A Probabilistic Machine Learning Approach to Detect Depression and Anxiety Levels Through Facial Expressions

Thesis Submitted in Partial of the Requirements for the
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I am grateful to the almighty Allah for making me able to research the topic that can be helpful to the mankind in future.

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ABSTRACT

We are living in a world where people are feared of sharing their feelings as someone can judge them and use their feelings against them or think the person is weak. This fear of sharing makes people depressed, and they fight their battle alone. From the study we have found depression and anxiety are becoming a common disease; people are not aware that they are moving to depression in their daily life. To detect the symptoms of depression early can save a life, the last stage of depression can make a human to do a suicidal decision. Computer vision and pattern recognition algorithms are more powerful to perform difficult tasks which can ignore by the human eyes, the machine can learn the human face and detect the expressions by pattern recognition algorithms that can help to detect anxiety and depression based on facial expressions. Probabilistic reasoning concepts and models will be used to get accurate levels of results which will be based on facial expressions. The study and implementation are bound to the features that can be only extracted from the faces and based on facial features machines can be able define human emotions, our model will learn by the emotions and decide whether a person is depressed or in a normal state.

Keywords: AAM (Active Appearance Model), FACS (Facial Action Code System), PCA (Principal Components Analysis), ANN (Artificial Neural Network), SVM (Support Vector Machine) BN (Bayesian Network)

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Chapter 1: Introduction

1.1 Depression

The world is in a pandemic and it affected a lot of our mental health, depression is a disease that was important to know before the pandemic but now it is most important to discuss, when someone feels lonely, sudden sadness, insecurity related to life, nightmare, low self-esteem, suicidal thoughts it can be depression, the same condition feels by the person it can be major depression, the good thing is depression is treatable if it diagnosis in early stage. (National Institute of Mental Health, 2017).

Life is unpredictable and in life, any point can be hurtful some people endure the pain, but some take them seriously and become mentally ill, with time it can be disastrous in the shape of depression. Depression is hard to detect because it is a cognitive disease and its symptoms come after time when a person falls with it. The Depression diagnosis process takes at least 2 weeks after studying human thoughts and behavior and can be treated. (National Institute of Mental Health, 2017).

The most common types of Depression are discussed with Major Depression and Dysthymia. Both have different with the symptoms present period in the person, if we study and observe symptoms in a person for two weeks every day then It can be Major Depression. Dysthymia kind of depression exists when a person observes depression symptoms for at least two years. (Depression Basics, 2016).

Like in the covid the main reason to develop depression in the people is their isolated living behavior which is enforced by the state in the quarantine period, many people experience depression after coming out from the quarantine period because of solitude. Depression depends on factors related to environmental, biological, psychological, and genetic combinations, it can be after effect of some serious illness, diabetes, heart problem (Depression Basics, 2016).

1.2 Depression Symptoms

The symptoms of the depressions gathered from the research papers are shown in the following table, symptoms are severe that can make a person decide to like to end his life with suicidal thoughts. The symptoms with severe are more contributed in depression part in any person and they cannot be ignored.

Table 1.1 Depression Symptoms

Symptoms
Sleep Trouble like early weakness, sleepless or can sleepover
Hopelessness and Feeling pessimist
Helpless and feeling worthless
Fatigue and Energy less
Interest loss, forget habits and activities
Weight changes rapidly
Concentration loss, unable to decide
Suicidal thoughts and attempts
Some psychical pain like a headache, digestive problem, and aches in the body
Drugs and alcohol addiction

With depression there is another disease that affects human health anxiety, most people who faced depression in their life also have anxiety, our research covers both anxiety and depression.

1.3 Anxiety

Anxiety develops when a person lives under stress, anxiety comes when humans have a fear for the future. Anxiety orders are persistent, excessive, and unreasonable. Persistent anxiety not going away, excessive anxiety has more than one reason, unreasonable anxiety does not need to worry. People get anxiety by social phobia, panic disorder, excessive anxiety have presented more than 90 days in 6 months. Anxiety disorder can be developed by daily events like tests in the classroom, relationships, home issues, and others. Anxiety order is dangerous because it makes humans hopeless and affects tiredness, sleeplessness. Mostly Depression and Anxiety symptoms are the same. (Holland, 2018).

In Pandemic covid China studies about the human mental disorder and research resulted younger faced depressive and sleepless disorder that related to GAD (generalized anxiety disorder). It is also mentioned younger people more than older people get this disorder. (Huang & Zhao, June 2020)

Anxiety and Depression can be differentiated, and we need to understand both, Anxiety is related to future events and people worrying about what will happen, it can be how to cross the road, stuck in the lift, fail in exams, nervousness during the viva. Anxiety can be controlled by self-confidence and control the cognitive thoughts, some people are in weak controlling their nerves so it is better to take care of them and give them confidence so they don't go into an anxiety disorder. Depression is related to past events and added fear or sadness in the cognitive thoughts, the depressive person never gets out of the past event, and overthinking about the past makes them sleepless, disturbed, and sad. Depression can be minimized by the focus on the things that we have now, talking to depressive people, and daily therapy help to forget or blur past events and can be a treatment of depression. (LLC, 2018) , (Holland, 2018).

1.4 Reasons for Depression and Anxiety

Many studies discussed both disorders gender-wise, women are more than men get in anxiety and depression disorder. Women's life period has more stages than men where menstrual and pregnancy that can be highly developed both disorders. (Fava, Rush, & Alpert, 2008).

We should discuss the factor which is related to getting depression. The young generation is deeply involved with social media and smartphones, which are the big reason for getting stressed and depressed. Instagram is used by 300million people monthly and studies show the younger who use Instagram have more chance to get depressed, the images of celebrities and lifestyle make normal people complex, this mostly happens with the younger age and they start to adopt the lifestyle, many fails and get in stress and then persistent stress in a result of depression. Social networks badly affect self-esteem, and many cases are now reported related to an anxiety attack. Younger when start to use the social media they cut them from real life, in covid, those are in quarantine faces more issue with the loneliness, they spent much of their time in social media where they only see negative news related to covid which make them highly anxious and depressed. (Fava, Rush, & Alpert, 2008).

The social media usages outcomes are very considerable and cannot be ignored because depression and anxiety affect the cognitive thoughts directly and many cases related suicide records, higher screen time, and activities of social network outcomes are suicidal and our research can prevent it from early stages by studying human behaviors and emotions. (Woods & Scott, 2016).

A research survey performed at the University of Pennsylvania shows in the following table where students get the iPhone with Facebook, Instagram, and Snapchat installed. The following table shows the measured parameters.

Table 1.2 Survey Measured Parameters

Parameters
Depression
Anxiety
Social Support
Loneliness
Self-esteem
Fear of missing out
Autonomy
Self-acceptance

143 undergraduates contribute to the survey the details are in the following table with the breakup of courses and semester.

Table 1.3 Student Details

Undergraduate	Semester	Course
71 students	Fall	psychology
72 students	Spring	psychology

The table shows the details of students who participated in the survey, the results are shocking in the sense if the daily usage of Facebook is more than 10 mins and every day it will directly affect the person's loneliness and depression. Facebook says connecting people but, it is making people also depressed and lonely (Hunt, Marx, & Lipson, 2018).

The previous discussed the symptoms of depression and anxiety, and what factors and reasons are making people depressed and anxious, our study is related to identifying

depression and anxiety from the facial features. The human face is defined in the computer science Facial Action Code System (FACS) it helps to detect facial expressions and detect features, the face is identical for every person and people react in every situation with facial expressions, facial expressions are very helpful to judge the human sentiments. In the face, some emotions signal us people are sad, happy, disturbed, surprised, disgusted and other emotions that can be extracted from the facial expression, these emotions are somehow helpful to detect human psychology, and ultimately, can calculate the stress, depression and anxiety levels. (Hunt, Marx, & Lipson, 2018).

1.5 Computer Vision

Computer Vision is the field related to visualizing objects by machine and for humans, we can easily detect and recognize the objects, same for the machine there can learn like a human brain to process the data and give results, Viola-Jones is the famous algorithm in the machine learning to detect faces with robust speed and high accuracy, we will discuss this algorithm in details (Viola & Jones, 2001). (Rowley, Baluja, & Kanade, 1998) Neural Network was the revolution in machine learning, Neural Network works like the human brain cells neurons, it uses too to detect the faces in an image. Our research work will use the algorithm that is widely used. AAM with FACS proposed in the research paper to detect the faces in images, PCA and Bayesian classifier uses for the object classification, Different paper discuss different approaches to detect the face object and found out Neural Network gives the best results in detecting the faces. FACS is helping to detect the human face expression with classifier AAM and Bayesian Classifier, these giving the high accuracy result (Paul & Sumam, 2012) (Nuruzzaman, Hussain, Tahir, Seman, & Abu, 2013)

We give a basic overview of depression, anxiety, reasons to get in depression, and what features can help to detect levels of depression and anxiety. We are only focused on the facial feature that can help to detect depression and anxiety levels. Our next Chapter will be discussed more the basic flow of our research implement and previous work that is related to our research work.

Chapter 2: Literature Review

The section reviews the papers with the basic flow for face detection and faces expression classifications, Computer Vision in machine learning is now able to do what the human brain can do, will discuss all the steps that will support our research work.

2.1 Face Detection

(Viola & Jones, 2001) present the algorithm named on the author Viola-Jones Algorithm, the algorithm is famous to use object detection. Human easily detect the object and classify them, for the same purpose Viola-Jones work on the grayscale image and then do the object bound on the color image, Viola-Jones work well on the frontier image, but the side pose has lacked inaccuracy. The algorithm is robust and accurate in the detect face after learning. Viola-Jones works in two stages.

1- Training
2- Detection

Training is to classify the objects from the labeled test data, the human face has similar attributes in which all human faces are divided into sections eye's part, nose parts, and lips parts. Viola-Jones algorithm work detection work in 4 steps

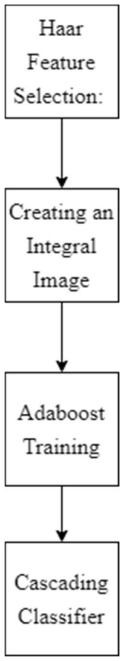

Figure 2.1 Viola-Jones Steps

Haar Feature Selection: Haar's algorithm was proposed by Haar in 1909 and it is used to detect the features, it works with the dark and light color rectangle to use the features in the face, dark rectangle place where grayscale has a dark color. It is replaced by the haar to the eyes, nose, eyebrows, and lips in the image.

Creating an Integral Image: The features are in the image in large numbers and hard to calculate, this step reduces the calculation time by creating the new pixels table with only four edges of the rectangle.

Ad boost Training: This step removes the irrelevant features and creates the linear combination from the relevant features.

Cascading Classifier: here when we have the image with features, the algorithm compares the image with the best-learned model and goes to stages to compare features for the face, If the face matched in the first step the algorithm stopped. For speeding up this algorithm performs the task in stages and output the result with faces.

"You Only Look Once," or YOLO is another technique to detect the object, it is based on the Convolutional Neural Network to detect the object, YOLO3 is used to detect the faces after training the model, it is famous and using with keras a python library (Brownlee, 2021). (Muhammad Shoaib Farooq, 2021) works on dark skin face detection, the proposed work uses CNN and its accuracy is 89%. (Hanan A. Hosni Mahmoud, 2021) with the covid period the mask in on face now, the method proposed to detect the concealed face and its accuracy is 97.51% in real-time, the proposed model compared with the voila, GAN but the proposed model achieved more accuracy. The proposed model uses the height, width of human and create the histogram then check the shoulder size after detecting the human face in surveillance videos.

(M.Al-Tuwaijari & Shaker, 2020) compare the approach of face detection with other models and propose the model based on Viola-Jones, they proved the Viola-Jones is robust to detect the faces in the images, they added the layers of LDA, Chicken and Bat Algorithm in feature extraction and the accuracy is 99.3 for face detection, it proved that with viola jones another algorithm can be used for better accuracy and speed.

2.2 Face Expressions Detection

We studied the research paper and the flow for the detection of Face Expression is shown in fig 1, the generic flow is shown in the figure for every step, in every step, there is the algorithm that makes the accuracy best and with robust speed.

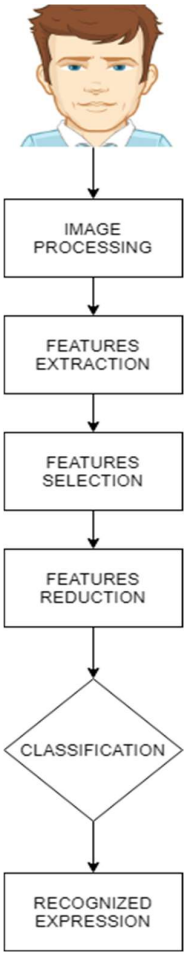

Fig. 2.2 Process to detect facial expressions.

The Fig 2.2 is the basic flow of recognized expressions, for every steps there are different techniques can be used, Image Processing have where the grayscale applied to get the better results, Rigelet Transform is the algorithm used to processing the image for better processing, We are discussing every steps in details and discuss about the which is the best algorithm and

techniques to implement every steps, Human face features are many in numbers but some features are present in every face, eyes position, eyes brows, nose, lips are same for every person so, for making the processing fast and detect the face Viola-Jones is used after pre-processing of images, the wavelet or Rigelet transform is the techniques that use in the pre-processing image so, face detect easily and after detection of face we apply the algorithm to recognized the face expressions, The 1st step is Image Processing where the image filter to get the features easily, 2nd Step is Extracting the Features in Face the FACS is used with the AAM to extract the features and Principle Component Analysis. Features Reduction is the third and most important step that makes the algorithm accurate and fast, In feature extraction, the algorithm gets the feature in large number and many features are not required to process and it takes a speed slow, feature reduction minimize the features information in a way that it can process the without extra information and the information will only process that needed, PCA with LDA used to make the feature reduction efficient to work. Classification is the final step to classify which expressions are in the face. The expression from the face depends on the emotions of the people and is easily judged by machine what humanity is facing. In Classification Artificial Neural Network, SVM is famous and efficient, we will study both and find what is the best solution for us. (Mantri, Agrawal, Patil, & Wadhai, 2015) work on the depression that can be detected from the emotions, the state in the introduction how unhappiness can be the reason for suicide. When depression controls human cognitive thought then it can be the reason for what no one can expect. They proposed the framework that follows the step defined in fig 2.2.

Image Processing Algorithm

(Kautkara, et al., 2010) worked on the RIDGELET transformation for recognizing the face before feature extraction normalizing the image with color changes then apply the RIGELET transformation to make the accuracy high for feature extraction. RIDGELET transformation is the generation first of curvelet transformation, it works on the two steps.
1st step is to do the Radon Transformation of the image and 2nd step is where wavelet transform applies.

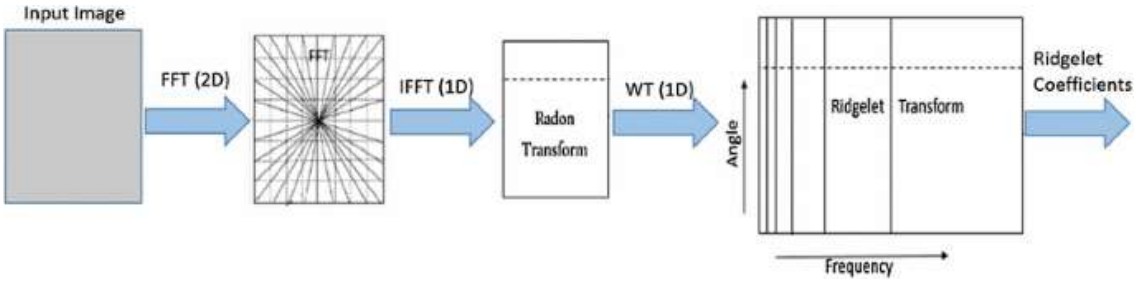

Fig. 2.3 RIDGELET Transformation

Fig 2.3 shows the process of RIDGELET transformation when the Input image passes Fast Fourier Transform (2D FFT) and it process it in 1D inverse Fourier Transform IFFT(1D) before the Finite Radon Transform (FRAT). Wavelet transform applies on the FRAT for Image RIDGELET Transform (Do & Vetterli, 2003). (Liu, Peng, & Zhou, 2016) worked on the Finite RIDGELET Transformation with SVM for features extraction, FRIT gives accuracy before the Feature Extraction and It is mainly used after the normalization of image.

Feature Extraction

Face in the video is difficult to process in Computer Vision because of side poses, movement and not getting the full face, Active Appearance Model (AAM) is the algorithm used to find the face in the frames by extracting features (Bagnato, et al., 2007)**.**

AAM is used to recognize the face and prove it is better than PCA and ICA, Face normally changes with time, some people get beard after time. The main thing is the aging factor AAM is also proven to solve this issue. Before AMM the Shaper Appearance Model (SAM) was used to get the feature of the face, but it ignores many features point and resulting in the error in recognition of the face, our research purpose is to recognize the man save their expression records with time and generate the depression level, AAM based on SAM and a statistical model, The AAM model is trained by Facial Action Code System that is a standard protocol for describing the face expression. FACS is works with main features based on muscular movement and defined the face expressions, eye movement, wrinkles in the face, lips movement, aging, beard, and without beard recognition. FACS trained the AAM model to do complex tackling of all problems related to facial expressions. (Nuruzzaman, Hussain, Tahir, Seman, & Abu, 2013).

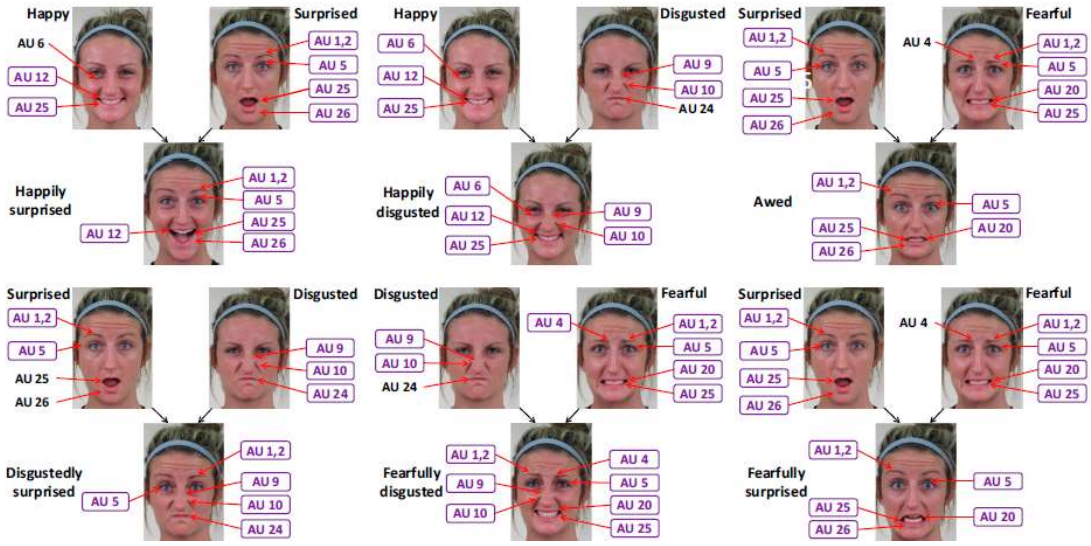

Fig. 2.4 Action Unit

Figure 2.4 shows the Action Unit used in FACS, facial action unit helps when the eyes are closed, lips open, tongue visible, dimple, and teeth visible. All actions combination has the labeled with when human is happy, sad, surprise and machine learning perform this and labeled the AUs, these action unit are 27 and combined defined the face expressions, it contains 25 eyes and head codes also 28 movements for the expression detection. FACS is the standard protocol and is used in machine learning for facial expressions. FACS was developed only for facial expressions but in machine learning, it is used for the emotions from videos and human sentiment. (Prince, Martin, & Messinger) (Farnsworth, 2016).

The computer Vision field is not more advanced where human eyes can ignore the events and expressions but when we process the videos frame machine is not ignorable with these algorithms and protocols. FACS is the main protocol based on that all algorithm works and detect expressions and sentiments of humans. (Prince, Martin, & Messinger) (Farnsworth, 2016).

(Giannakakisa, et al., 2016) present the model with AAM for the anxiety and stress of the face, AAM with FACS trained model widely known for detect expressions and emotions are a combination of facial expression, stress directly influence the depression and with this, we can detect the depression of the human.

Feature Reduction

Feature reduction is an important step in Computer Vision, normally facial recognition images have 5000 features and many are not useable for processing data, for making the process fast feature reduction algorithms reduce the large set of features into a limited and important set of features. The principal component analysis is used to make the dependent variables into the independent variables, if we reduce the features then it can also show visually. PCA is used in the image processing to reduce the features set to speed up the processing, PCA works with the eigenvector and eigenvalues to get the important feature for classification, it detects the maximize of variation in the dataset by PC1, PC2 to PCn, and the eigenvalues uses to get the important field, in facial processing eigenvalues are eigenfaces (Lehe, n.d.)
(Gosavi & Khot, 2013) worked on the architecture for facial expression detection, their model uses the PCA to reduce features, the accuracy of the model is 92% and precision is 72%.

(Ooi, Low, Lech, & Allen, 2011) added the Linear Discriminant Analysis (LDA) with PCA and it helps better to classify after feature reductions, PCA uses eigenfaces to reduce the feature and PCA+LDA named the Fisherfaces to reduce the features in facial data.

LDA makes the new axes in the data point separate, it works on the mean for everyone features set, for classify the features easy it maximizes the mean distance of every features set and the distance within the feature set minimize so, same features set to shrink and closed within the subspace and the mean distance between the each features set maximize (Raschka, 2014).

Classification

Classification is the last step in facial expressions recognition where the model gives the results using classification algorithms that the features present in the image lie in which class, for this there are algorithms famous that give excellent results by using mathematical techniques.

Support Vector Machine is used in the classification of facial expression, it works on linear data only and does not work on non-linear data, kernel used in the SVM makes the polynomial data linear. (scikit-learn, n.d.). (Liu, Tang, & Wang, 2020) present the model based on Convolution Neural Network for feature extraction and L2-SVM used for the classification in Facial Expression Recognition (FER).

Today the famous algorithm that uses for machine learning and classification is the Artificial Neural Network (ANN), ANN works like the real brain and the concept comes from the neuron network in the brain, neurons have the value between 0 and 1, neurons help in classification what they learned to like our brain learn every time with experiences in environment, ANN have 3 layers Input Layer. Hidden Layer and Outputs Layer (Dormehl, 2018).

Machine learning and Deep Learning both use the ANN, for machine learning ANN is used for the only classification, and for Deep Learning it uses for feature extraction and classification.

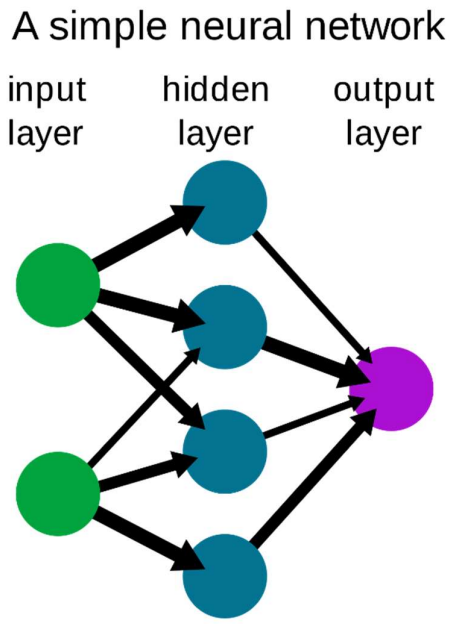

Fig. 2.5 Artificial Neural Network layers

Fig. 2.5 shows the layers of ANN, input layers absorb input from the environments, and it works to gather the data to pass the hidden layers, where hidden layers process the data and

find the pattern of data to classify for the output layers, output layers give the result based on their learning by the classification. These neurons connected with the edges and edges have the weight, the wight higher make the neuron active and by these, it classified the input to output.

AAN is used in deep learning, for learning faces it is called deep faces learning, ANN is found the best inaccuracy in learning faces and classify them, when neuron active it gives the number between 1 or 0, if all connected edges have weight 0 the algorithm added bias 1, there will be some output. (Moawad, 2018).

ANN in deep learning is used to learn from the output layers, where we were given the data for learning from output layers and hidden layers process them to learn the data pattern for later usage, the Phenomenon name is Back Propagation in ANN it starts with the output layers and do the back propagations and update the weights of neural network. The learning for ANN is slow but when it uses for classification it gives high accuracy. (Moawad, 2018).

ANN is working with single dimension neurons but there is Convolutional Neural Network (CNN) which work with multiple dimension neurons height, weight, and dept, CNN layers are the same but for the images processing, there is a need to have more than one dimension, in hidden layers of CNN it take multidimensional input from the input layers to process (Karpathy, n.d.). (Yu & Zhang, 2015) present the architecture name Deep Convolutional Neural Network (DCNN) that is based on CNN, the architecture has 7 hidden layers that process the facial feature from the image and recognize expression, DCNN performed better in accuracy than SVM and other algorithms, the error rate of the architecture based on DCNN is 0.23% which is much low than other architecture used in facial expression recognition.

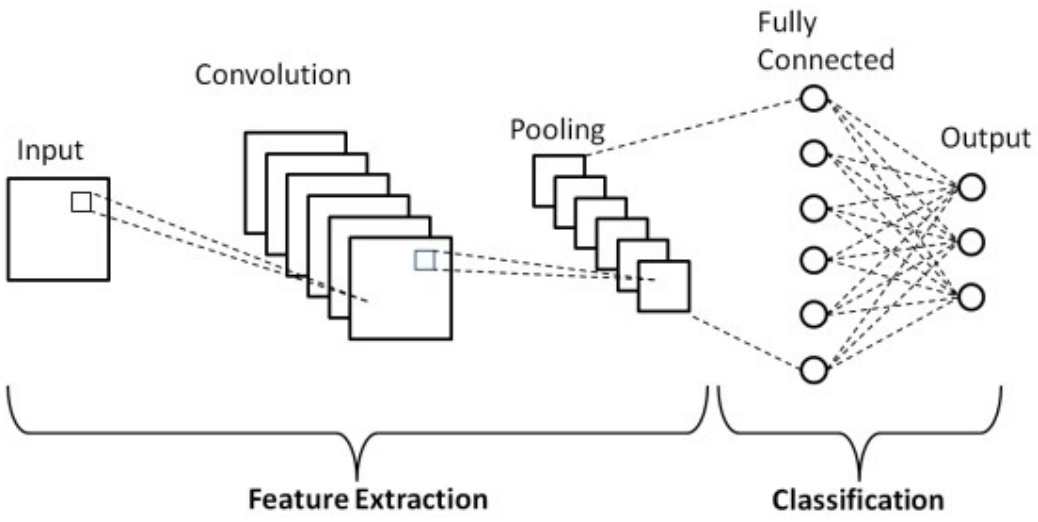

Fig. 2.6 Convolutional Artificial Neural Network layers

Fig 2.6 show the basic structure for the CNN, CNN is used for the image classifications, the architecture is a power full to process multidimensional data and we will use the CNN the recognize the expressions from the facial features, CNN is proven to learn the model and classify them at good accuracy than other algorithms and architectures.

2.3 Depression and Anxiety Symptoms from Facial Expressions

It is very important to discuss the symptoms of depression and what they role play and effect in depression disorder detection, (NairU, Nair, Kashani, & Reid, 1999) present the survey results where they found the symptoms which affect the human brain disorder, 11 symptoms developed after study the survey results, the research survey respondent are 3500 students of universities, they researched to get the importance of symptoms that influence to the depression and make a hierarchy to diagnose depression in early stage for treatment. Neural Network is applied for the gathered information from the survey and created the learning model for detecting depression later. The following table shows the depression symptom that feels by depressed respondents and non-depressed respondents. DSM-III criteria are used to get the major depression diagnosis they applied the same criteria for every respondent and neural network model used for it.

Table 2.3.1 Respondents Table and Positive Predictive Value (NairU, Nair, Kashani, & Reid, 1999)

Symptom	Depressed Respondents	Non-depressed Respondents	Totals Respondent	PPV (%)
Sadness	109	990	1099	9.92
Suicidal ideation	86	778	864	9.95
Somatic complaint	52	792	844	6.16
Sleeping trouble	100	637	737	13.57
Hopelessness	64	515	579	11.05
Tiredness	80	438	518	15.44
Difficulty in concentration	76	271	374	21.9
Appetite change	56	239	295	19.16
Psychomotor retardation	56	236	292	19.18
Loss of interest	50	163	213	23.47
Feelings of guilt	52	153	205	25.37

The symptoms present in table 2.3.1 are 11, if 5 out of 11 symptoms present for two weeks in any person then the person is in depression. According to the research, the (I) sadness is the major symptom and (II) 4 symptoms out of other from the list then the person is in depression. Fig 3.1 shows the process of neural network where symptoms of depression pass from the Input Layers and in Hidden Layers 5 and 10 neurons process the input then Output Layers shows the important number of each symptom. The neural networks returned the 15 patterns of 261 parameters. They have the survey data so used that by Backpropagation for the training of the model.

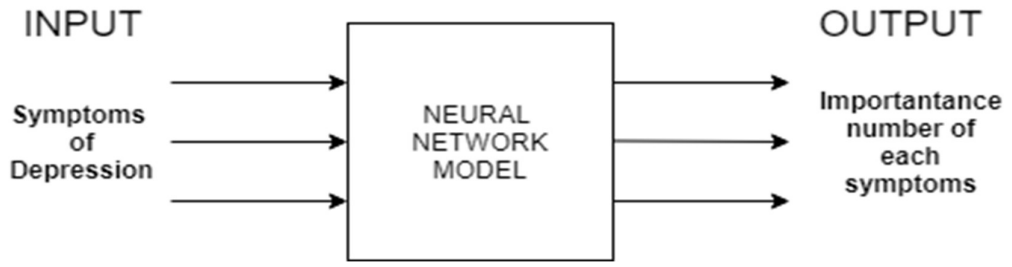

Fig 2.3.1 Neural Network Model to find importance number of symptoms.

Table 2.3.2 Contribution Analysis

Symptom	Importance Number	PPV (%)
Sadness	1.00	9.92
Loss of interest	0.93	23.47
Tiredness	0.90	15.44
Sleeping trouble	0.88	13.57
Difficulty in concentration	0.70	21.9
Suicidal ideation	0.61	9.95
Feelings of guilt	0.45	25.37
Appetite change	0.44	19.0
Psychomotor retardation	0.37	19.18
Hopelessness	0.28	11.05
Somatic complaint	0.00	6.16

Table 3.2 is the result after the analysis of survey data with the neural network, the sadness has the highest number and influence to the depression as important symptoms, other symptoms are not as important as sadness, the symptoms are shown in the table with decreasing order of importance, Neural network is the predicted model the criteria set to detect the depression has set the threshold, if the network result is less than < 0.4 then it will be considered the person is not in depression disorder, the network result is greater than < 0.6 then it will be considered the person is in depression disorder. The output in between 0.4 > to < 0.6 then will not consider the person of depression disorder, it will be discarded by the model.

Table 2.3.3 is listed the symptoms that find by backward elimination procedure on the list of 11 symptoms, they apply the regression maximum likelihood on all the variables that are dependable to depression, the variables that eliminate because they have P values > 0.10, and the variables that are helpful in the diagnosis of depression have P values < 0.0001, other than hopelessness, psychomotor retardation, and Somatic complaint are the symptoms help to detect the depression.

Table 2.3.3 Logistic regression maximum likelihood

Symptom	CHI-SQUARE	P (%)	ESTIMATE
Intercept	200.23	0.0001	
Sadness	0.93	0.0001	-0.44
Appetite change	0.90	0.0001	-0.17
Sleeping trouble	0.88	0.0001	-0.50
Tiredness	0.70	0.0001	-0.29
Loss of interest	0.61	0.0001	-0.18
Feelings of guilt	0.45	0.0001	-0.15
Difficulty in concentration	0.44	0.0001	-0.25
Suicidal ideation	14.68	0.0001	-0.27

The symptoms that are important to detect depressions can be extracted from the face by learning facial expression, sadness, sleep disturbance, tiredness, loss of interest these are the symptoms that highly influence depression. Surprise, Happy, Sad, Anger, and Disgust are the expressions related to depression symptoms. (Vedantham, Settipalli, & Reddy, 2018) proposed the model which can get the facial expression by Neural Network Classifications that are comparable with the depression symptoms, by the study the depression symptoms can extract from facial features and use them to detect depression is an early stage for treatment.

(Vedantham, Settipalli, & Reddy, 2018) presented the research work for anxiety and stress, both cognitive disorders detected by the facial expressions, movement of eyes. They also experiment to detect heart rate by face color, the accuracy of the model to detect anxiety is 73% and it is used only for the detection of stress and anxiety. (Vedantham, Settipalli, & Reddy, 2018) worked on Bayesian Network to detect dysthymia which is a type of depression, they state anxiety and stress influence directly to depression and created the Bayesian Network based on Conditional Probability Table (CPT).

2.4 Depression Detection Flow and Models

In the previous study we have figured out to detect depression from the facial feature, in this section, we will study the Depression detection flow that can be used to implement the system, we studied the detecting of facial expression after facial expressions the emotions detection is needed for the depression as depression is depends on human sentiments, we have discussed the important symptoms of the depression in previous sections and some of the sadness, tiredness, happiness can get from the facial features. (Venkataraman & Parameswaran, 2018) discussed the video frames, if we find out the expressions from the video frames and categorize each frame with the facial expression that happy face, sad face, angry face and then get the average of all frames then we can get the level of every emotion in a video of a person. The flow we defined in Figure 3 which we created by studying deep all the research papers and finalizing the generic flow that can use to detect depression levels after Facial Expression Recognition and Emotions level.

(Venkataraman & Parameswaran, 2018) discussed the facial features Happy, Contempt, and Disgust that can be extracted from the face, these features dependently impact on the depression level.

Table 2.4.1 Depression Level Estimate Table

Happy Feature	Contempt, Disgust Features	Depression Level
Moderate	High	Mildly Depressed
Low	High	High Depression
High	High	High Depression (Concealed Depression)
Moderate	Low	Sad
High	Low	Not Depressed (Happy)

Table 2.4.1 shows when the Happy feature is low with the Contempt and Disgust features High then the depression will be high, It defined the condition of depression based on the

features that can be extracted from the face, the study show when Happy Feature and Contempt, Disgust features both will be it will be High Depression because a person is not in a normal state where his sentiments are showing the features high which are supposed to be low with another.

We have now all the flow finalized from the research papers, to implement the probabilistic model Bayesian Network is the proposed model we will use, the level of depression can get easily with the CPT of dependent variables, (Chang, Fan, Lo, Hung, & Yuan, 2015) created the Bayesian network with CPT in Fig 3 where Dysthymia is influenced by Sleep Disturbance and Fatigue, by Bayesian Network easily find the level of depression of a person, the network value is between 0 to 1 when we have any evidence on any nodes it will update the whole network, Bayesian network is performing better with the incomplete information too if there some evidence missing in any nodes it will also give some result to treat a patient.

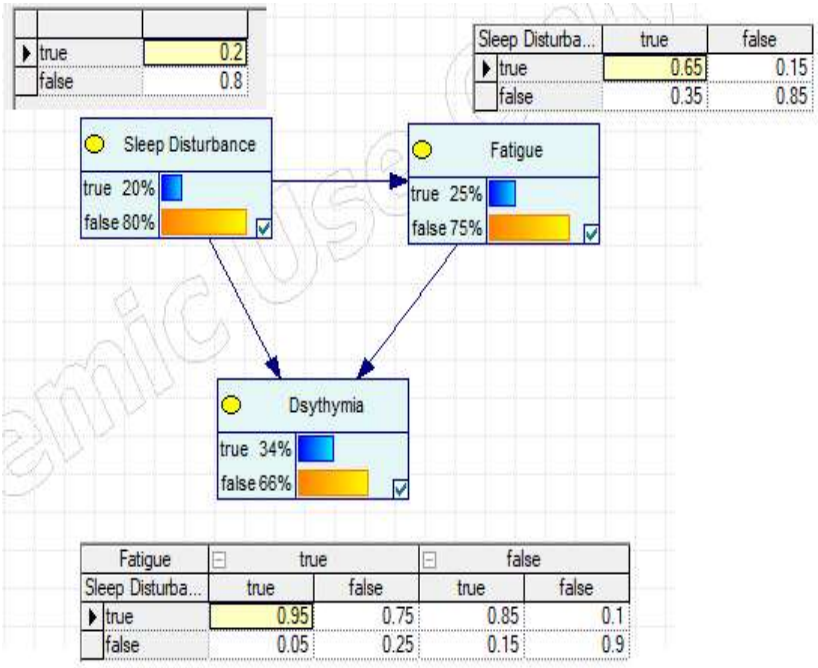

Fig 2.4.2 BN Inference Network with CPT

The complete network is in Fig 2.4.2 where variables influence the Dysthymia, for the Bayesian Network we can create the network and apply evidence depending on the feature, we don't need to get all evidence on all nodes if we have evidence for some variables, we can use and get the result from the network.

By studying all the previous work we can now implement our model and propose the solution to the world to detect depression from facial features, In the next chapter we will discuss our implementation and then the results we achieved through a detailed study of previous work and research.

Chapter 3: Methodology and Proposed Model

3.1 Data sets of Facial Expression Recognition

The dataset for training the Facial expression recognition is available from the Kaggle with name fer 2013 and the dataset is labeled with the sad, happy, neutral, digest, anger, fear, surprise, (Deep-Emotion: Facial Expression Recognition Using Attentional Convolutional Network, 2019) worked on the Fer 2013, JAFFE and FERG datasets and trained the model using these datasets. The proposed solution used the Convolutional Neural Network for the implementation.

Table 3.1.1 Datasets of FER

Datasets	Number of Images
FER (Facial Expression Recognition) 2013	35,887
JAFFE (The Japanese Female Facial Expression)	217
CK+ (Cohen Kenadee Data)	593
FERG	55,767

Table 3.1.1 shows the famous dataset for training facial expression recognition with the number of images, we show some images from the dataset as samples, the dataset includes the images for expression of disgust, happiness, sad, fear, surprise, angry, the model's images in the sequence of every expression, the dataset is for the training of model with the expression of all 6 and 1 neutral.

Fig 3.1.1 JAFFE Sample Images

JAFFE dataset contains 217 images of the Japan Model with 6 facial expressions and 1 neutral, Fig 3.1.1 we add the samples from the datasets (Lyons, Kamachi, & Gyoba, 1998).

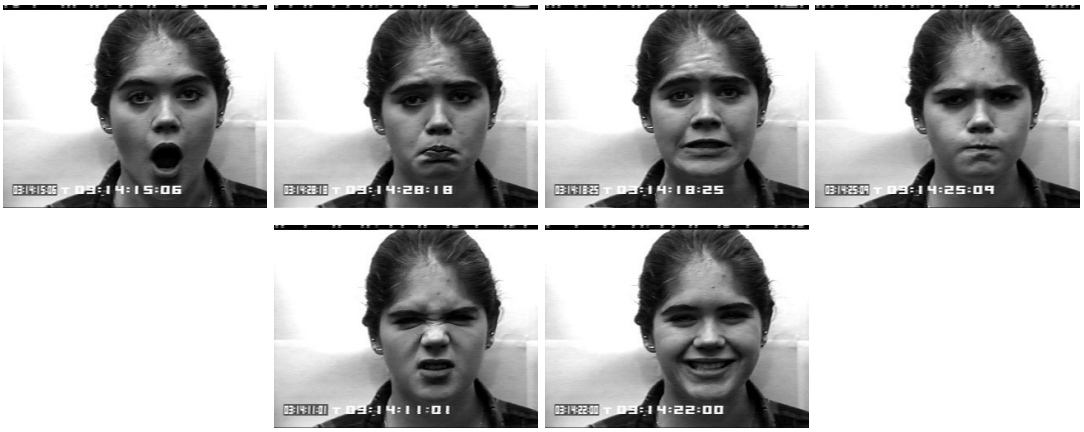

Fig 3.1.2 CK+ Sample Images Person

Fig 3.1.2 are from the CK+ sample images, the images are from a dataset of CK+ it has, the datasets are validated with AU code but not the emotions labeled, the dataset used for the training of model and then classification by AAM, SVM, and CNN. The dataset is a sequence of images with the expressions of sadness, happiness, disgust, surprise, anger, fear (Lucey, et al., 2010)

FER 2013 is the dataset of a large set of images with labeled images in the folders, all expressions with the folder names have the images will all gender and ages, it is also included the image of children with the expression, we added the samples for all expressions in following, we show 6 images for all the expressions from the datasets.

Fig 3.1.3: FER 2013 Angry Facial Expression Samples

Fig 3.1.3 is the sample images from the Angry data for training the model, it has the images of every gender male and female, also contain the images for children, young and old. The images were used for the training of the model with the detection of angry features from the face. The next figure shows the next expression of disgust face samples. The FER 2013 data is well structured with the labeled of every expression in the dataset.

Fig 3.1.4: FER 2013 Disgust Facial Expression Samples

Fig 3.1.4 shows the samples of images from the dataset, and it is labeled with the Disgust facial expression, the set of angry images include the children's images and all genders.

Fig 3.1.5: FER 2013 Fear Facial Expression Samples

Fig 3.1.5 are the images of fear expressions, these sets contain the images of female and male gender and children too young.

Fig 3.1.6: FER 2013 Happy Facial Expression Samples

Fig 3.1.6 are the images of happy expressions; these sets contain the images of the female and male gender with the age groups children, young and old.

Fig 3.1.7: FER 2013 Neutral Facial Expression Samples

Fig 3.1.7 are the images of neutral expressions since the model should also learn the faces with the neutral features, these sets contain the images of the female and male gender with the age groups children, young and old.

Fig 3.1.8: FER 2013 SAD Facial Expression Samples

Fig 3.1.8 are the images of sad expressions, sadness images are in different types some with the face on the mouth, eyes closed, mouth opened largely. these sets contain the images of the female and male gender with the age groups children, young and old.

Fig 3.1.9: FER 2013 Surprise Facial Expression Samples

Fig 3.1.9 are the images of surprise expressions since the model should also learn the faces with the surprise features so it can distinguish them from another facial expression, these sets

contain the images of the female and male gender with the age groups children, young and old.

3.2 Model Training

We have the datasets, and we train the models from the dataset, Convolutional Neural Network is used to train the model with the data of IMBD for gender classification and emotions with 7 classes from the dataset of FER 2013 (Arriaga, Valdenegro-Toro, & G. Pl¨oger, 2019)

The dataset used to train the model of CNN, the implementation is done by the python Keras CNN model and OpenCV library which are the well-known libraries for machine learning. The implementation is used for 2013 data to train the CNN model, its accuracy is 66% for training the model (Arriaga, Valdenegro-Toro, & G. Pl¨oger, 2019)

(Arriaga, Valdenegro-Toro, & G. Pl¨oger, 2019) worked on CNN model to train the classifier with their model based on CNN for real-time emotion detection, the model for detection face then apply CNN for the real-time classification of the image and extract the emotions. The OpenCV library is used to detect the faces, for gender separation, the model is trained by IMDB faces data, the classifier is trained by the Xception architecture that reduces the last year parameter in the CNN. CNN has 98% parameters in the last fully connected layers but the proposed model with Global Average pooling 2D architecture reduce many parameters in the last connected layers by transform parameter to scalers, CNN architectures are advanced now to make the speed fast with accuracy. The model training code is available on GitHub as an opensource to train their datasets, we used an already trained model in our architecture of depression detection.

3.3 Real-Time Expression Detection

The trained model we used to get the facial emotion detection, the model is trained to detect the emotion of women, men, and children. The program detects the emotion in real-time and OpenCV is used to process the real-time video and every frame is passed to the model and return the emotion in the frame, to render the image canvas from the NumPy library is used, the program shows the probabilities for all expressions from the frame, the expression with

the high probability labeled to the frame. We tested the model to the real-time videos and the videos from the internet to test the expressions.

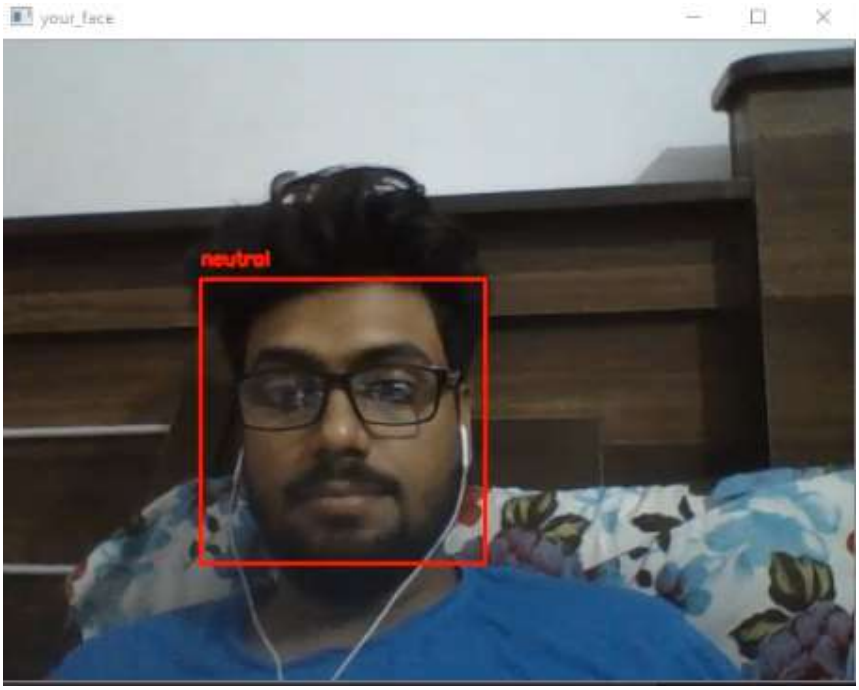

Fig 3.3.2: Neutral face real-time Frame

Fig 3.3.3: Neutral face real-time Frame (Probabilities)

Fig 3.2.2 is the frame from the real-time video capture and the program labeled it the neutral face based on the probabilities of expression classes, the highest probability is for the neutral face, the probabilities of the frames are in Fig 3.2.3. The program works with both gender

male and female, it works will all 7 facial expressions and we added other facial expression recognition in the following.

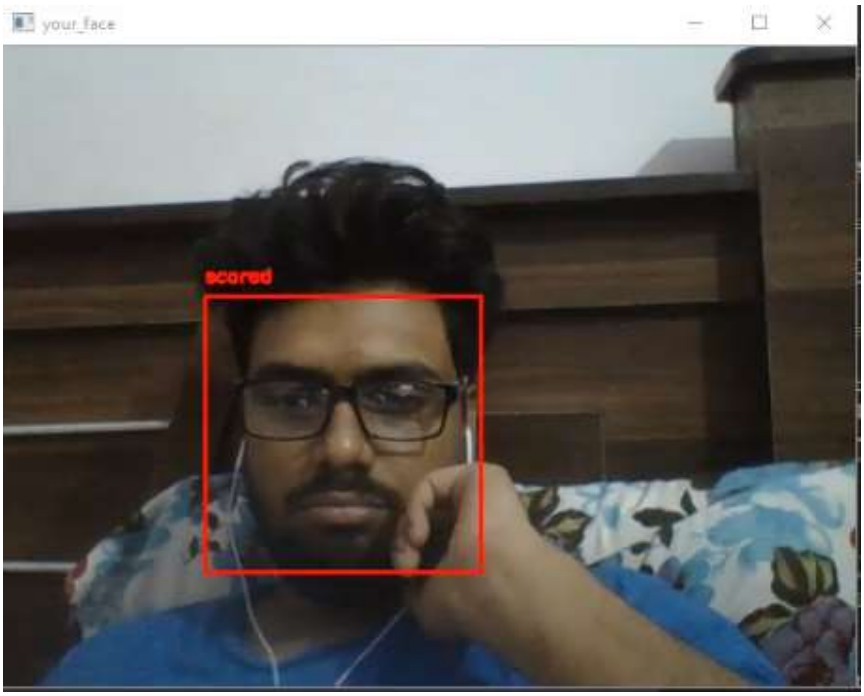

Fig 3.3.4: Scared face real-time Frame

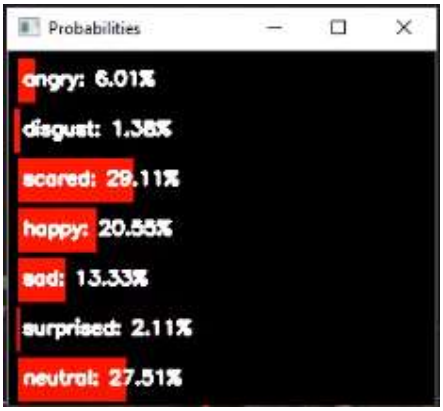

Fig 3.3.5: Scared face real-time Frame (Probabilities)

Fig 3.2.4 the model detected the frame as scared in the real-time video and Fig 3.2.5 shows there are other chances for the expressions like neutral probability is closed to scared probability.

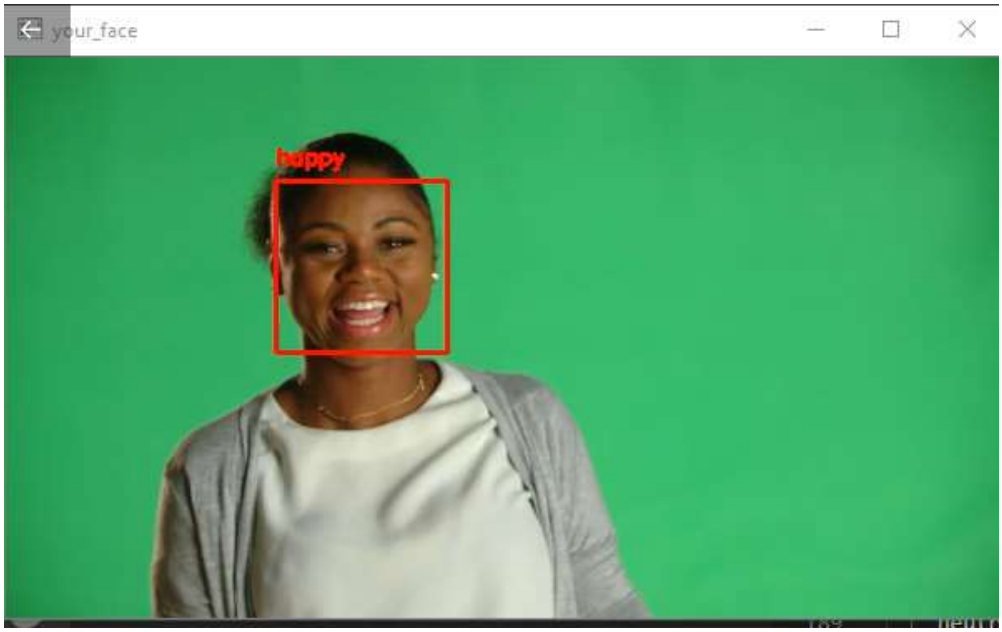

Fig 3.3.6: Happy face Frame from video

Fig 3.2.6 is the video frame from the video, so we added the feature to get expressions from the videos with real-time videos. The woman is happy and the model detects it happy, The probability is shown in Fig 3.3.7 where happy expression features are the highest.

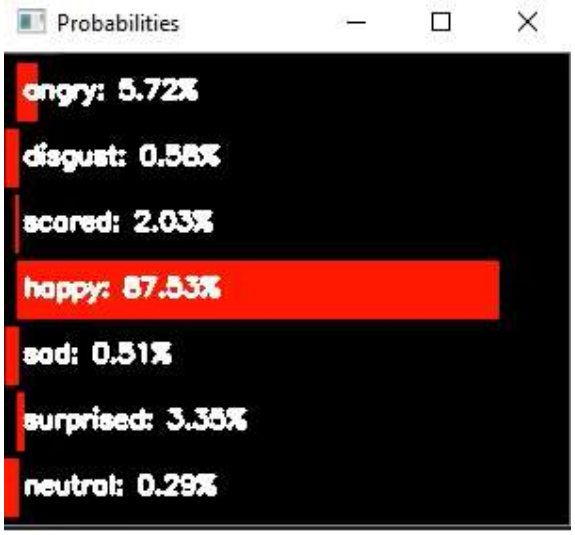

Fig 3.3.7: Happy face women Frame (Probabilities)

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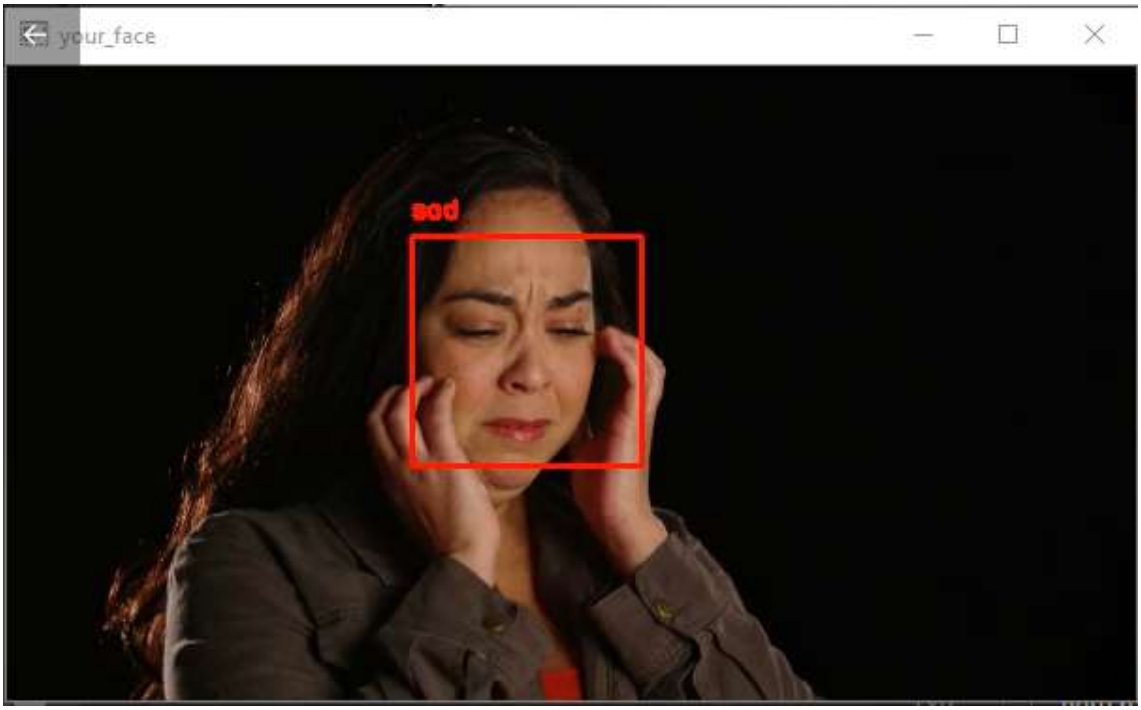

Fig 3.3.8: Sad face Frame from video

Fig 3.3.9: Sad face women Frame (Probabilities)

We try another sad video, and the Frame is a capture from the sad video in Fig 3.2.8, the video from Fig 3.2.6: and Fig 3.2.8: get from the videezy stock that is an online platform for the free videos.

Fig 3.3.10: Happy face child Frame (Probabilities)

The video from the videezy we tried on our model to get the expressions to work with the children and the video is the happy child video, and it gives the result according to expectations.

3.4 Depression and Anxiety Detection

We can get the real-time expressions from the videos and now we use this expression to convert them into emotions and then emotions will be inference to depression and anxiety, for this purpose we study in the literature review that the average of the expressions from the videos will be the emotions of the person in the video, we implement in our program to captures every frame expression probability and save in the records with the person. We take the mean for every frame probability and set the threshold for every expression mean if the mean of expressions passes the threshold value, we consider the emotions is in present in the video, a person can have multiple emotions at different times.

From the facial Expression we created the Bayesian Network where depression inference the facial features since, in literature review we discuss the survey report where depression people fill the survey and reported which symptom we faced while depression, we get CPT from the survey (NairU, Nair, Kashani, & Reid, 1999)

Bayesian Network for the depression we created in the Genie program, is the graphical presentation for the network and easy to create and test the network with believes values. (Druzdzel, 1999) for learning the Bayesian network from the data, the Power Contractor is used to create the model it learns the structure of the data and is then used to classify (Druzdzel, 1999)

We developed the Bayesian network from the research survey and we know somehow all facial feature has some role in the depression symptoms, for the sadness, happiness, angry, disgust and scared features inference the depression and anxiety from the previous studies, we added them in the network with the inference from Depression to symptoms that extracted by facial features, We make every features with independent with each other and from the survey data we found out depressed people felt angry, sad, happy and scared while they were in depression and use the CPT to create the network.

The advantage of the Bayesian network is that it is not required the whole symptom to give the result, if we have some symptoms knowledge the network will give the depression level according to it.

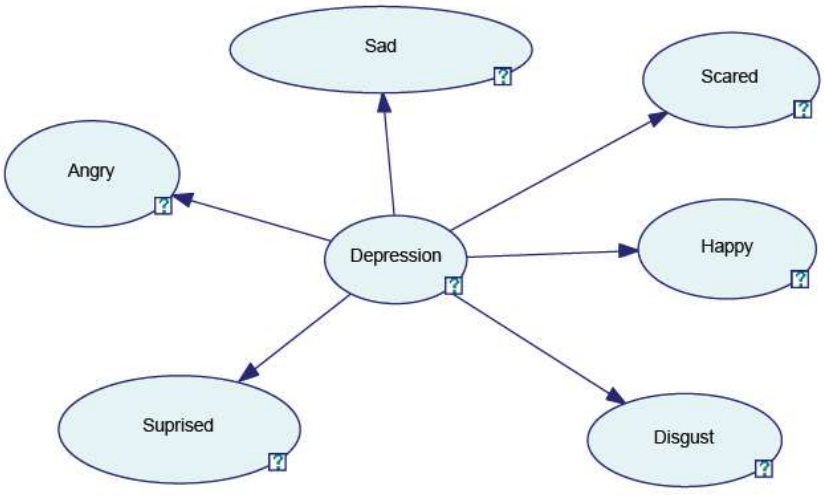

Fig 3.4.1: Depression Bayesian Network

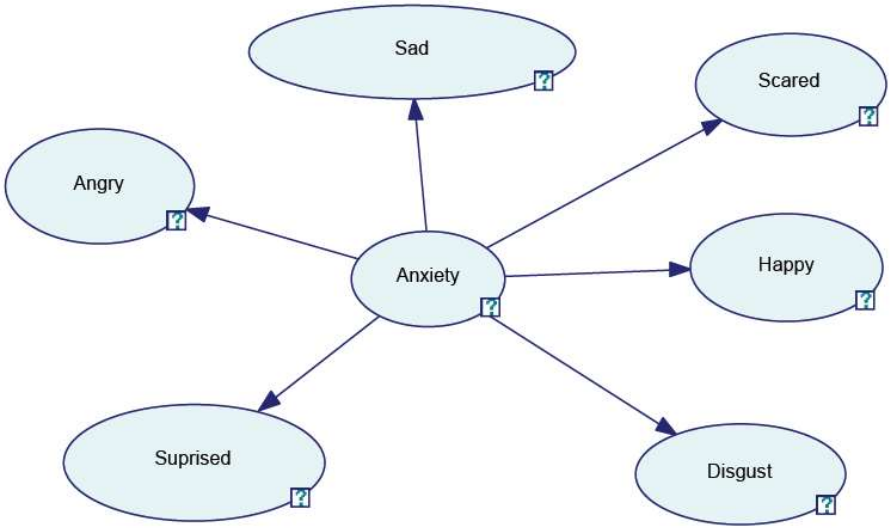

Fig 3.4.2 Anxiety Bayesian Network

The depression and anxiety network in is Fig 3.4.1 and Fig 3.4.2, is implemented with python in the program with the CPT and it gives the result based on the network proposed whether the user is in depression or not. When we get more information and data the thing is the network CPT will be updated and with time network will learn itself by training the model.

When the expression means value matched the threshold value then the network set the node with evidence and update the whole network that is why the Bayesian Network is performed better to detect the level of depression.

Table 3.4.1 Threshold for Bayesian Network Evidence

Emotions	Evidence (True) Threshold
Angry	10%
Sad	10%
Happy	40%
cared	10%
Surprised	5%
Disgust	5%
Neutral	60%

Table 3.4.1 shows the threshold set for the Bayesian Network classes evidence when the mean value of any expressions meets the threshold value the node-set with evidence, the Bayesian Network update the depression level, from the previous studies the sadness is dependent to the depression and later Disgust and happiness directly influence the depression. Our solution is great in this case we can set thresholds according to the information.

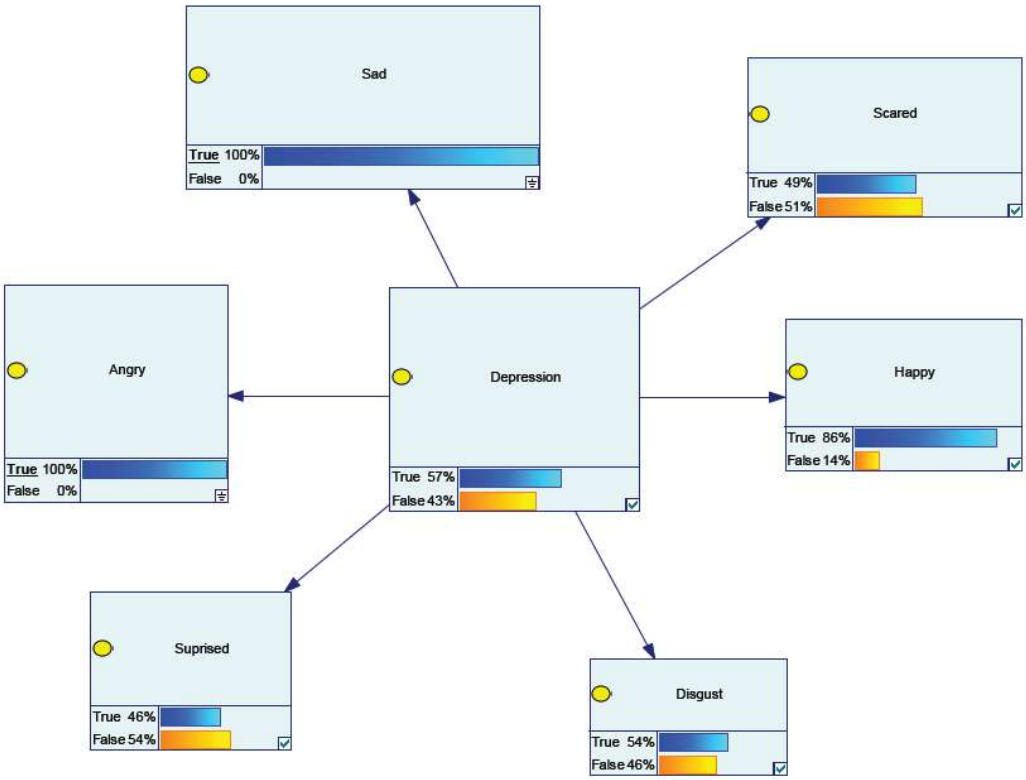

Fig 3.4.3 Bayesian Network with Evidence

Fig 3.4.3 shows if the evidence comes on any nodes, it will update the whole network with the values of every node and make us the level of depression, the Bayesian Network is the found best for this purpose to detect the level of depression and anxiety. The most important thing is as we get the data, we can update the network with CPT.

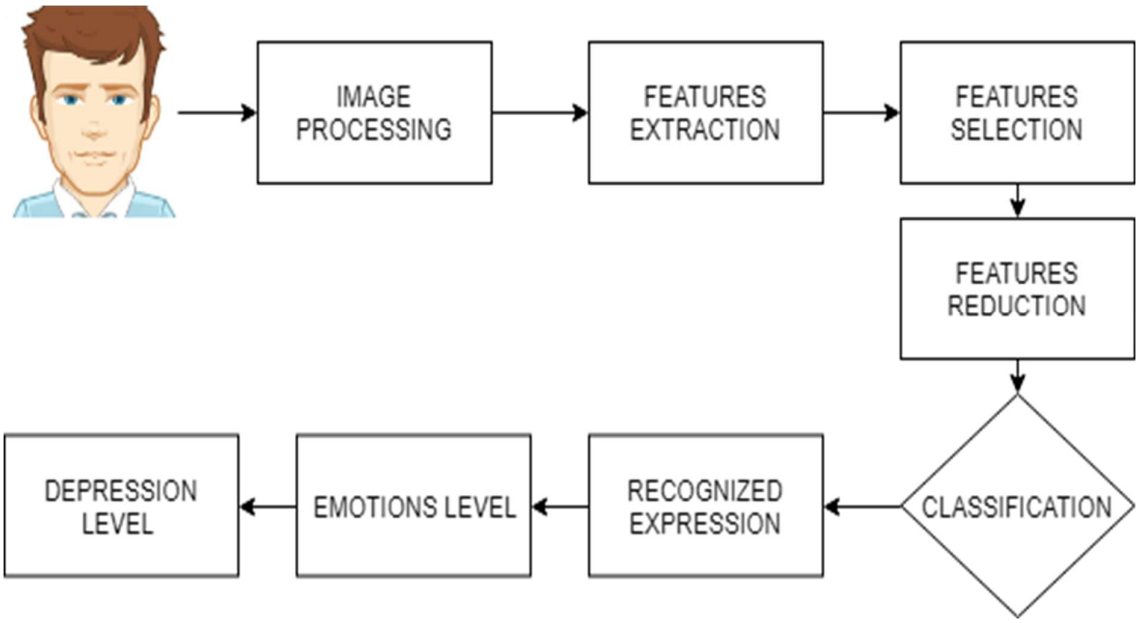

Fig 3.4.4 Complete Flow to Detect Depression level

Fig 3.4.4 is the complete flow we proposed to implement the depression detection and for every step, discussed the algorithm that is suitable for the accuracy and speed. We solved it by probabilistic reasoning and used the Bayesian Network which can be great in this problem as Bayesian Network can learn the network with time and in the future, it will be progressively updated with time. We worked and proved that Facial Features can use to detect depression and anxiety by the machine learning approach. The proposed model implemented has steps that are discussed in the following. Viola-Jones with OpenCV2 is used to detect the face, for the expression recognition the Mini-Xeption is used that based on the Xeption algorithm and CNN (Syed Aley Fatima, 2021) and the last step Bayesian Network implemented to detect depression level.

Chapter 4: Results and Conclusion

In the research we proved that the anxiety and depression levels can be detected from the facial expression, and we worked on the proof of concept from the previous work, we studied the algorithms that can use the flow of Emotions detection and use the best which can be high in accuracy and speed, from the study we are now able to detect the anxiety and depression from the facial expression, our final result is the model that can be used to detect the level of depression and anxiety that we are proposing in the research work.

We researched the symptoms of depression and anxiety and gathered information on what symptoms are important and directly influence depression. We discussed the facial expressions that are important with linked to the symptoms of depression and finally we proposed the solution based on the facial expression to use for detection of depression level.

Table 4.4.1 Confusion matrix of Mini-Xception

Expression	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	60.0	0.1	0.0	0.0	25.0	0.0	10
Disgust	0.0	55.0	0.5	0.7	11.9	25.0	0.0
Fear	12.9	0.01	65.78	0.5	0.12	17.8	0.0
Happy	0.02	0.5	0.02	95.55	0.08	14.5	0.78
Sad	25.0	11.9	0.12	0.08	85.0	0.05	7.50
Surprise	0.0	25.0	17.8	14.5	0.05	73.68	11.9
Neutral	10.0	0.0	0.0	0.78	7.50	11.9	89.66

The average accuracy of the Mini-Xception algorithm is 95.60%. Since the proposed model work is dependent on accuracies of emotions recognition from the face then the comparison of the mini-xception model used in this work with other models and the results are in the following tables.

Table 4.4.2: Accuracy of Emotion Recognition on FER 2013 Datasets

Method	Classification Accuracy
VGG + SVM	63.31%
Google Net and Alex Net	83%
Attention Convolution Network	93.3%
CNN	66%
Mini-Xception	95.60%

The proposed model is highly dependent on the accuracies of emotions recognition from faces, the datasets and model accuracies we have are described in table 4.4.2, and with time we will achieve more accuracies with face emotions recognitions. Mini-Xception used in the implementation of the model has the highest accuracy for run-time video emotions recognition.

The proposed model is using all expressions from the face on the other hand the proposed work by (Manjunath Tadalagi, 2021) uses the 3 facial expressions Happy, Sad, and Disgust.

Table 4.4.3: Comparison proposed depression level model with other work

AUTHOR	Expressions	Technique
(Manjunath Tadalagi, 2021)	Happy, Sad, Disgust	Table 2.4.1 Depression Estimation Table
Proposed Work	Happy, Sad, Disgust, Angry, Surprise, Fear, and Normal	Bayesian Network from the detailed survey results and studies.

The future work related to this research is that we will combine more features set that can extract from humans, like speech, heartbeats, blood pressure, and other human attributes that can be linked with the symptoms of depression.

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