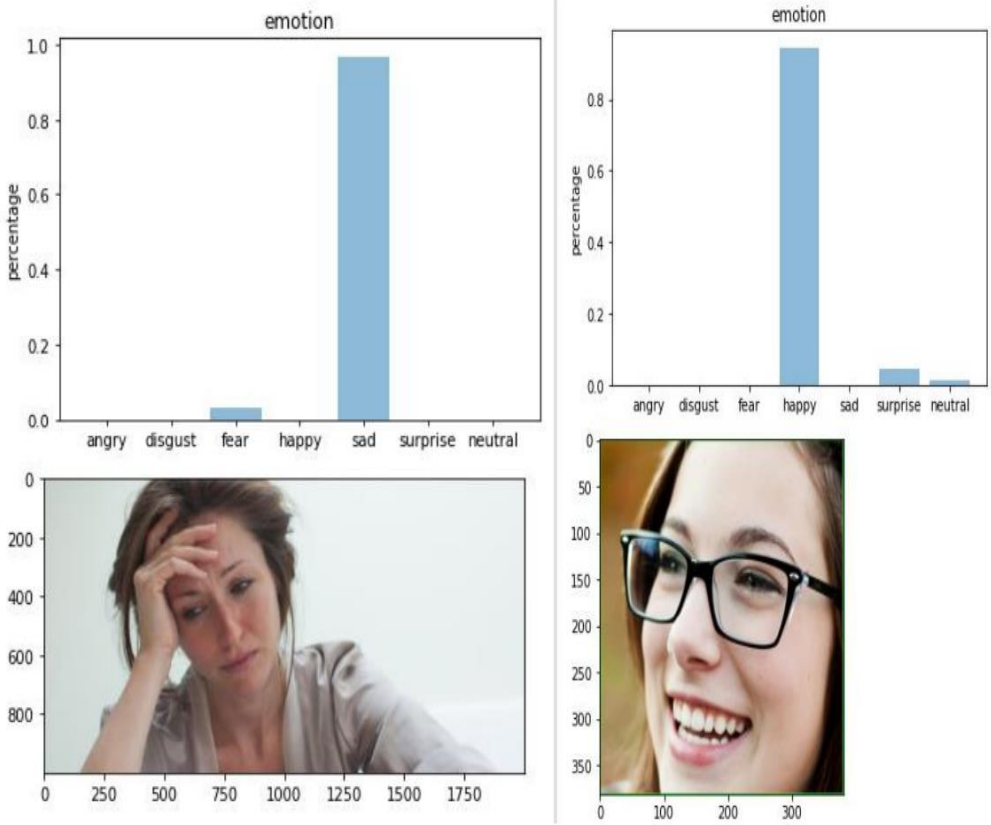



Fig 5. Results showing the expression of the given image obtained using CNN algorithm

## 13. CONCLUSION FOR FUTURE WORK

Here we have implemented a facial expression recognition system using the software MATLAB. In MATLAB we used a feed-forward classifier to obtain the expressions of the image. There are specific and defined features of the image that need to be extracted to detect facial expressions. As an example, 21 points can be identified in the human face altering as a result of one's emotional state. By following these feature points, the face will be detectable. In this scheme, MLP neural network is employed to classify facial expressions. In this paper, the Japanese female facial expression (JAFFE) database and another from a popular website, free-pik have been chosen for training and testing the network. An appropriate algorithm with minimal error using MATLAB is designed. 60 test samples have been used to test the performance of the proposed algorithm. These samples have been placed at the network input, in sets of 10. In various simulations, the average performance of the proposed algorithm in the MATLAB environment was 91.76%. The working flow of my project is similar to this. As it is specified that the proposed work is an ongoing project, hence there are many scopes for the project to explore, by improving the template matching procedure by using different image processing techniques and trying out the project for different images other than the database used here. Also, to implement it with different novel techniques like neural networks, artificial intelligence, and other classification techniques.

## 14. REFERENCES

[1] Jyoti Kumaria, R.Rajesha, KM.Poojaa, ".Facial expression recognition: A survey", Second International Symposium on Computer Vision and the Internet . 2015.

[2] Ghulam Muhammad1, Mansour Alsulaiman1, Syed Umar Amin, Ahmed Ghoneim, And Mohammed F. Alhamid "A Facial-Expression Monitoring System for Improved Healthcare in Smart Cities" Special Section On Advances Of Multisensory Services And Technologies For Healthcare In Smart Cities.

[3] Andre Teixeira Lopesa, Edilson de Aguiarb, Alberto F. De Souzaa, Thiago Oliveira-Santosa, "Facial Expression Recognition with Convolutional Neural Networks: Coping with Few Data and the Training Sample Order". Preprint submitted to Pattern Recognition July 21, 2016

[4] Received May 12, 2017, accepted May 28, 2017, date of publication June 7, 2017, date of current version July 3, 2017..

[5] W. Ouyang, K. Wang, X. Zhu, and X. Wang, "Chained Cascade Network for Object Detection," 2017 IEEE International Conference on Computer Vision (ICCV), Oct. 2017.

[6] Z. Zhang, "Feature-Based Facial Expression Recognition: Sensitivity Analysis and Experiments with a MultiLayer Perceptron, "International Journal of Pattern Recognition and Artificial Intelligence (IJPRAI), 1998.

[7] S. Z. Li, A. K. Jain, Handbook of Face Recognition, Springer Science & Business Media, 2011.

[8] D. C. Ali Mollahosseini and M. H. Mahoor. Going deeper in facial expression recognition using deep neural networks. IEEE Winter Conference on Applications of Computer Vision, 2016.

[9] T.Q. Ngo, and S. Yoon, "Facial Expression Recognition on Static Images," Future Data and Security Engineering (FDSE), Lecture Notes in Computer Science, vol. 11814. Springer, 2019, pp. 640-647.

[10] H. Soyel and H. Demirel, "Improved SIFT matching for pose robust facial expression recognition, "Face and Gesture, Santa Barbara, CA, 2011, pp. 585-590.

[11] P. S. Aleksic and A. K. Katsaggelos, "Automatic facial expression recognition using facial animation parameters and multistream HMMs," IEEE Transactions on Information Forensics and Security, vol. 1, no. 1, pp. 3-11, March 2006.

[12] P. Zarbakhsh and H. Demirel, "Fuzzy SVM for 3D facial expression classification using sequential forward feature selection, " Proc. IEEE 9th International Conference on Computational Intelligence and Communication Networks (CICN), Girne, 2017, pp. 131-134.

[13] Zarbakhsh, P., Demirel, H. Low-rank sparse coding and region of interest pooling for dynamic 3D facial expression recognition. SIViP 12, 1611–1618 (2018).

[14] Zarbakhsh, P., Demirel, H. 4D facial expression recognition using multimodal time series analysis of geometric landmark-based deformations. Vis Comput 36, 951–965 (2020).

[15] Pushpaja V. Saudagare, D.S. Chaudhari, "Facial Expression Recognition using Neural Network –An Overview," International Journal of Soft Computing and Engineering (IJSCE), vo2. 1, no. 1, pp. 224-227, March 2012.

[16] Belal Ahmad,Ravinder Kumar,Marghoob Ahmad Usmani, "Facial Expression Recognition Using Artificial Neural Network", International Journal of Engineering Development and Research (IJEDR), Vol.4, Issue 3, pp.663-666, August 2016.

[17] Hanh Phan-Xuan, Thuong Le-Tien, Sy Nguyen-Tan,FPGA Platform applied for Facial Expression Recognition System using Convolutional Neural Networks,Procedia Computer Science,Volume 151 , pp. 651-658, May 2019.

[18] S. Saurav, R. Saini and S. Singh, "FPGA Based Implementation of Linear SVM for Facial Expression Classification," Proc. International Conference on Advances in Computing, Communications and Informatics (ICACCI), Bangalore, 2018, pp. 766-773.

[19] J. Lin, S. Liou, W. Hsieh, Y. Liao, H. Wang and Q. Lan, "Facial Expression Recognition Based on Field Programmable Gate Array," Fifth International Conference on Information Assurance and Security, Xi'an, 2009, pp. 547-550,

[20] Suwa, M., N. Sugie and K. Fujimora, "A preliminary note on pattern recognition of human emotional expression," Proc. 4th International Joint Conference on Pattern Recognition, November 7-10, 1978, Kyoto, Japan, pp: 408

[21] P. EKMAN AND W. FRIESEN, FACIAL ACTION CODING SYSTEM, CONSULTING PSYCHOLOGISTS PRESS, 1978.

[22] F. Kawakami, H. Yamada, S. Morishima and H. Harashima, "Construction and Psychological Evaluation of 3-D Emotion Space," Biomedical Fuzzy and Human. Sciences, vol.1, no.1, pp.33–42 (1995). 2427 .

[23] M. Rosenblum, Y. Yacoob, and L. S. Davis, "Human expression recognition from motion using a radial basis function network architecture," IEEE Trans. on Neural Networks, vol.7, no.5, pp.1121-1138(Sept.1996).

[24] M. Pantic and L. J. M. Rothkrantz, "Automatic analysis of facial expressions: the state of the art," IEEE Trans. Pattern Analysis & Machine Intelligence, vol.22, no.12, pp.1424-1445(Dec. 2000).

[25] Y. S. Gao, M. K. H. Leung, S. C. Hui, and M. W. Tananda, "Facial expression recognition from line-based caricature," IEEE Trans. System, Man, & Cybernetics (Part A), vol.33, no.3, pp.407- 412(May, 2003)