A PRELIMINARY REPORT ON

EEG-BASED EMOTION RECOGNITION USING BRAIN COMPUTER INTERFACE

SUBMITTED TO THE SAVITRIBAI PHULE PUNE UNIVERSITY, PUNE IN THE PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE

OF

BACHELOR OF ENGINEERING (COMPUTER ENGINEERING)

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CERTIFICATE

This is to certify that the project report entitles

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are bonafide students of this institute and the work has been carried out by them under the supervision of **Prof. S. C. Karande** and it is approved for the partial fulfillment of the requirement of Savitribai Phule Pune Uni- versity, for the award of the degree of **Bachelor of Engineering** (Computer Engineering).

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Abstract

Recent developments and studies in brain-computer interface (BCI) technologies have facilitated emotion detection and classification. The aim of BCI is to interpret brain activity into digital form which acts as a command for a computer. The applied domains for these studies are varied, and include such fields as communication, education, entertainment, and medicine. EEG-based brain-computer interface (BCI) system used for emotion recognition is proposed to detect basic emotional states. To understand trends in electroencephalography (EEG)-based emotion recognition system research and to provide researchers with insights into and future directions for emotion recognition systems, this study set out to emotion detection, recognition, and classification. To develop a study which shows the analysis of different emotion recognized.

Keywords:

Brain Computer Interface(BCI), Electroencephalogram(EEG), Emotion Detection, Emotion Recognition

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Chapter 1

INTRODUCTION

A Brain Computer Interface (BCI) is a system that takes a biosignal, measured from a person, and predicts (in real-time) certain aspects of the persons emotional state.Emotion recognition has emerged as a notable research topic in this field as it provides a window on the users internal mental state.There existing many techniques used for automatic emotion recognition that are based on facial expressions,verbal speech, or body language. However, these techniques are limited by the observation of external indicators of emotion, which can be easily subject to deception. For this reason, researchers have been exploring the human emotion based on physiological signals such as electrocardiography (ECG), electromyogram (EMG), electroencephalograph (EEG), galvanic skin response (GSR), or multimodal approaches. These modalities capture the physiological changes associated with emotional states.

To address these problems, the objective of this study is to explore a new method to select suitable subject-specific frequency bands instead of using fixed frequency bands for the emotion recognition. An EEG-based BCI is proposed to detect basic emotional states during viewing facial expressions. We further evaluate the online performance for the emotion recognition.

1.1 MOTIVATION

Today health is an important aspect of human life.Human Emotion reflect human emotional state. The interaction with a person can be made better if we have understanding of emotional state the person. Also the understanding of the emotional state can be used by the

person to make necessary changes and bring a positive impact. There existing many techniques used for automatic emotion recognition that are based on facial expressions, verbal speech, or body language.However, these techniques are limited by the observation of external indicators of emotion, which can be easily subject to deception. For this reason, this study have been exploring the human emotion based EEG signals.

1.2 PROBLEM DEFINITION

BCI are systems that enable any user to exchange information with the environment and control devices by using brain activity. Brain signals can be acquired by means of invasive or non-invasive methods. In the former methods, electrodes are implanted directly in the brain and the signal is acquired directly from the scalp of the user. Despite the existence of several methods to acquire brain signals,the most used method is the electroencephalogram (EEG) because it is non-invasive, portable, inexpensive, and can be used in almost all environments. Recently ,the availability of low cost and increasingly portable EEG equipments in the market has increased. The objective of this study is to recognize and identify different emotion and help user to achieve emotional stability. There are several challenges in using BCI systems for detecting emotions, such as the choice of the method, the channels of acquisition of brain signals that best provide information regarding the emotional state of an individual and reach a good accuracy in the recognition of emotions.

1.3 OBJECTIVE

The objective of this study is to recognize and identify different emotion and help user to achieve emotional stability. This will be done using EEG signals.The different state of mind defines different emotional states and as per the outcomes of this states the user will make decisions and this will help to better understand the human behaviour.

1.4 PROJECT SCOPE AND LIMITATIONS

1.4.1 Project Scope

The scope of this project is limited to only a working prototype.The EEG headset used is only an example which can be used to accurately detect emotion states of different age group of peoples.Using the five channel headset collect EEG data from different subjects which have minimum five year age gap between them and emotion state varies from different age groups system able to detect the emotional state of subject.Using classifier train the model and detected happy and sad emotional state.The scope of the project limited only for two emotional state.

1.4.2 Limitations

1. For any distribution of ele strengths detected on the scalp, there is a literal infinity of possible spatial patterns of electrical activity that could have generated it. This is exacerbated by the fact that the skull is a poor conductor, and so current tends to splash off of it and flow laterally, substantially reducing any potential spatial localization.

2. For any distribution of electrical field strengths detected on the scalp, there is a literal infinity of possible spatial patterns of electrical activity that could have generated it. This is exacerbated by the fact that the skull is a poor conductor, and so current tends to splash off of it and flow laterally, substantially reducing any potential spatial localization.

3. The system working on five channel headset use for collection of the EEG data but accuracy which is less compare to sixteen channel headset.It could be possible to get more accuracy using multiple channels headset.

1.5 METHODOLOGIES OF PROBLEM SOLVING

Emotions are a complex state of feeling that affect about the physical and psychological changes that control our behaviour. Various methods have been used in the past to detect human emotions. The most commonly used techniques such as emotion recognition using text, Emotion Recognition Using Facial Expressions, Emotion Recognition Using Body

Movements and Gestures. Emotion Recognition Using Physiological Signals, EEG based emotion recognition. Out of this methods,we have used Electroencephalography based method for analysis and accuracy. Moreover, to do the processing of EEG signals, we have used Fast Fourier Transform methodology. For the actual classification, many algorithms have been used. However,SVM has been proved to give accurate results. We have tried and testified the same by using SVM and comparing the classification with other algorithms like Naive bayes and Random Forest. While implementing the above methodologies, we have used software engineering approach.

For project problem solving we used software engineering approach which contains four steps:

1. Identify the problem
2. Gather Information
3. Iterate potential solutions
4. Test your solution

These four steps are applied to our project as follows:

1. Identify the problem:

   Emotion plays an important role in our daily life and work. Real-time assessment and regulation of emotion will improve peoples life and make it better. For example, in the communication of human-machine-interaction, emotion recognition will make the process more easy and natural. Another example, in the treatment of patients, especially those with expression problems, the real emotion state of patients will help doctors to provide more appropriate medical care. In recent years, emotion recognition from EEG has gained mass attention.We identified problems which affect the human mental health such as mental disorder and loneliness, stress.This study help to identified emotional state it will help to track mind state and mental health management.Human emotion recognition plays an important role in the interpersonal relationship. Emotional state of a person may influence concentration, task solving and decision making skills, affective computing our vision is to make systems able to recognize and influence human emotions in order to enhance productivity and effectiveness of working with computers.

2. Gather Information:

   We gathered information on human mental health we found that mental disorder which affect human mental health.And psychological disorder also affect both children and adults. We also gathered information on the technologies used,from that EEG based technology is non-invasive which help to recognition of human emotion.

3. Iterate potential solutions:

   Through the obtained information, the potential solutions were using text,facial expression,using body movement and gestures and physiological Signals. However, we needed real-time detection. Hence, we found that EEG was the best solution.

4. Test your solutions:

   we build the model split data into training and testing We tested our solutions on data sets and on real-time streaming data. This shows that the proof of concept model that we built using the data sets can be extended to real-time analysis using EEG signals.

Chapter 2

LITERATURE SURVEY

- **Paper Title:**An EEG-Based brain-computer interface for emotion recognition
  Year:2016
  Author: Jiahui Pan,Yuanqing Li,Jun Wang
  Description : An EEG-based brain-computer interface (BCI) system used for emotion recognition is proposed to detect basic emotional states.This paper explores a new method to select suitable subject-specific frequency bands instead of using fixed frequency bands for the emotion recognition.

- **Paper Title:**Emotions Recognition Using EEG Signals: A Survey
  Year:2017
  Author: Soraia M. Alarcao ,Manuel J. Fonseca
  Description : Survey of the neurophysiological research performed from 2009 to 2016, providing a comprehensive overview of the existing works in emotion recognition using EEG signals. Analysis on main aspects involved in the recognition process (e.g., subjects, features extracted, classifiers), and compare the works per them and praposes a set of good practice recommendations that researchers must follow to achieve reproducible,replicable, well-validated and high-quality results

- **Paper Title:**Initial analysis of brain EEG signal for mental state detection of human being
  Year:2017
  Author: Nisha Vishnupant Kimmatkar ; B. Vijaya Babu

Description : The focus of this paper is the Initial analysis of brain EEG signal for mental state detection of human being. This paper presents initial analysis of EEG signal,databases and emotion classification system for the development of Intelligent Emotion Recognition System.

- **Paper Title:**EEG emotion detection review
  Year:2018
  Author: Lars Rune Christensen ; Mohamed Ahmed Abdullah
  Description : Discusses the most common techniques that can yield to better results, along with discussing the common experiment steps to classify the emotion, starting from collecting the signal, and extracting the features and select the best feature to classify the emotions. Along with highlighting some standing problems in field and potential growth areas.

- **Paper Title:**Emotion recognition from EEG signals through one electrode device
  Year:2017
  Author: Mehmet Ali Sarkaya, Gkhan nce
  Description : This paper presents a novel method to detect human emotion with a single-channel commercial BCI device. The proposed EEG-based emotion recognition system was tested on human test subjects using a deep learning neural network and an accuracy above 87 percent was achieved.

- **Paper Title:**Detecting Emotion from EEG Signals Using the Emotive Epoc Device
  Year:2012
  Author: Rafael Ramirez and Zacharias Vamvakousis
  Description : This paper describes a machine learning approach to detect emotion from brain activity, recorded as electroencephalograph (EEG) with the Emotiv Epoc device.

- **Paper Title:**EEG-based Emotion Recognition during Watching Movies
  Year:2012
  Author: Dan Nie, Xiao-Wei Wang, Li-Chen Shi, and Bao-Liang Lu
  Description : This study aims at finding the relationship between EEG signals and human emotions. EEG signals were used to classify two kinds of emotions, positive and negative.The extracted features from original EEG data were used in a linear

dynamic system approach to smooth the features.The top 100 and top 50 subject-independent features were achieved, with average test accuracies of 89.22 per cent and 84.94 per cent, respectively.

Chapter 3

SOFTWARE REQUIREMENT SPECIFICATION

3.1 INTRODUCTION

3.1.1 Purpose

The system under development will provide a generic method to various emotion recognition and user application. Resulting in a faster and rapid development of recognition applications over various field's . It will help the experts in various domains to track emotional activity done by a specific user and place a monitor on the user if there is any kind of questionable activity detected.

3.1.2 User Class and Characteristics :

In this system there are 4 main entities :

- **Brain Signals:** The brain signals will be taken as input.
- **Preprocessing:** The acquisition of signal will be done in here. Also the pre-processing such as data noise reduction, data cleaning will be done.
- **Processing:** The feature selection of the pre-processed data is made which leads to different pattern generation. After the pattern recognition the feature is classified.
- **Emotion:** The emotions recognized will be taken as output entity .

Assumptions:

- Select the data for application.
- Pre-process the acquired data.
- This data is processed with the help of machine learning algorithm for pattern generation.
- As per the generated pattern the the feature will be extracted which will lead to the classification.
- Different emotion will be classified.

Dependencies:

- Python libraries: Python libraries are required to preprocess the real-time streamed data and are used for training the classifier for detecting emotions through EEG
- EEG Headset: An EEG headset is required to obtain the real-time brainwave data of the driver
- Bluetooth: Bluetooth is required to transmit data wirelessly from the headset to preprocessing software

3.2 FUNCTIONAL REQUIREMENTS :

Our system mainly depends on the correct installment and attachment of the EEG headset which will be the prime source for EEG information retrieval. Accordingly, the following are the functional requirements of our proposed system:

3.2.1 System Feature 1

Brain Signals:

The electrodes are placed on the scalp to measure the amplitude of electric impulse. These signals can be classified based on the frequency bands. The different rhythms of brain are delta, theta alpha, beta and gamma.

RHYTHYM	FREQUENCY RANGE (Hz)	AMPLITUDE (μv)	STATE OF MIND
DELTA	Up to 4	High amplitude (20-200)	Deep sleep
THETA	4-8	More than 20	Emotional stress, drowsiness and sleep in adults
ALPHA	8-13	30-50	Relaxed awareness
BETA	13-30	5-30	Active thinking, active attention, alert
GAMMA	Above 31	Less than 5	Mechanism of consciousness

Figure 3.1: Different Brain Rhythms

3.2.2 System Feature 2

Data Acquisition System:

A device is used to capture scalp EEG signals for data acquisition user wears an EEG cap with 5 electrodes.Artifacts and noise in the signal requires the efficient detection and removal.The acquired signal then acts as an input to the filter. The filter filters out the noise signal from the signal and prevents the distortion of the signal.

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3.2.3 System Feature 3

Data Processing and Algorithm:

The processing of EEG signals in a BCI system is divided into two parts: the selection of the signal characteristics and classification of these characteristics. The choice of the method to be used in the first step depends if the signal characteristics are time or frequency domain. In the second stage, the choice of method is independent of the signal domain.The analysis methods and algorithms use for feature extraction and classification.

3.2.4 System Feature 4

Signal characteristics classification:

The EEG signals processing is the classification of the signals into signals of interest for a

given application using translation algorithms.Examples of translation algorithms include linear discriminant analysis, k-nearest neighbor, support vector machine, and artificial neural network.

3.2.5 System Feature 5

Emotion Recognized:

In this stage different emotions are recognized based on pattern which is classified using classification algorithm.

3.3 EXTERNAL INTERFACE REQUIREMENTS

3.3.1 User Interfaces

The system does not require interfaces. A User Interface(UI), however, is available by EmotivePRO which can be used while doing research. The UI displays the continuous temporal spectral power of brain waves. The line graph will fluctuate based on eye blinks and spectral power density. There are many features available such as view a real time display of EMOTIV headset data streams including raw EEG, Performance Metrics (0.1Hz), motion data, data packet acquisition and loss, and contact quality in this UI which can be used for aiding our project in visual representation rather than graphical and mathematical representation.

3.3.2 Hardware Interfaces

1. EEG Headset
2. Electrodes

3.3.3 Software Interfaces

1. A module pre-trained on driver EEG data to detect emotional state of a subject
2. EEG to bluetooth module driver software is required

3.3.4 Communication Interfaces

Method for communication:

Wireless : Many forms including Bluetooth 4.0; backward compatible with 3.0

EEG headset transmits data wirelessly at 128 or 256 Hz, so we can record high resolution brain data outside of the laboratory and without being tethered to a computer.The EEG headset communicate wirelessly with the Bluetooth module driver software.Headset compatible with Bluetooth Low Energy.The software received data help of proprietary USB receiver which having 2.4GHz band.

3.4 NON FUNCTIONAL REQUIREMENTS:

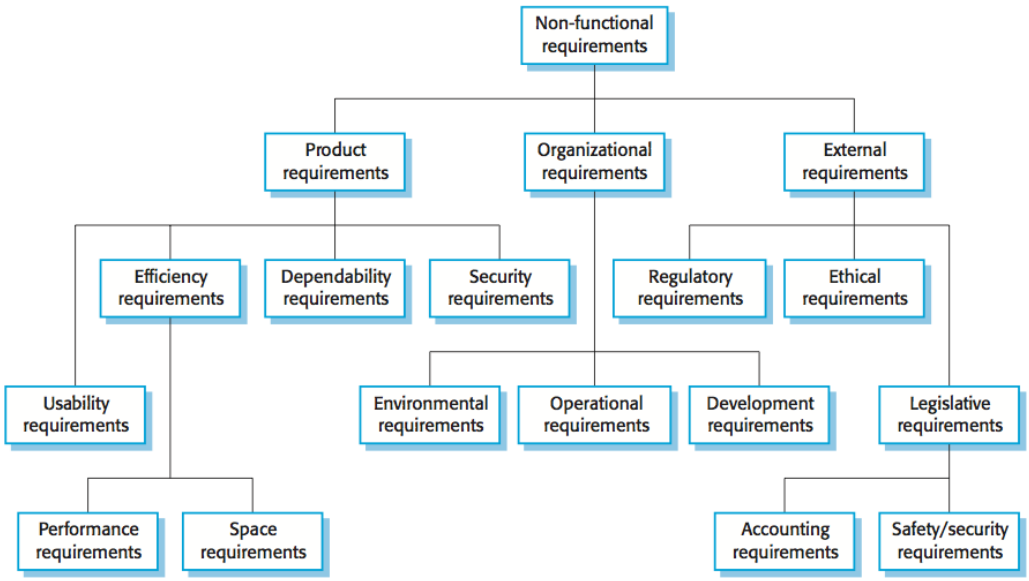


Figure 3.2: Non Functional Requirement

Security:

Security requirements ensure that the software is protected from unauthorized access to the system and its stored data. It considers different levels of authorization and authentication across different users roles. For instance, data privacy is a security characteristic that describes who can create, see, copy, change, or delete information. Security also includes protection against viruses and malware attacks.

Reliability:

Reliability defines how likely it is for the software to work without failure for a given

period of time. Reliability decreases because of bugs in the code, hardware failures, or problems with other system components. To measure software reliability, you can count the percentage of operations that are completed correctly or track the average period of time the system runs before failing.

Performance:

Performance is a quality attribute that describes the responsiveness of the system to various user interactions with it. Poor performance leads to negative user experience. It also jeopardizes system safety when its is overloaded.

Availability:

Availability is gauged by the period of time that the systems functionality and services are available for use with all operations. So, scheduled maintenance periods directly influence this parameter. And its important to define how the impact of maintenance can be minimized. When writing the availability requirements, the team has to define the most critical components of the system that must be available at all time. You should also prepare user notifications in case the system or one of its parts becomes unavailable.

3.4.1 Safety Requirements

The given system requires no login or other personal credentials. Hence there are no hard-security requirements. Keeping the drivers privacy in mind, the EEG data about his emotional state will be used only for analysis purposes i.e. security of his/her personal information will be maintained.

- **Goal :**
  A goal is a statement of the importance of achieving a desired target regarding some behavior, datum, characteristic, interface, or constraint. It is above the level of a policy and not sufficiently formalized to be verifiable.
- **Policy :**A policy is any strategic decision that establishes a desired goal.

- **Requirement :**A requirement is any mandatory, externally observable, verifiable (e.g., testable), and validatable behavior, datum, characteristic, or interface.

3.4.2 Software Quality Attributes

The following are the quality attributes considered:

- **Reliability:**

  Measure if product is reliable enough to sustain in any condition. Should give consistently correct results. Product reliability is measured in terms of working of project under different working environment and different conditions.

- **Maintainability:**

  Different versions of the product should be easy to maintain. For development it should be easy to add code to existing system, should be easy to upgrade for new features and new technologies time to time. Maintenance should be cost effective and easy. System be easy to maintain and correcting defects or making a change in the software.

- **Usability:**

  Different versions of the product should be easy to maintain. For development it should be easy to add code to existing system, should be easy to upgrade for new features and new technologies time to time. Maintenance should be cost effective and easy. System be easy to maintain and correcting defects or making a change in the software.

- **Portability:**

  This can be measured in terms of Costing issues related to porting, Technical issues related to porting, Behavioral issues related to porting.

- **Correctness:**

  Application should be correct in terms of its functionality, calculations used internally and the navigation should be correct. This means application should adhere to functional requirements.

- **Efficiency:**

  To Major system quality attribute. Measured in terms of time required to complete any task given to the system. For example system should utilize processor capacity, disk space and memory efficiently. If system is using all the available resources then user will get degraded performance failing the system for efficiency. If system is not efficient then it can not be used in real time applications.

- **Integrity or Security:**

  Integrity comes with security. System integrity or security should be sufficient to prevent unauthorized access to system functions, preventing information loss, ensure that the software is protected from virus infection, and protecting the privacy of data entered into the system.

- **Testability:**

  System should be easy to test and find defects. If required should be easy to divide in different modules for testing.

- **Flexibility:**

  Should be flexible enough to modify. Adaptable to other products with which it needs interaction. Should be easy to interface with other standard 3rd party components.

- **Reusability:**

  Software reuse is a good cost efficient and time saving development way. Different code libraries classes should be generic enough to use easily in different application modules. Dividing application into different modules so that mod-

ules can be reused across the application.

- **Interoperability:**

  Interoperability of one system to another should be easy for product to exchange data or services with other systems. Different system modules should work on different operating system platforms, different databases and protocols conditions. Applying above quality attributes standards we can determine whether system meets the requirements of quality or not.

3.5 SYSTEM REQUIREMENTS

3.5.1 Database Requirements

For training the classifiers of the emotion detection module, the system requires a EEG based happy and sad state data set which is obtained from the driver.Database contain different feature such as subject age and values from different channel sensors.It has label column which labeling base on emotion of person like happy and sad.

3.5.2 Software Requirement:

The system is implemented using Python programming language.
The primary software requirements for the system are as follows:

1. EmotivePRO:

   The EmotivePRO software tool for visualizing, recording,and streaming of EEG data from headset.

   The following are the functions:

   (a) Data acquisition:

   View a real time display of EMOTIV headset data streams including raw EEG, Performance Metrics (0.1Hz), motion data, data packet acquisition and loss, and contact quality. Save recordings to our secure cloud storage and playback or export for analysis.

(b) Marking:

Define and insert timed markers into the data stream, including on-screen buttons and defined serial port events. Markers are stored in the EEG data files and can be viewed in real time and playback modes.

(c) Quick Analysis:

Customize and view frequency data for live or recorded data with automatic FFT and power band graphs. Get results without having to export your data.

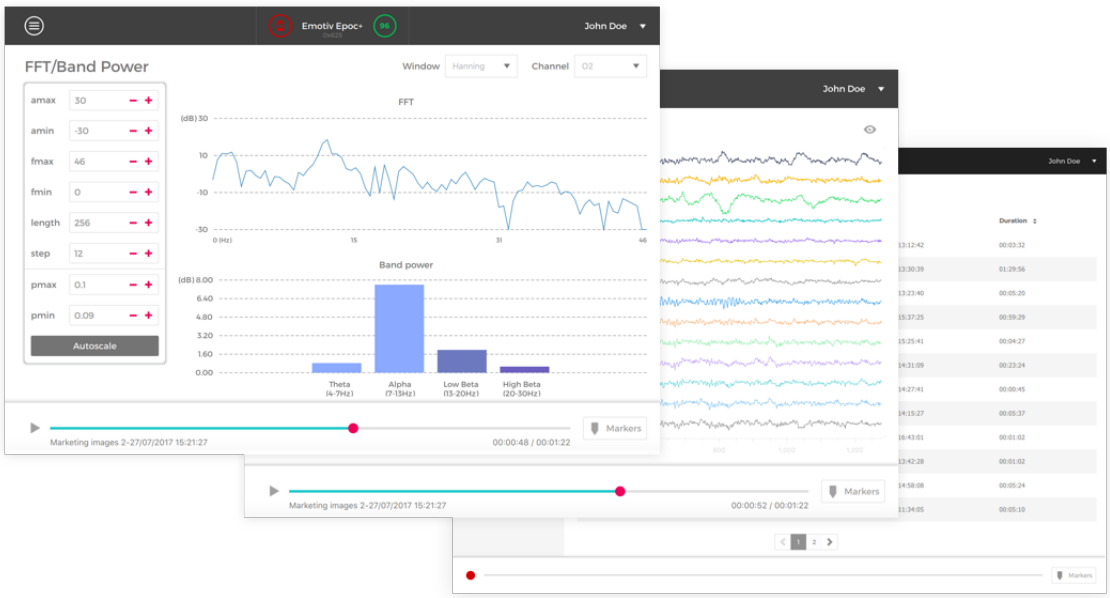


Figure 3.3: EmotivPRO

2. Python 3.7:

Python 3.7 is used for the code implementation of both the modules. It uses different packages needed for the project like scikit learn, numpy, pandas, graphviz,spectrum, preprocessing and so on. Scikit-learn is one the most popular ML libraries. It supports many supervised and unsupervised learning algorithms.Scikit-learn is a more-than-sufficient tool to work, for implementing more complex algorithms. The most important package used is the MNE package. It is an open-source Python software for exploring, visualizing, and analyzing human neurophysiological data like MEG, EEG, sEEG, ECoG, and more.

3. EEGLAB:

   The EEGLAB toolbox we used for preprocessing EEG data. EEGLAB is a MATLAB toolbox distributed under the free GNU GPL license for processing data from electroencephalography (EEG), magnetoencephalography (MEG), and other electrophysiological signals. Along with all the basic processing tools, EEGLAB implements independent component analysis (ICA), time/frequency analysis, artifact rejection, and several modes of data visualization.

3.5.3 Hardware Requirements:

The proposed system requires an EEG headset.The EEG headset provied by collage. EMOTIV is a bioinformatics company advancing understanding of the human brain using electroencephalography (EEG).We have used a headset with 5 channels i.e. electrode locations.This headset makes use of dry electrodes since gel-based electrodes have a high setup time and require accurate knowledge of the positions of the EEG electrodes. This would imply that the driver would have to have detailed knowledge about the electrode positions, thus causing inconvenience. Thus, hardware requirements of EMOTIV insight headset as:

- EEG sensors: 5 channels: AF3, AF4, T7, T8, Pz
- Wireless: Bluetooth Low Energy Includes proprietary USB receiver 2.4GHz band
- Frequency response: 0.5-43Hz, digital notch filters at 50Hz and 60Hz
- Motion sensors:Accelerometer,Gyroscope,Magnetometer,Sampling rate 64 Hz,Resolution 16 bits
- Battery: Internal Lithium Polymer battery 480m
- Supported platforms:
  Windows: 7,8,10; 8GB RAM; 500MB available disk space
  MAC: OS X; 8GB RAM; 500MB available disk space
  iOS: 9 or above; iPhone 5+ Android: device with Bluetooth Low Energy

3.6 ANALYSIS MODELS: SDLC MODEL TO BE APPLIED

Software Development Life Cycle:

A software development life cycle is a essentially a series of steps, or phases, that provide a model for the development and lifecycle management of an application or piece of software .it is an well defined, structured sequence of stages in software engineering to develop the intended software product or module.

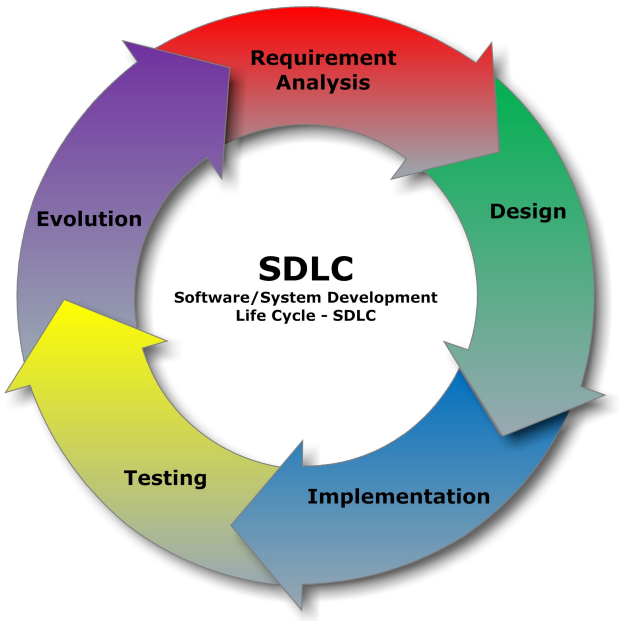


Figure 3.4: SDLC model

3.6.1 SDLC Activities

- **Communication :**

  It is an first step where the user initiates the request for desired software product. He contacts the service provider and tries to negotiate the terms. He submits his request to the service providing organization in writing.

- **Requirement Gathering :**

  This steps onwards the software development term works to carry on the project . the

requirements contemplated and segregated into user requirements, system requirements and functional requirements. The requirements are collected using a number of practioners. After the requirement gathering developer make the documentation . Once the requirement analysis is done the next step is to clearly define and document the product requirements and get them approved from the customer or the market analysts. This is done through an SRS (Software Requirement Specification) document which consists of all the product requirements to be designed and developed during the project life cycle.

- **Designing The Product Architecture :**

  SRS is the reference for product architects to come out with the best architecture for the product to be developed. Based on the requirements specified in SRS, usually more than one design approach for the product architecture is proposed and documented in a DDS - Design Document Specification.

- **Building or Developing the Product :**

  In this stage of SDLC the actual development starts and the product is built. The programming code is generated as per DDS during this stage. If the design is performed in a detailed and organized manner, code generation can be accomplished without much hassle.

- **Testing the Product :**

  This stage is usually a subset of all the stages as in the modern SDLC models, the testing activities are mostly involved in all the stages of SDLC. However, this stage refers to the testing only stage of the product where product defects are reported, tracked, fixed and retested, until the product reaches the quality standards defined in the SRS.

- **Deployment in the Market and Maintenance :**

  Once the product is tested and ready to be deployed it is released formally in the appropriate market. Sometimes product deployment happens in stages as per the business strategy of that organization.

3.6.2 SDLC Models

Iterative Model Design

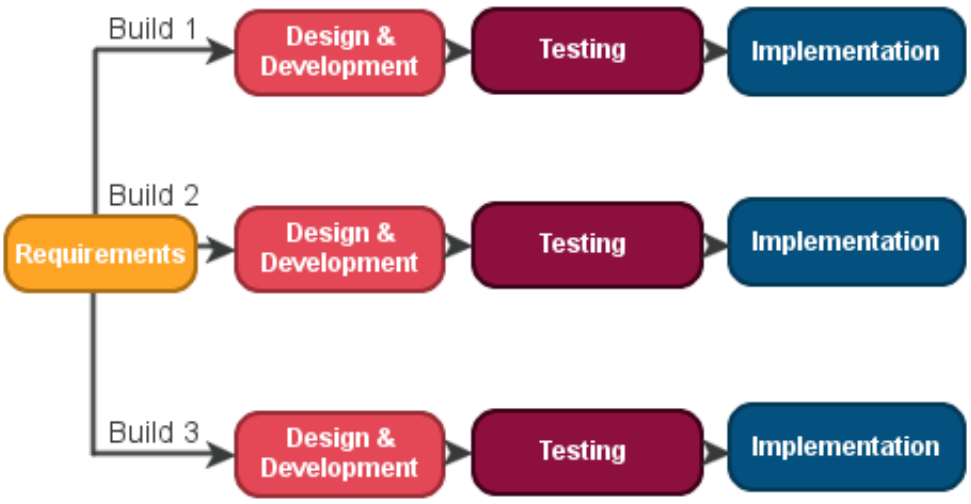


Figure 3.5: Iterative model

This model is used in our project. Iterative process starts with a simple implementation of a subset of the software requirements and iteratively enhances the evolving versions until the full system is implemented. At each iteration, design modifications are made and new functional capabilities are added. The basic idea behind this method is to develop a system through repeated cycles (iterative) and in smaller portions at a time.

Chapter 4

SYSTEM DESIGN

4.1 SYSTEM ARCHITECTURE

Our system is an implementation of the domain: Brain-Computer Interaction. BCI deals with EEG (Electroencephalogram) signals. These signals are fired by the neurons in the brain when they interact with each other. These electrical impulses can be measured using an EEG headset. Thus using BCI as the base, the system architecture diagram 4.1 of our project is as shown below: The system first extracts EEG signals from the headset worn

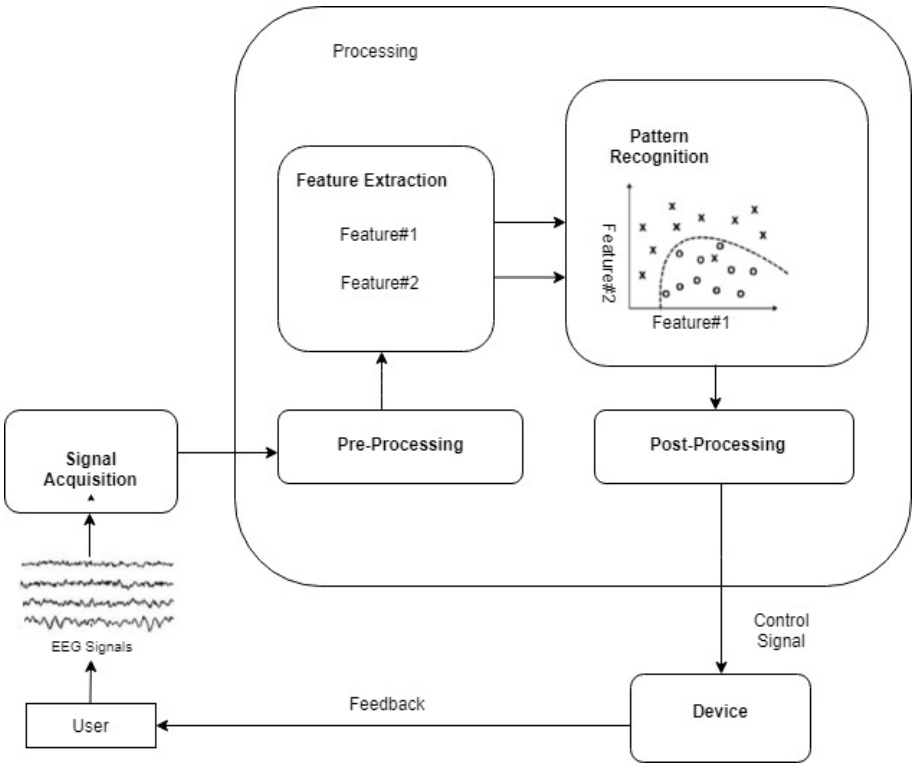


Figure 4.1: System Architecture

by the driver. After the required Preprocessing then preprocess data is given to the trained classifier which train and test the data set and classify the emotional state of person.Also this system give Feedback to the person.

4.1.1 Mathematical Model

. Let S denote the system. The tuple which represents the system is depicted as:

$S : \{I, O, F, Sc, Fc\}$

where:

I is Set of Inputs

o is Set of Outputs

F is Functions

Sc is Success Cases

Fc is Failure Cases

Detailed Description:

$I = \{I1, I2, I3, I4, I5\}$

$I1$: Electroencephalography Data

$I2$: Classified happy Data

$I3$: Classified sad Data

$I4$: Labels for happy state

$I5$: Labels for sad state

$O = \{O1, O2\}$

$O1$: Happy Emotion Prediction

$O2$: Sad Emotion Prediction

$F = \{F1, F2\}$

$F1$: Preprocessing

$F2$: Emotion Classification

$Sc = \{Sc1, Sc2\}$

$Sc1$: Proper preprocessing of EEG Data

$Sc2$: Accurate classification of Emotion

$Fc = \{Fc1, Fc2\}$

$Fc1$: Failure in preprocessing

$Fc2$: Inaccurate classification of Emotion

4.2 DATA FLOW DIAGRAM

4.2.1 DFD Level 0

A level 0 data flow diagram (DFD), also known as a context diagram, shows a data system as a whole and emphasizes the way it interacts with external entities. This DFD level 0 example shows how such a system might function within a typical workflow. The DFD level 0 shows single process node and its connection to external entity.
The diagram below shows a basic input and output of the system.

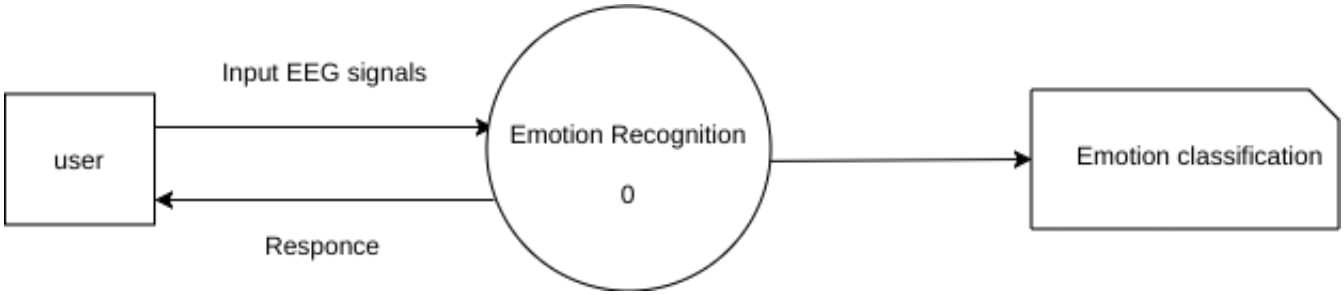


Figure 4.2: DFD Level 0

4.2.2 DFD Level 1

DFD level 1 provides more detail breakout of pieces of the context level diagram. A level 1 data flow diagram (DFD) is more detailed than a level 0 DFD but not as detailed as a level 2 DFD. It breaks down the high level processes of the context level diagram into subprocesses that can then be analyzed and improved on a more intimate level.

The diagram below shows a detailed flow of data through the entire system

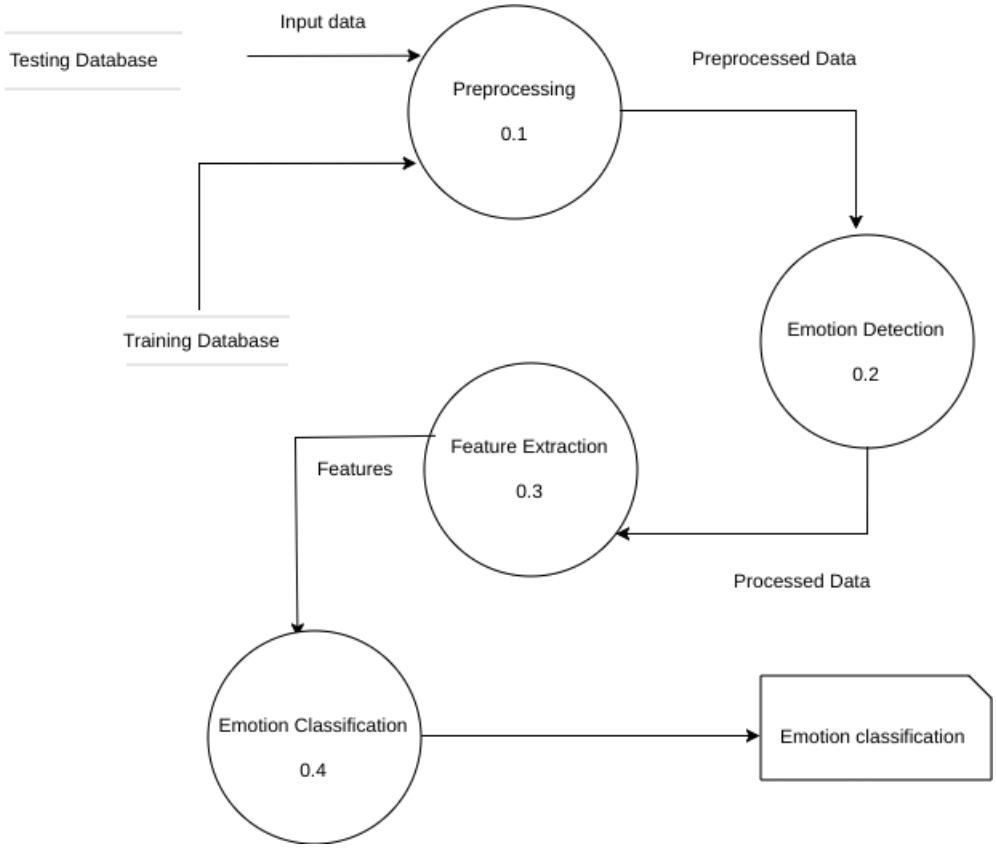


Figure 4.3: DFD Level 1

4.2.3 DFD Level 2

A level 2 data flow diagram (DFD) offers a more detailed look at the processes that make up an information system than a level 1 DFD does. It can be used to plan or record the specific makeup of a system.

The diagram below shows a detailed flow of data in the Block Creation Process

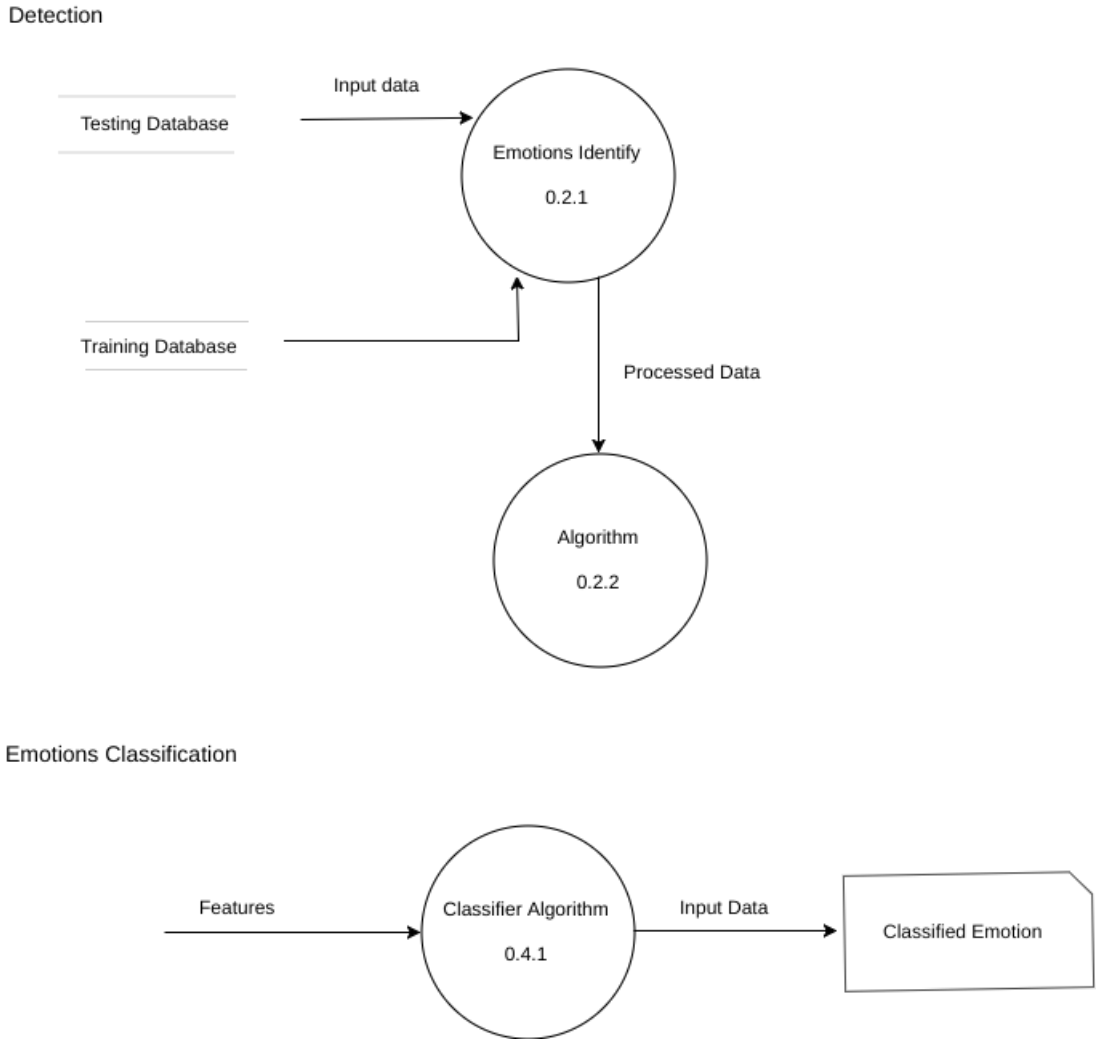


Figure 4.4: DFD Level 2

4.3 UML DIAGRAMS

4.3.1 Use case Diagram

Use case diagrams are usually referred to as behavior diagrams used to describe a set of actions (use cases) that some system or systems (subject) should or can perform in collaboration with one or more external users of the system (actors).Representing the goals of system-user interactions Defining and organizing functional requirements in a system Specifying the context and requirements of a system Modeling the basic flow of events in a use case

In our system we have 2 primary actors: User system . The various tasks performed by them are described in the diagram below.

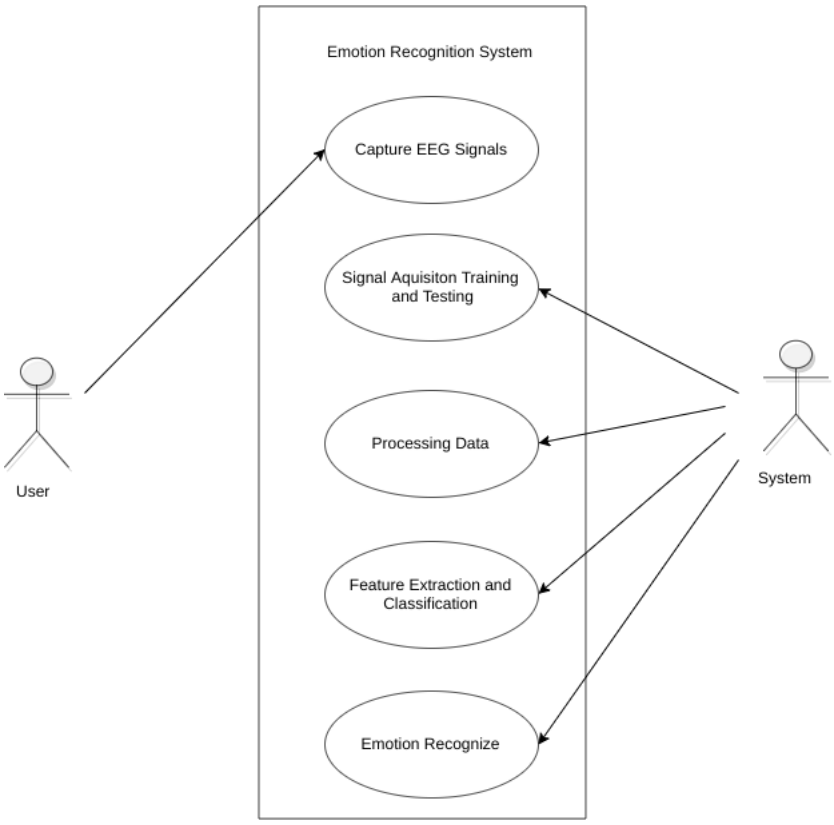


Figure 4.5: Use Case Diagram

4.3.2 Class Diagram

The class diagram is a central modeling technique that runs through nearly all object-oriented methods. This diagram describes the types of objects in the system and various kinds of static relationships which exist between them.

The are two main entities in our system. These major entities are modelled as classes in the diagram below. These entities are User and the system. The various operations done by these entities are mentioned in the operations field of the class.

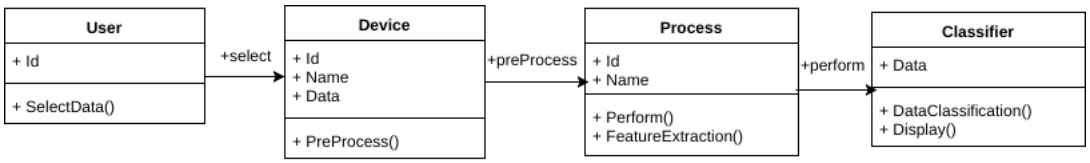


Figure 4.6: Class Diagram

4.3.3 Activity Diagram

Activity diagram is another important diagram in UML to describe the dynamic aspects of the system. Activity diagram is basically a flowchart to represent the flow from one activity to another activity. The activity can be described as an operation of the system. The control flow is drawn from one operation to another.

The diagram below shows a flow of major activities in the system.

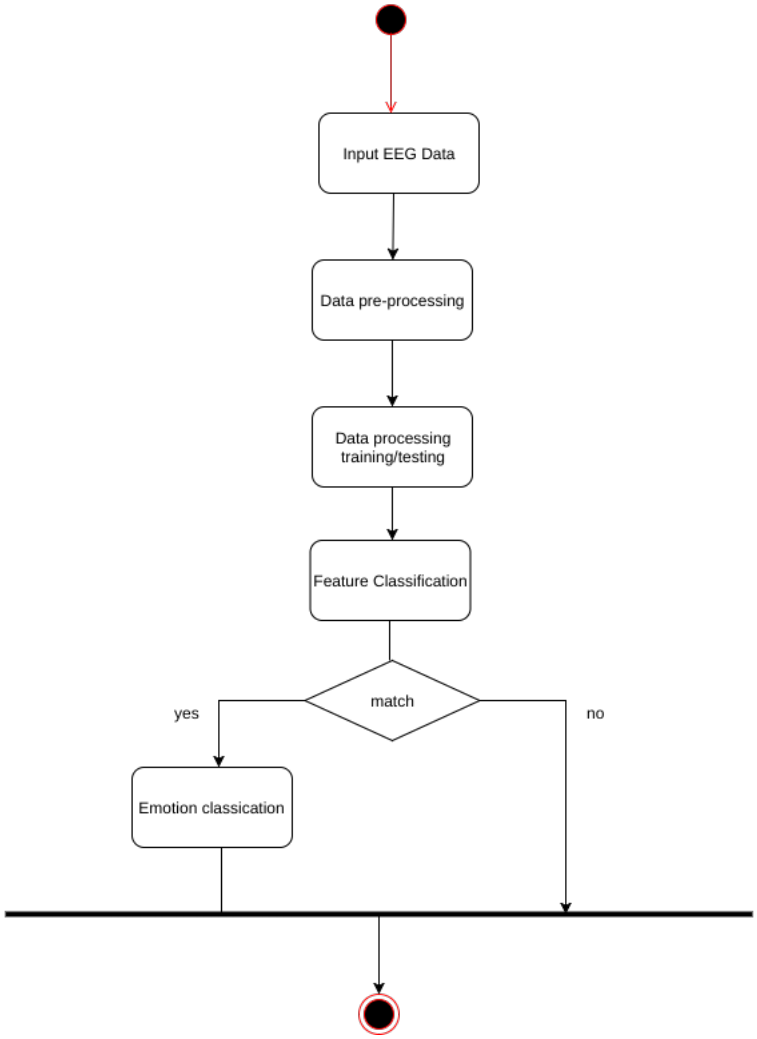


Figure 4.7: Activity Diagram

4.3.4 Sequence Diagram

Sequence diagrams are sometimes called event diagrams or event scenarios.A sequence diagram shows, as parallel vertical lines (lifelines), different processes or objects that live simultaneously, and, as horizontal arrows,the messages exchanged between them, in the order in which they occur.

The diagram below shows the exchange of messages between various entities in the system.

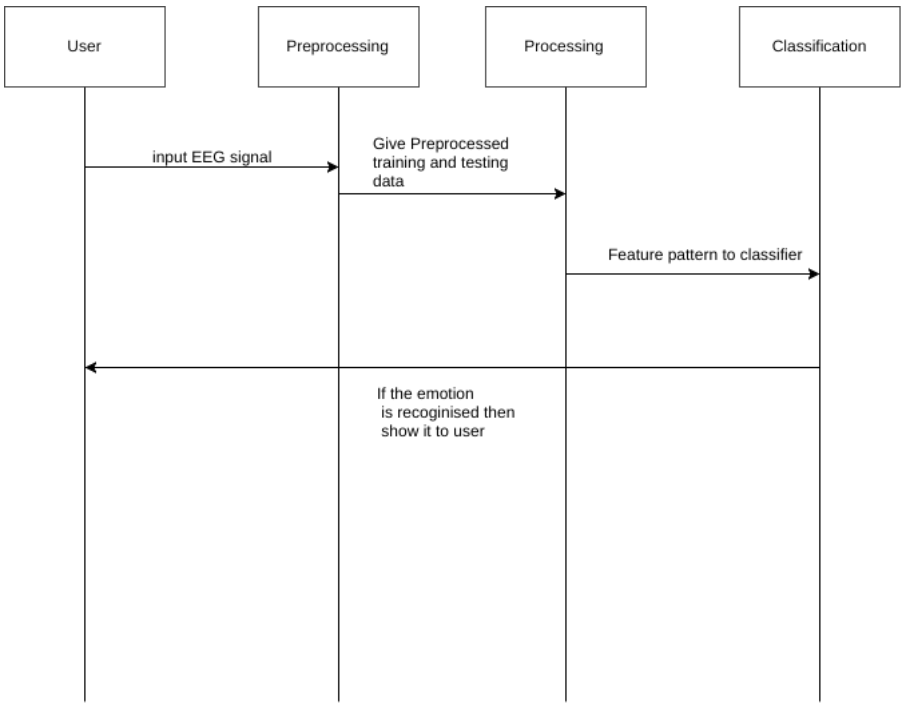


Figure 4.8: Sequence Diagram

4.3.5 Deployment Diagram

A deployment diagram in the Unified Modeling Language models the physical deployment of artifacts on nodes.To describe a web site, for example, a deployment diagram would show what hardware components (”nodes”) exist (e.g., a web server, an application server, and a database server), what software components (”artifacts”) run on each node (e.g., web application, database), and how the different pieces are connected (e.g. JDBC, REST, RMI).

The diagram below shows an architecture that will be required for the development and deployment of the system.

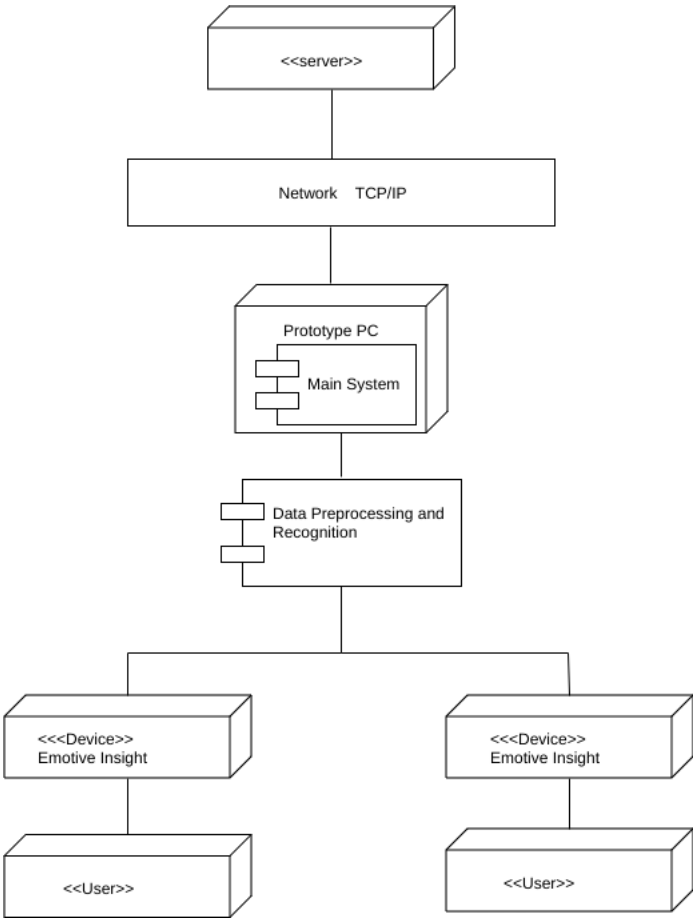


Figure 4.9: Deployment Diagram

4.3.6 Component Diagram

Component diagram depicts how components are wired together to form larger components or software systems.They are used to illustrate the structure of arbitrarily complex systems.

The diagram below shows the major components involved in the system.

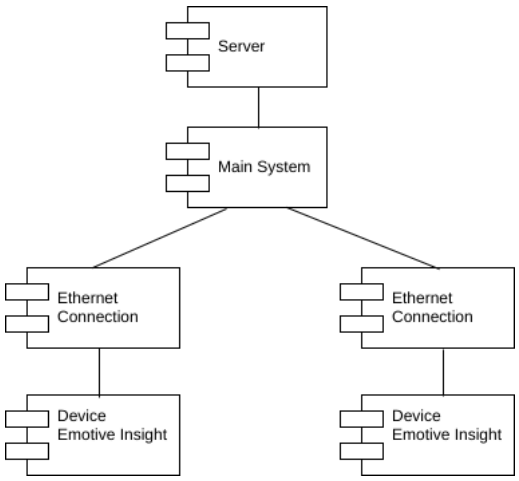


Figure 4.10: Component Diagram

Chapter 5

PROJECT PLAN

5.1 PROJECT ESTIMATE

The estimation is a process of giving value of things approximately which can be used for further transactions. This often can be considered as a rough calculation for a transaction.

The project estimation is a rough idea of how much input a project is going to need. It gives the developer and the client/customer a idea about the value needed to build a project. This estimates can be used for considering whether a project is feasible in real time.

The project estimation includes following parameters.

5.1.1 Time

The time is a essential entity in any project estimation. The project is divided and completed in many phases. The total time for the overall project completion undergoing various phases of development is given as ten months approximately.

5.1.2 Efforts

Since the characteristics of the each project dictate the distribution of efforts, thirty per cent of the effort are spent on Analysis and Design of the project. A similar amount of efforts are spent on Testing the project. The Coding of the project can accommodate about forty per cent of the efforts.

5.1.3 Cost

The cost of the project is calculated in terms of effort applied and the resources used. It can be broken down as follow: EEG Headset: The EMOTIV INSIGHT is a EEG device designed for Brain-Computer Interface (BCI). It can be purchased from EMOTIV website and cost 299 dollars.

5.1.4 Project Resources

The other parameters that account for project estimation are:

- Hardware Resources
    1. The EMOTIV Insight 5 Channel Mobile EEG.
    2. Battery: Internal Lithium Polymer battery 480m
    3. Wireless: Bluetooth Low Energy Includes proprietary USB receiver 2.4GHzband
- Software Resources
    1. Windows: 7,8,10; 8GB RAM; 500MB available disk space
    2. Python 3.7
    3. EmotivPRO
- Man/Month
- Technology

5.2 RISK MANAGEMENT

Risk management is the process of identification, analysis and acceptance or mitigation of uncertainty in decisions. Project risk management is a process that includes the identification of potential risk and the evaluation of the potential impact of the risk and a to eliminate or minimize the impact of the risk eventsoccurrences that have a negative impact on the project.

5.2.1 Risk Identication

Identifying and managing the risks and implications associated with any project is a vital step in reducing the risks impact on the overall progression of the project.Identifying the risks implications early on in the project allows preventative actions to be put in place the minimize the likelihood of the risks occurring.

Table 5.1: Risk Identication

ID	Description	Source	Category
1.	Hardware Failure	Damaged Components	High
2.	Failure of real time data transfer	Transfer lag	Low
3.	Negligence towards wearing the headset	User	High

5.2.2 Risk Analysis

The risks associated with this project are:

- Loss of code.
- Loss of project documents.
- Project failure risk: The project is either abandoned.
- Over payment risk: You end up paying much more than you should for the project
- Reputation risk: There is a chance that the recording done might have flaws in it.The output so generated based on this input will give wrong result.This could lead questionability to our work.
- Opportunity risk: The time spent and effort developing something when another solution would have been far more successful.
- Deadend risk: The device used is a five node. The EEG data is recorded using the electrode which have a contact to human scalp. The possibility that the scalp generates a different EEG signal is infinite. So the chance that the dataset generated having a no future use or the credibilty.
- ROI Risk: The study that you do is not justified in terms of investment.

5.2.3 Overview of Risk Mitigation, Monitoring and Management

The goal of the risk mitigation, monitoring and management plan is to identify as many potential risks as possible. Risk Mitigation is a problem avoidance activity, Risk Monitoring is a project tracking activity,Risk Management includes contingency plans that risk will occur.The following actions will be taken to reduce risks in this project:

- Github to backup code and prevent loss, use own initiative to keep on top of project plan
- Regularly make backups of project report and important documents, if an unplanned day off occurs make up for work lost.
- Replacement of damaged devices
- Immediately storing the data and applying processing on it
- Fix the headset on the head

5.3 PROJECT SCHEDULE

Project scheduling is a mechanism to communicate what tasks need to get done and which organizational resources will be allocated to complete those tasks in what time-frame.A project is made up of many tasks, and each task is given a start and end (or due date), so it can be completed on time.
Project scheduling occurs during the planning phase of the project.

5.3.1 Project Task Set

The primary tasks included during the project stages are:

1. Problem Statement Formulation
2. Concept Scoping and Planning
3. Risk Assessment
4. Proof of Concept

5. Implementation of each module
6. Integration of modules with the main system
7. Testing and Deployment

5.3.2 Timeline Chart

The following figure shows the entire timeline of the project. We have drawn the Gantt chart for the timeline as below:

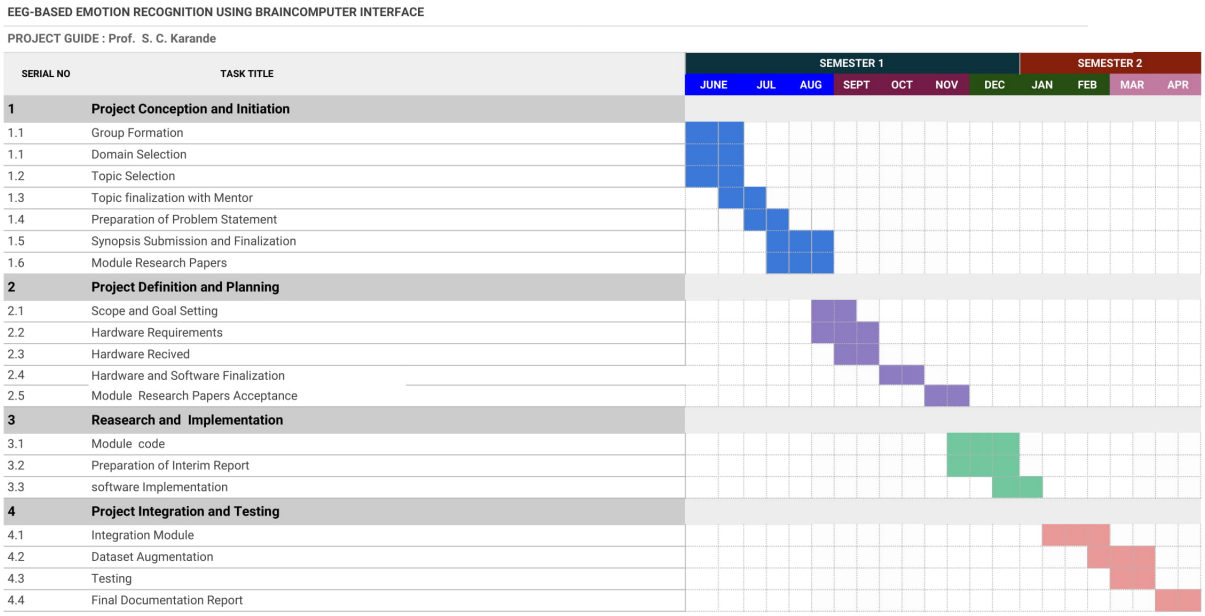


Figure 5.1: Gantt Chart for Project Timeline

5.4 TEAM ORGANIZATION

5.4.1 Team Structure

Our project team consisted of the following team members, all from the Computer Department:

1. Rishikesh Kakad
2. Vaibhav Gole
3. Yoganand Kanhed

Along with these team members, our internal guide Prof. S. C. Karande Mam was the most important and indispensable part of the team who provided us with sound guidance, motivation, support and deadlines without whom our project would not have been timely managed.

5.4.2 Management, Reporting and Communication

The management of the timely completion of tasks was seen to by our internal guide. We, the group members of the project managed the entire project by splitting it into multiple unit tasks and by assigning deadlines to them. The reporting of the project status to our guide was done as and when the unit tasks were accomplished. Similarly, the reporting was timely and up to date. The communication between the group members was through college meetings, discussions, emails and text message groups. The distribution of tasks, queries and integration was resolved through communication. Similarly,the communication of the members with Prof. S. C. Karande Mam was through reviews, personal meetings and emails.

Chapter 6

PROJECT IMPLEMENTATION

The project can be divided into two modules as:

1. Emotion Recognition Module (Happy and Sad)
2. Age based Emotion Recognition

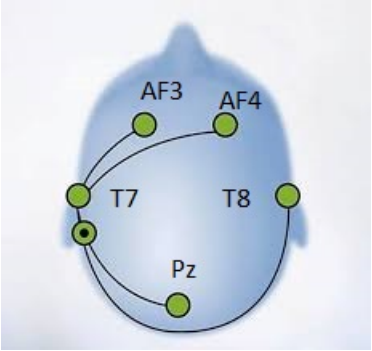


Figure 6.1: Headset Overview

6.0.1 Emotion Recognition Module

Emotion recognition is a technique used in software that allows a program to ”read” the emotions on a human using advanced processing. Emotion plays an important role in our daily life and work. Real-time assessment and regulation of emotion will improve peoples life and make it better. For example, in the communication of human-machine-interaction, emotion recognition will make the process more easy and natural. Another example, in the treatment of patients, especially those with expression problems, the real emotion state of patients will help doctors to provide more appropriate medical care.
In our module we have used the emotiv insight device to record the data.

6.0.2 Age based Emotion Recognition

The age can be simply stated as length of an existence extending from the beginning to any given time. The emotion can be seen as a form of natural meduim of expression. Age considering a important factor in human interaction can be considered for predicting the human behaviour. It can also be used for further predicting the cognitive ability as well as cognitive impairment. In this module we have tried to co-relate the emotion and age of the subject.

6.1 OVERVIEW OF PROJECT MODULE

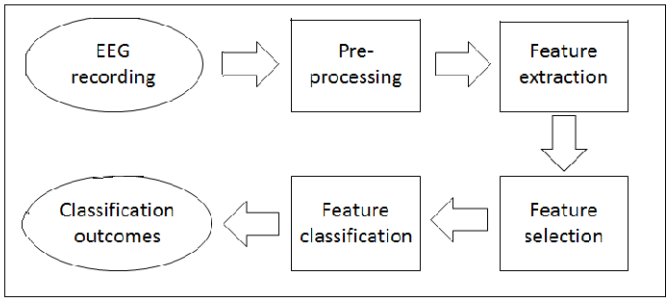


Figure 6.2: System Overview

6.1.1 EEG Data Recording

EEG and motion data are stored by EmotivPRO in a standard binary format, EDF, which is compatible with many EEG analysis programs.

6.1.2 Pre-processing

Convert EDF to CSV:

1. Navigate to the Recordings screen
2. Click on Convert EDF to CSV icon beside the search field
3. Select the EDF file you would like to convert

4. Wait for the file to be converted. Once conversion has completed you will see a verification message appear

5. Find the output CSV file in the same location with the source EDF file

6.1.3 Feature Extraction

Feature extraction is the process of collecting discriminative information from a set of samples. Feature extraction is the transformation of original data to a data set with a reduced number of variables, which contains the most discriminatory information. Feature extraction involves reducing the amount of resources required to describe a large set of data

6.1.4 Feature Selection

Feature Selection is the process where you automatically or manually select those features which contribute most to your prediction variable or output in which you are interested in.Feature Selection is one of the core concepts in machine learning which hugely impacts the performance of your model

6.1.5 Feature Classification

Feature classification is the grouping of features based on some criteria. Feature classification is a data mining task, which can be applied to the data sets with class labels already known for the target attribute or dependent attribute (after preprocessing).

6.2 TOOLS AND TECHNOLOGIES USED

6.2.1 Hardware Tools

- The EMOTIV Insight 5 Channel Mobile EEG.
- Battery: Internal Lithium Polymer battery 480m
- Wireless: Bluetooth Low Energy Includes proprietary USB receiver 2.4GHzband

6.2.2 Software Tools

- EmotivPRO
- Python 3.0
- Ubuntu 16.04
- Windows: 7,8,10; 8GB RAM; 500MB available disk space

6.3 ALGORITHM DETAILS

6.3.1 Classification

We have used the Support Vector Machine , Decision Tree and KNN for the classification purpose. We concluded that KNN shows the highest accuracy with EEG data. The algorithms compared are explain below:

1. **Support Vector Machine(SVM) :**

   The objective of the support vector machine algorithm is to find a hyperplane in an N-dimensional space(NŁŁthe number of features) that distinctly classifies the data points. Support Vector Machine (SVM) is a supervised machine learning algorithm which can be used for both classication or regression challenges.However, it is mostly used in classication problems.

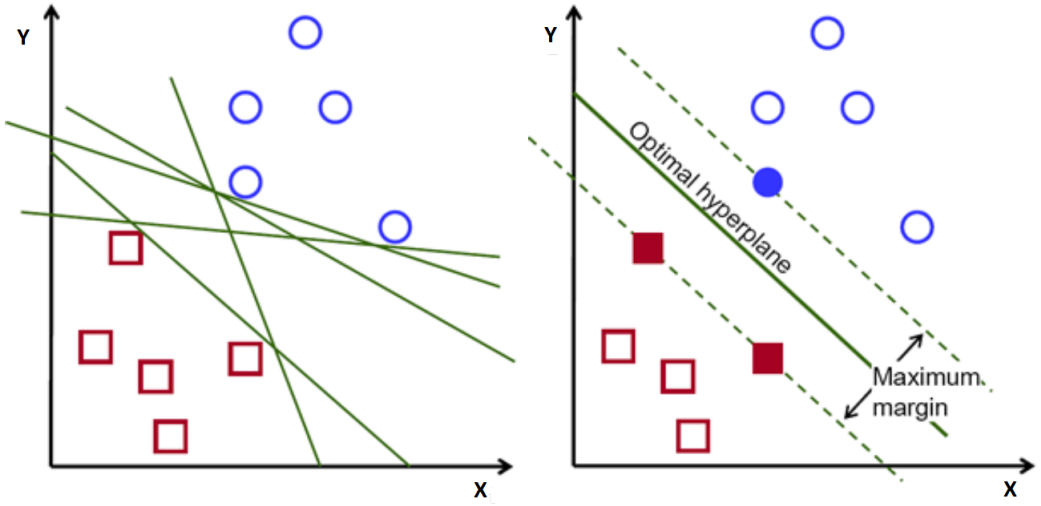


Figure 6.3: Support Vector Machine

2. **Decesion Tree :**

   A decision tree is a decision support tool that uses a tree-like graph or model of decisions and their possible consequences, including chance event outcomes, resource costs, and utility. It is one way to display an algorithm that only contains conditional control statements.

   A decision tree is a flowchart-like structure in which each internal node represents a test on an attribute (e.g. whether a coin flip comes up heads or tails), each branch represents the outcome of the test, and each leaf node represents a class label (decision taken after computing all attributes). The paths from root to leaf represent classification rules.

   Tree based learning algorithms are considered to be one of the best and mostly used supervised learning methods. Tree based methods empower predictive models with high accuracy, stability and ease of interpretation. They are adaptable at solving any kind of problem at hand (classification or regression).The possible solutions to a given problem emerge as the leaves of a tree, each node representing a point of deliberation and decision.

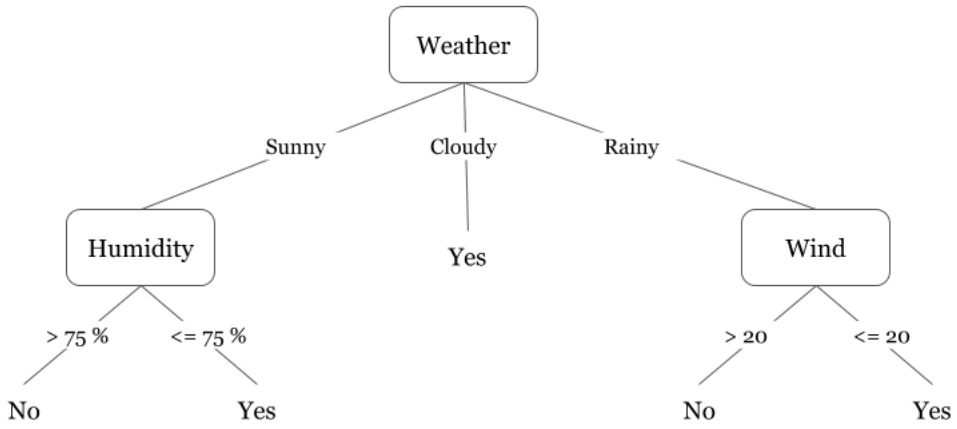


Figure 6.4: Decision Tree

3. **KNN**

   KNN is a non-parametric, lazy learning algorithm. Its purpose is to use a database in which the data points are separated into several classes to predict the classification of a new sample point.KNN Algorithm is based on feature similarity.

   KNN is used for classification. The output is a class membership (predicts a class:a discrete value). An object is classified by a majority vote of its neighbors, with the object being assigned to the class most common among its k nearest neighbors

   K nearest neighbors is a simple algorithm that stores all available cases and classifies new cases based on a similarity measure (e.g., distance functions). The KNN algorithm assumes that similar things exist in close proximity. In other words, similar things are near to each other.

   The KNN Algorithm

   1. Load the data

   2. Initialize K to your chosen number of neighbors

   3. For each example in the data.

   4. Calculate the distance between the query example and the current example from the data.

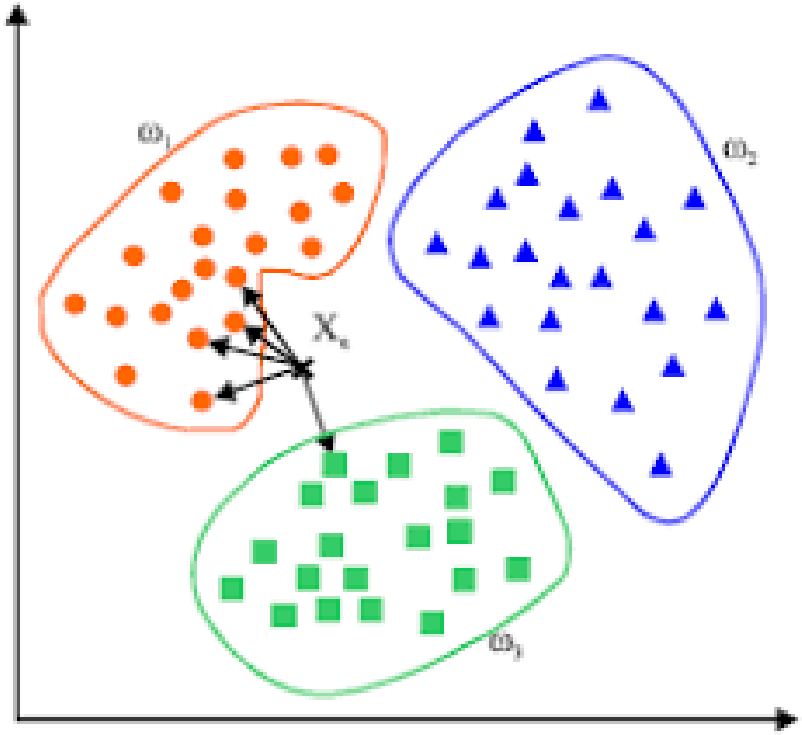


Figure 6.5: Use Case Diagram

5. Add the distance and the index of the example to an ordered collection.

6. Sort the ordered collection of distances and indices from smallest to largest (in ascending order) by the distances.

7. Pick the first K entries from the sorted collection.

8. Get the labels of the selected K entries.

9. If regression, return the mean of the K labels.

10. If classification, return the mode of the K labels.

The algorithm is versatile. It can be used for classification, regression, and search.

Chapter 7

SOFTWARE TESTING

7.1 INTRODUCTION

Testing is a process of verifying and validating if the developed software is correct, complete and has the quality which is acceptable. That means, it is checking if a software system meets specifications and that it fulfills its intended purpose.To make our software perform well it should be error free.If testing is done successfully it will remove all the errors from the software.

7.1.1 Principles of Testing

- All the test should meet the customer requirements.
- Exhaustive testing is not possible.As we need the optimal amount of testing based on the risk assessment of the application.
- All the test to be conducted should be planned before implementing it.
- It follows pareto rule(80/20 rule) which states that 80 per cent of errors comes from 20 per cent of program components.
- Start testing with small parts and extend it to large parts.

7.2 TYPE OF TESTING

7.2.1 Unit Testing

Unit Testing is a level of software testing where individual units/ components of a software are tested.It focuses on smallest unit of software design. In this we test an individual uni or group of inter related units.It is often done by programmer by using sample input and observing its corresponding outputs. In our project, the testable components were:

- Emotion Classification Module
- EmotivPRO headset hardware testing

Each of the above modules were tested independently. For both the classifications,the inputs were the training and testing data from the datasets and the output were accuracies which were acceptable.For Emotion classification module two state of data independent train and test to achieve desire output.It focus on individual components of input dataset file tested.The EmotivPRO hardware testing consisted of placing the electrode on respective position on the scalp and according and wirelessly transmitting the data to the software associated with it.

7.2.2 Integration Testing

The objective is to take unit tested components and build a program structure that has been dictated by design.Integration testing is testing in which a group of components are combined to produce output. Various unit tested modules have been tested for their usage after integration.Test drivers and test stubs are used to assist in Integration Testing. The integration of the units is as follows:

- Emotion Classification Module
- EmotivPRO headset hardware testing

7.2.3 System Testing

The process of testing an integrated system to verify that it meets specified requirements.In this we just focus on required input and output without focusing on internal working. In System testing we Verify thorough testing of every input in the application to check

for desired outputs.System testing takes, as its input, all of the integrated components that have passed integration testing.

7.2.4 Acceptance Testing

Acceptance testing is formal testing with respect to user needs, requirements, and business processes conducted to determine whether or not a system satisfies the acceptance criteria and to enable the user, customers or other authorized entity to determine whether or not to accept the system.Acceptance Testing is a level of software testing where a system is tested for acceptability.

Chapter 8

RESULTS

We have used the EMOTIV Insight wearable headset device to record the real time EEG data of the subjects. The subjects were shown respective videos for inducing respective emotions and the data was recorded.The entire dataset has been split into 80 percent for training and 20 percent for testing purpose.

8.1 RESULTS FOR EMOTION DETECTION MODULE

8.1.1 SVM

The following table 8.1 shows the confusion matrix metric obtained for the testing data.

Table 8.1: Confusion Matrix for Support Vector Machine

Actual/Predicted	Happy	Sad
Happy	995	183
Sad	179	1077

The table 8.2 below gives the various performance parameters for SVM :

Table 8.2: Performance Parameters

Scores	Values
Accuracy	85.12
Misclassification Rate	14.88
Precision	85.00
Specificity	79.21
F-Score	85.00

Finding the optimum value of gamma in Support Vector Machine is critical. The following table 8.3 indicates the best value for gamma i.e 0.01 and As the value increases the results degrade consistently.

Table 8.3: Performance Tunning

Performance Parameter	Accuracy
0.01	85.825
0.05	83.442
0.1	82.374
0.5	73.705
1.5	67.584
5.0	55.875

8.1.2 Decision Tree

The following table 8.4 shows the confusion matrix metric obtained for the testing data.

Table 8.4: Confusion Matrix for Decision Tree

Actual/Predicted	Happy	Sad
Happy	1074	104
Sad	105	1151

The table 8.5 below gives the various performance parameters of the classifier:

Table 8.5: Performance Parameters

Scores	Values
Accuracy	91.41
Misclassification Rate	8.59
Precision	91.00
Specificity	91.64
F-Score	91.00

8.1.3 KNN

The following table 8.6 shows the confusion matrix metric obtained for the testing data.

Table 8.6: Confusion Matrix for KNN

Actual/Predicted	Happy	Sad
Happy	1178	0
Sad	65	1191

The table 8.7 below gives the various performance parameters of the classifier:

Table 8.7: Performance Parameters

Scores	Values
Accuracy	97.32
Misclassification Rate	5.0
Precision	91.00
Specificity	94.00
F-Score	97.00

8.1.4 Comparison of Algorithms for Emotions Detection

We have results from three different classifiers. KNN is found to be an optimum classifier for this purpose. Using this classifier we have classified the emotions successfully into respective emotional states. The following table 8.8 shows the accuracy obtained by the different classifiers that we had used.

Table 8.8: Comparison of Algorithms

Parameters	SVM	Decision Tree	KNN
Accuracy	85.12	91.41	97.32

8.2 SCREENSHOTS

Figure 8.1: Emotiv Insight

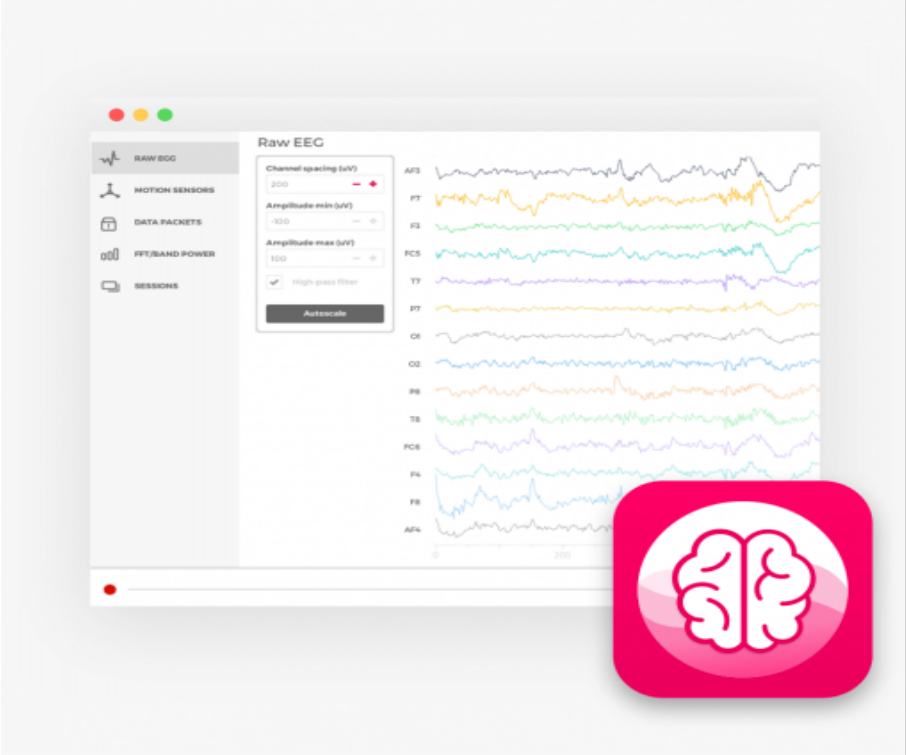


Figure 8.2: EmotivPRO

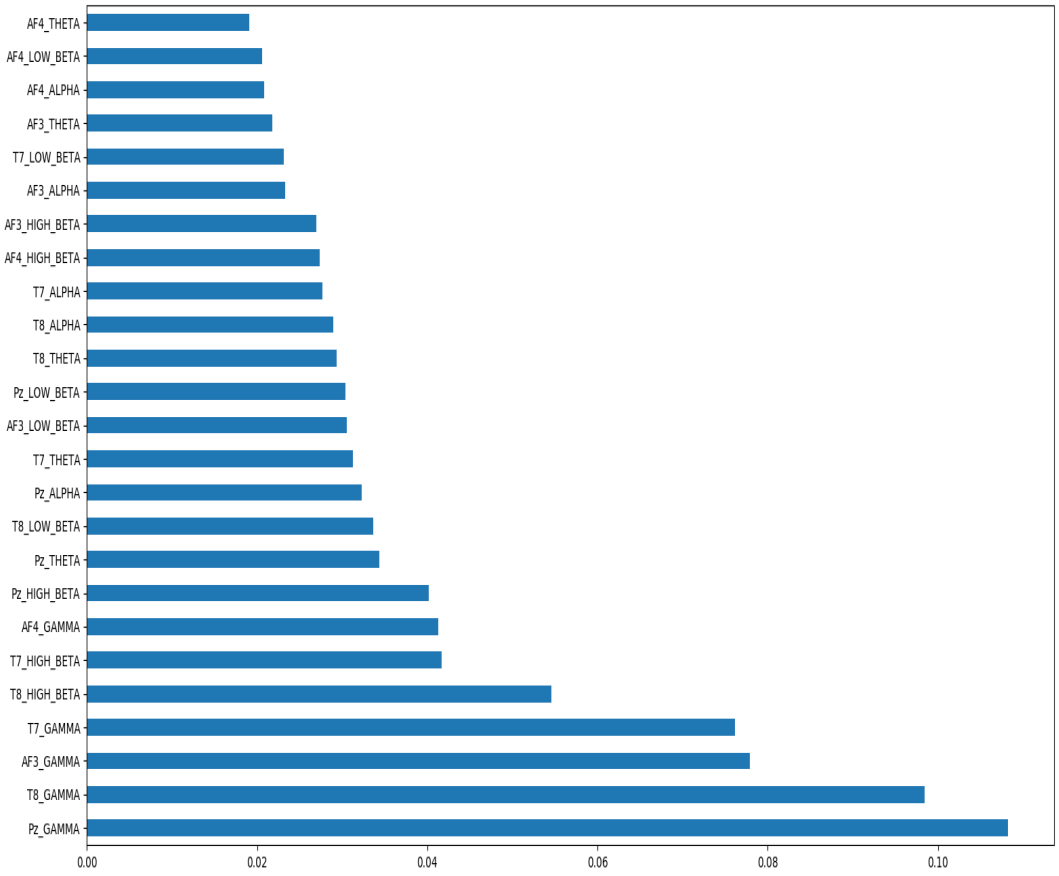


Figure 8.3: Features importance for Emotions

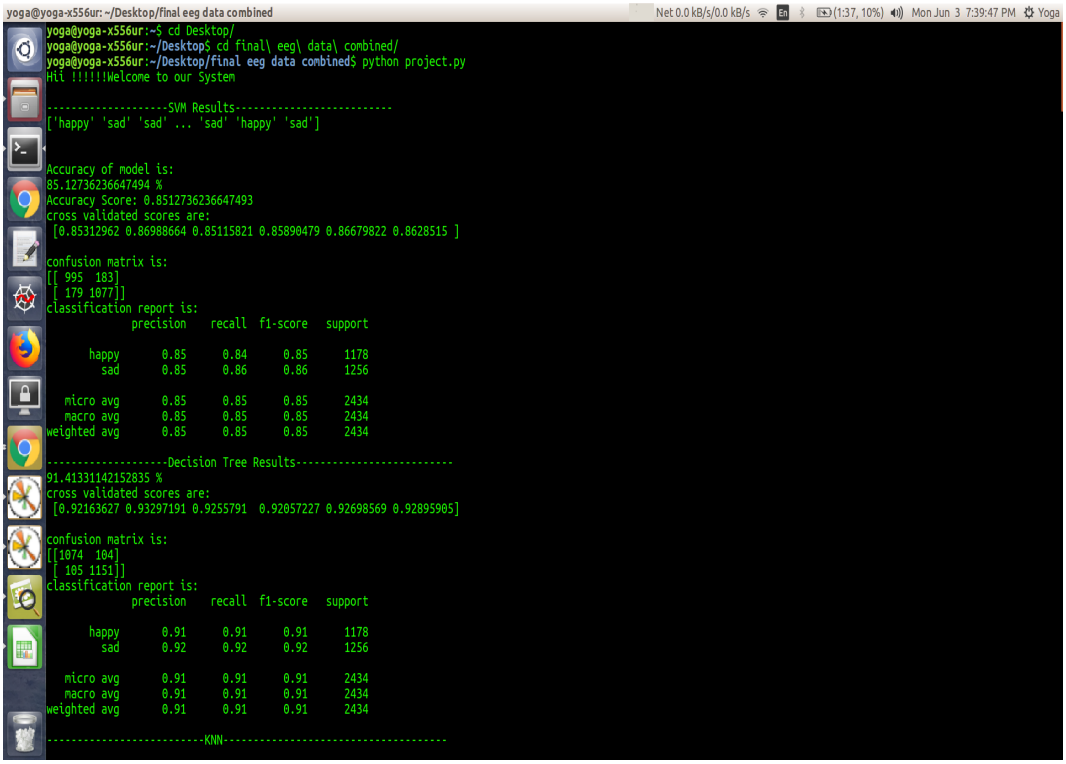


Figure 8.4: Emotion Classification Results

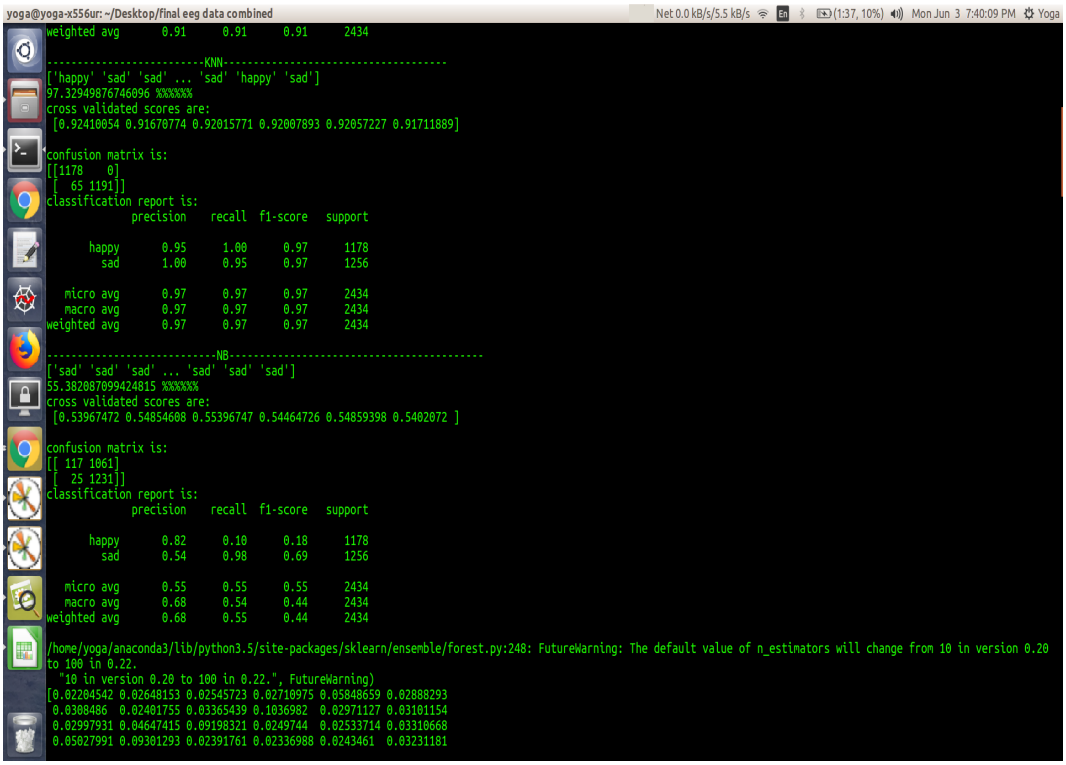


Figure 8.5: Emotion Classification Results

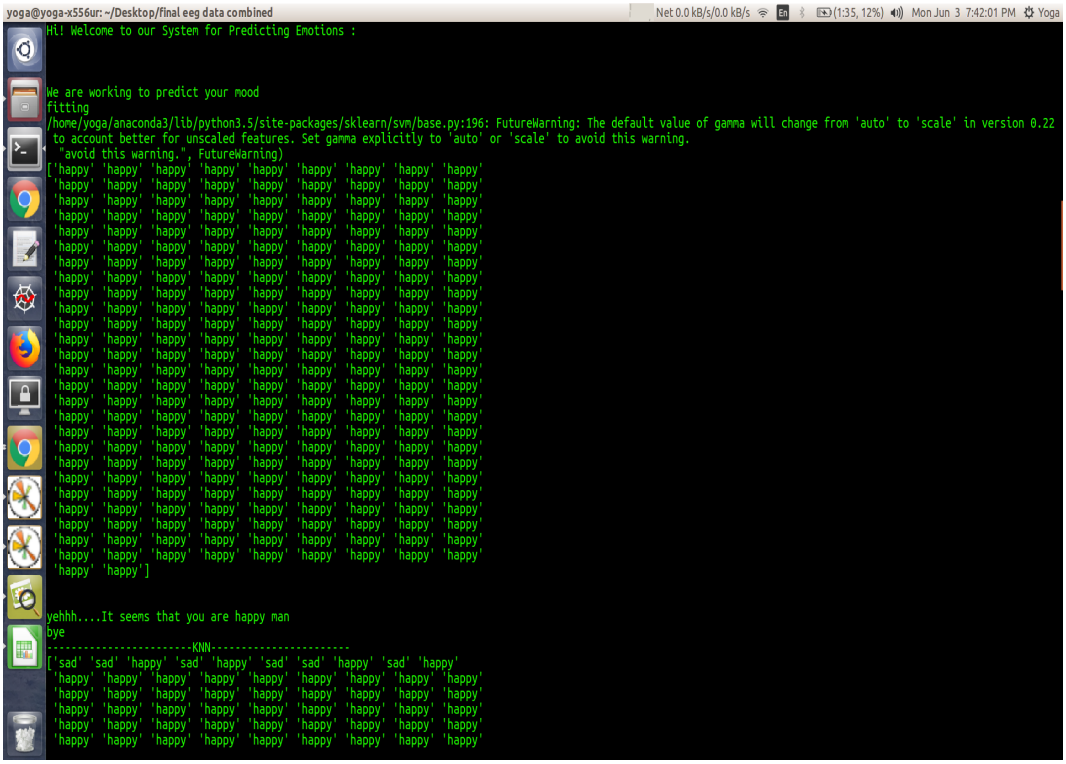


Figure 8.6: Emotion Detection Results

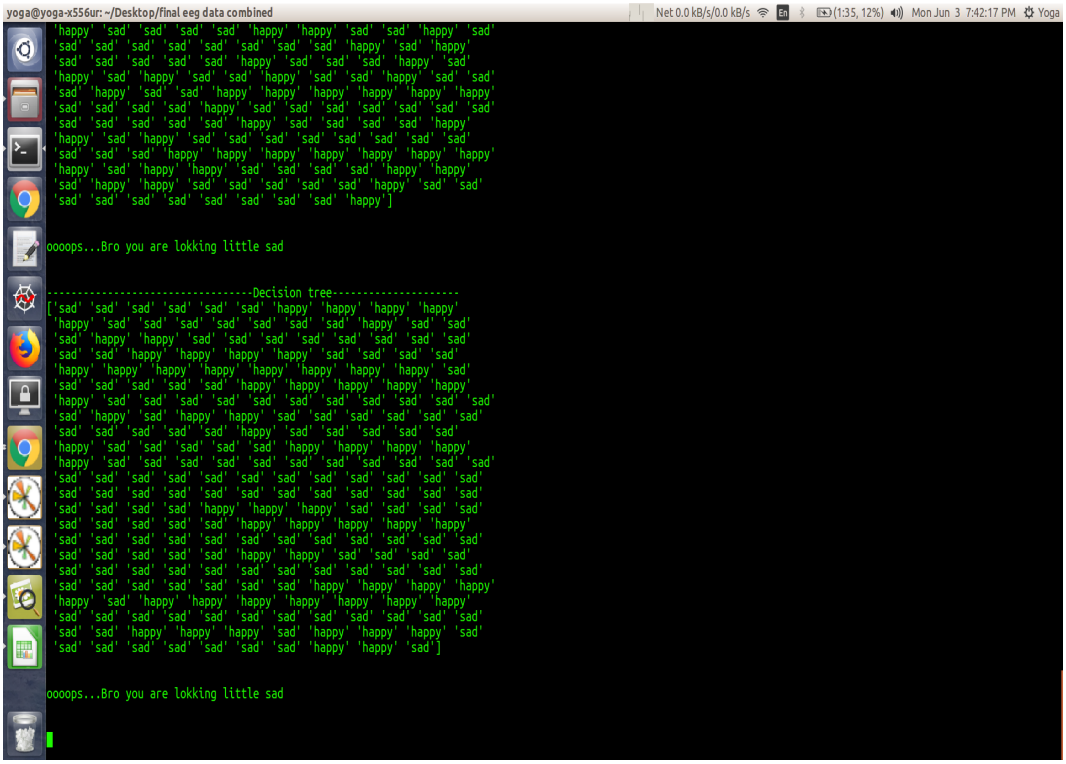


Figure 8.7: Emotion Detection Results

Chapter 9

CONCLUSIONS

9.1 CONCLUSION

The emotional state of a person defines their interaction with other people or objects. Therefore, the recognition of human emotions is becoming a concern in the development of systems that require human-machine interaction. There are several sources of information to assist in the recognition of emotions, such as facial expressions, voice and physiological signals, among others. In this study we implemented an emotion recognition system based on the BCI interface and EEG signals. Therefore, we could conclude that the use of EEG is a good choice for classifying emotions by emotion recognition systems based on BCI interface. We found that gamma signal plays a major role in happy and sad emotion state of the person. The system was modeled for various age group. This gave system a versatility for the performance . A slight change of value was recorded in the observation.

9.2 FUTURE SCOPE

- Cognitive Ability: The cognitive ability of the person can be determined by using the EEG signal. This study can be used to determine any irregularity in the brain.
- Cognitive Impairment: The cognitive impairment can be predicted and detected using the EEG signals from the brain.
- Sixteen channel: Future scope would include implementing this system on a wider range of age group. We could use a device with 16 channel or advance to record the

data.It will lead to increased accuracy and efciency of processing the data.

- Multiple Emotion: Furthermore, the current work only focuses on the two emotions.The system can be made more efficient to detect multiple number of emotions.
- Real-time: Moreover, the system processing can be made so as to make the system real-time.
- Gender based: The study can be made more enhance and can be calibrated to better efficiency by considering the gender of the subject.

9.3 APPLICATIONS

- Medical: The system can be designed for the doctors to understand the ongoing emotional changes in a patient to better treat the patient. Doctor can use the study based assumption to provide the treatment according to the age of the patient. Doctor can provide better care for the patient.
- Trust Assessment: The study can be used by authority to determine a criminal psychology which can used for getting confession for legal binding.
- Entertainment: The change of emotion according to age can be best used by the entertainment and advertising industry. It can lead to subject oriented suggestion and playback.
- Mood Monitoring: In service industry institute can use this study for better tools and facility provision.

Appendix A

Feasibility Assessment

A.1 Feasibility Assessment

Our project is EEG based emotion recognition and detection. We detect emotional sate of person such as happy and sad based on age. Emotional state may vary according to age. We record the data based on five year age gap. We analyzed the data set and classified emotion and predicted output.We have used real time generated datasets like happy dataset and sad dataset for detection and emotion recognition respectively.These datasets are used for training our classifier according to the brainwave data i.e. alpha, beta, theta, gamma and delta bands.

A.1.1 Technical Feasibility

- Different datasets (Happy, Sad) are available for use
- Machine Learning libraries required for this project are free and open source.
- Algorithms required for the project have a free to use license.

A.1.2 Time Feasibility

The project has been implemented in a period of 6-8 months.

A.1.3 Economic Feasibility

The EEG Emotiv insight headset provide by the college hence it made it feasible for our project. In short, our project was fully feasible and sustainable.

A.2 Satisfiability Analysiss

Informally an algorithm is any well-defined computational procedure that takes some value or a set of values as input and produces some value or a set of values as output. To analyze an algorithm is to determine the amount of resources such as time and space necessary to execute it.In order to choose the best algorithm for a particular task, we need to be able to judge for how long a particular solution will take to run or how long two solutions will take to run and choose the best of the two.We don't need to know how many minutes or seconds it will take, but a way to compare algorithms against one another.

Time Complexity: P, NP, NP-Complete, NP-Hard.

P :

If the running time is some polynomial function of the size of input, for instance, if the algorithm runs in linear or quadratic or cubic time, then we say that the algorithm runs in Polynomial time and the problem is solved in Class P.

NP :

This refers to the programs that don't run in polynomial time on a regular machine but in polynomial time on a non-deterministic Turing machine. A non-deterministic Turing machine can do everything a regular computer can do and more. This means there is not necessarily a polynomial-time way to find a solution but once you have a solution it takes only polynomial time to verify that it is correct.

NP-Complete :

NP is a complexity class which represents the set of problems X for which it is possible to reduce any other NP problem Y to X in polynomial time.

NP-Hard :

Intuitively these are the problems that are even harder than the NP-Complete problems. These problems need not be in NP and also need not be Decision problems.

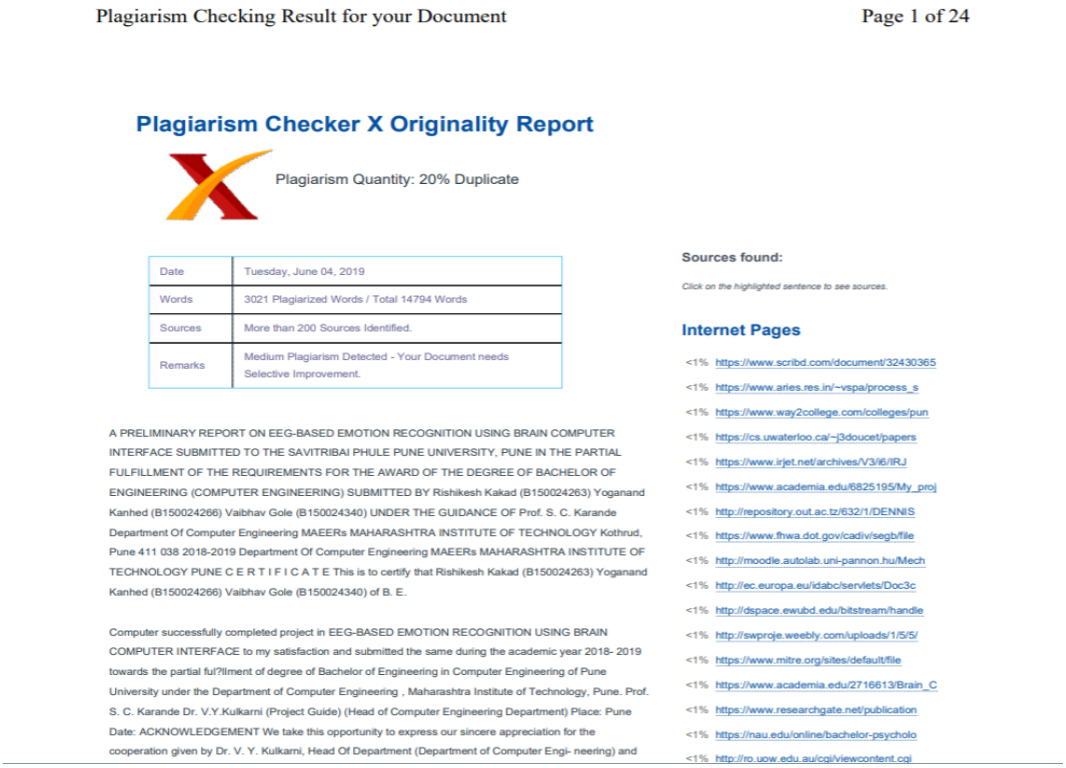
Algorithm Type :

The algorithms which we have used for our system are P type. Since the results are obtained within a quadratic measure of the input data size, our model has P type complexity.

Appendix B

Plagiarism Check Report

We checked our report for plagiarism using an Plagiarism CheckerX app. The application provided us with the result for plagiarism. The results obtained for our report was 80 per cent Original and 20 per cent duplicate which co-relates to a high level of Originality with small-level optimisations.



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Plagiarism Checker X Originality Report

Plagiarism Quantity: 20% Duplicate

Date	Tuesday, June 04, 2019
Words	3021 Plagiarized Words / Total 14794 Words
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A PRELIMINARY REPORT ON EEG-BASED EMOTION RECOGNITION USING BRAIN COMPUTER INTERFACE SUBMITTED TO THE SAVITRIBAI PHULE PUNE UNIVERSITY, PUNE IN THE PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF ENGINEERING (COMPUTER ENGINEERING) SUBMITTED BY Rishikesh Kakad (B150024263) Yoganand Kanhed (B150024266) Vaibhav Gole (B150024340) UNDER THE GUIDANCE OF Prof. S. C. Karande Department Of Computer Engineering MAEERs MAHARASHTRA INSTITUTE OF TECHNOLOGY Kothrud, Pune 411 038 2018-2019 Department Of Computer Engineering MAEERs MAHARASHTRA INSTITUTE OF TECHNOLOGY PUNE C E R T I F I C A T E This is to certify that Rishikesh Kakad (B150024263) Yoganand Kanhed (B150024266) Vaibhav Gole (B150024340) of B. E.

Computer successfully completed project in EEG-BASED EMOTION RECOGNITION USING BRAIN COMPUTER INTERFACE to my satisfaction and submitted the same during the academic year 2018- 2019 towards the partial ful?llment of degree of Bachelor of Engineering in Computer Engineering of Pune University under the Department of Computer Engineering , Maharashtra Institute of Technology, Pune. Prof. S. C. Karande Dr. V.Y.Kulkarni (Project Guide) (Head of Computer Engineering Department) Place: Pune Date: ACKNOWLEDGEMENT We take this opportunity to express our sincere appreciation for the cooperation given by Dr. V. Y. Kulkarni, Head Of Department (Department of Computer Engi- neering) and

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Figure B.1: Plagiarism Checker Originality Report

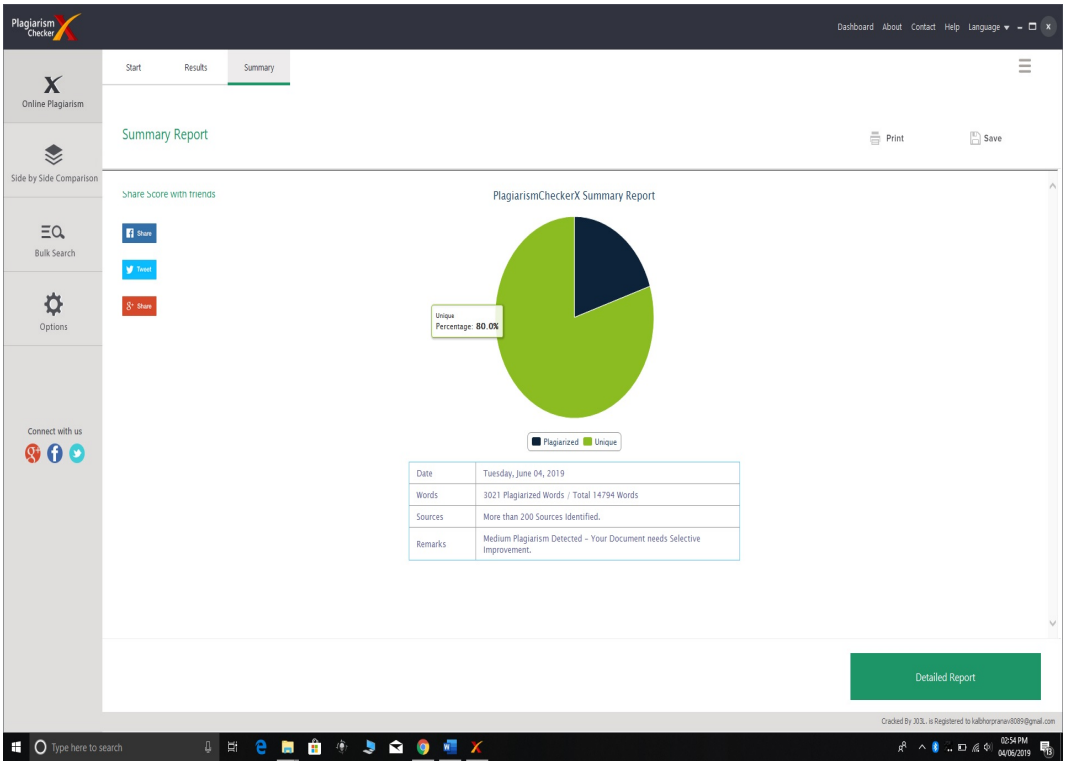

Figure B.2: Plagiarism Pie Chart

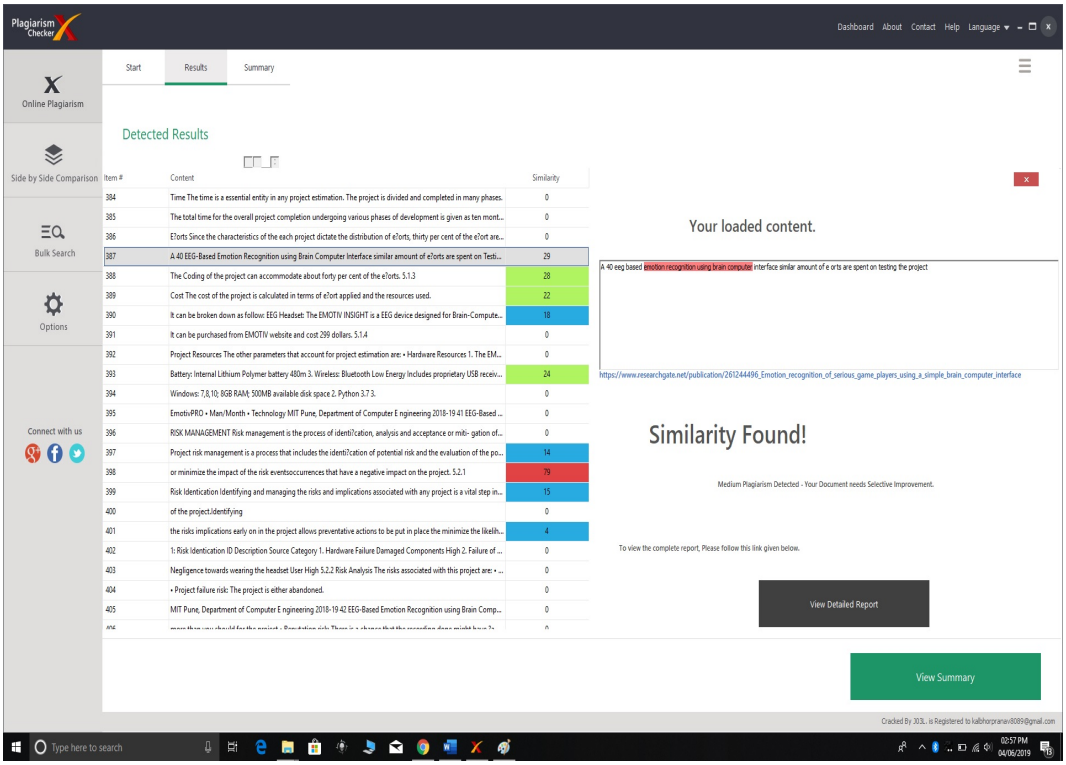

Figure B.3: Depiction of Similarity to the Source

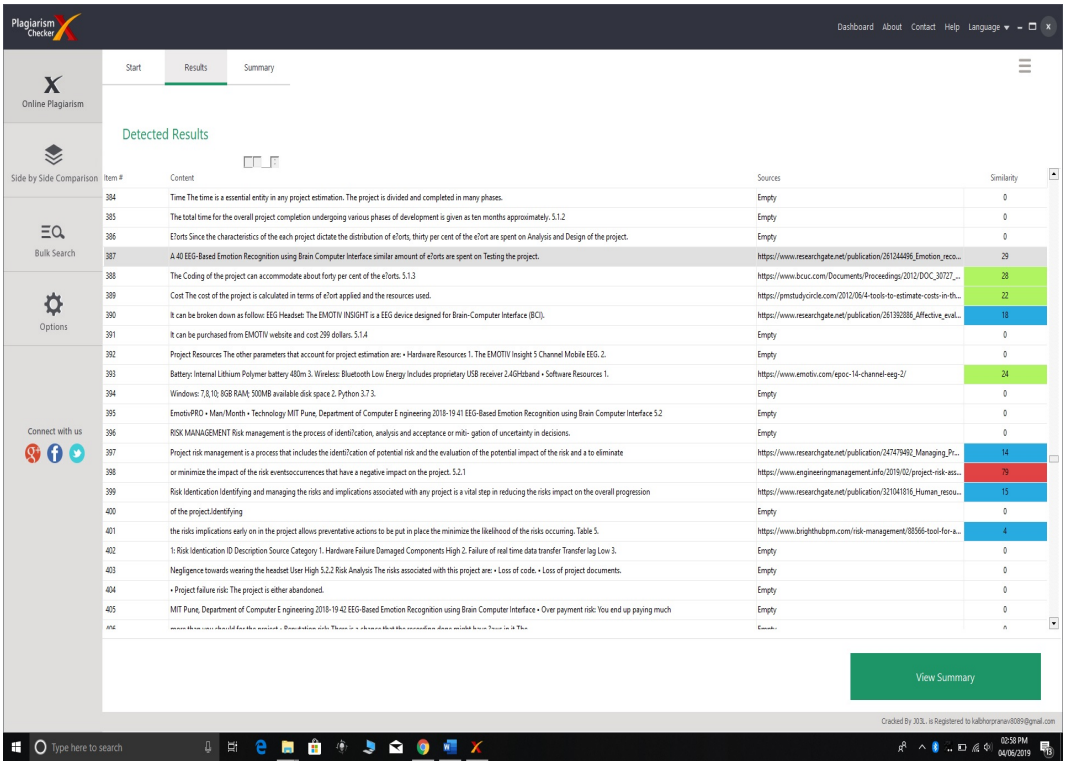

Figure B.4: Individual Statements's Analysis

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