EMOTION QUANTIFICATION ALONG VALENCE AXIS USING EEG SIGNALS

A Dissertation

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Master of Engineering
In
Electronic Instrumentation and Control

Submitted by

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DECLARATION

I hereby certify that the work being presented in the thesis work entitled **"Emotion Quantification Along Valence Axis Using EEG Signals"** in fulfillment of award of degree of **Master of Engineering** in **Electronics Instrumentation and Control** submitted in Electrical and Instrumentation Engineering Department, Thapar University, Patiala is an authentic record of my own work carried under the supervision of Mr. Moon Inder Singh, Assistant Professor, Department of Electrical and Instrumentation Engineering, Thapar University, Patiala, Punjab.

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ABSTRACT

Emotion is an important feature of human personality that affects the quality of interaction between humans. It is fundamental to human experience and rational decision-making. Recently the researchers have shown great interest in detecting emotions automatically. A number of techniques have been employed for this purpose using channels such as voice and facial expressions. However, these channels are not very accurate and can be faked. The necessity of studying emotions has become necessary to fulfill the human need of brain computer interfacing. This task can be accomplished only if we can successfully classify emotions into its constituent classes. This task requires the accurate acquisition of physiological and EEG data. To achieve this objective a step is taken forward in the direction of classifying emotions into different classes from the EEG data. To accomplish the goal of classifying emotions into two classes Low Valence and High Valence i.e. unpleasant and pleasant along the valence axis, the EEG data available at enterface06 website collected using International Affective Picture System (IAPS) as a stimulus has been taken into consideration. For this, we required sophisticated features that have been extracted from the raw EEG data using tools like Power Spectral Density (PSD), Short Time Fourier Transform (STFT), and Event Related Potential (ERP). These features individually and in appropriate combinations were further used for emotion classification by using different classifiers such as Navie Bayes, Artificial Neural Network (ANN), Feedforward and Multilayer Layer Neural Network. The data available on the enterface 06 website was collected from five participants in three sessions, where all subjects were right handed males. In this, out of EEG raw data of 5 participants, the analysis has been performed on 3 participants namely P3, P4, and P5 and 7 electrodes namely Cz, F1, F2, FC1, FC2, Fz, and Pz. To reduce the data set, the EEG data for 3 participants has been down-sampled at sampling rate of 256Hz by using open software called EEG Lab.

Using frequency domain, the maximum and minimum PSD values were determined according to different EEG frequency bands namely delta, theta, alpha, beta, and gamma.

Short Time Fourier Transform (STFT) features were extracted using Fast Fourier Transform (FFT) function by applying the discrete FFT to the signal. In STFT we determined the mean in different EEG frequency bands.

Another feature used for classification was Event Related Potential (ERP) wherein P100, N100, P200, N200, and P300 potentials were used as attributes for classification. On classification of STFT features with Naive Bayes, the accuracy determined was mere 51% where as the accuracy obtained with PSD and combination of PSD and STFT features with the same classifier was 56% and 64% respectively. The accuracy for ERP features remained at 56%. Since the accuracy achieved with these features using Naive Bayes classifier was very low another classifier with one hidden layer using Artificial Intelligence technique was implemented on MATLAB R2011a version. The accuracy obtained while using ERP as an attribute for all 3 participants stood at 76.59%. To further enhance the accuracy the work was performed on Multilayer 2-hidden layer network, which resulted in 100% accuracy on ERP features for two classes.

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Nikhil Singhal

ORGANIZATION OF THESIS

The thesis begins by introducing HCI (Human Computer Interface) module, depiction of the EEG signal in time- frequency domain and data acquisition in **Chapter 1**. This is followed by the review of previous work and studies that has already been carried out for emotion recognition in **Chapter 2**. **Chapter 3** explains the human brain function. **Chapter 4** defines the emotion. **Chapter 5** explains the methodology on which the whole work stands and **Chapter 6** delves into the results tabular form, bar graph form and discussions over the results. Finally **Chapter 7** concludes the thesis and outlines directions for future work.

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LIST OF ABBREVIATIONS

EEG	Electroencephalogram
HCI	Human Computer Interface
ALS	Amyotrophic Lateral Sclerosis
GSR	Galvanic Skin Response
CNS	Central Nervous System
PNS	Peripheral Nervous System
BCI	Brain Computer Interface
BDF	Biosemi Data Format
IAPS	International Affective Picture System
SAM	Self Assessment Manikin
VEP	Visual Evoked Potential
STFT	Short Time Fourier Transform
PSD	Power Spectrum Density
SVM	Support Vector Machine
MD	Mahalanobis
KNN	K-Nearest Neighbor
FDA	Fisher Discriminate Analysis
EDF	European Data Format
ICA	Independent Component Analysis
fNIRS	functional Near Infrared Spectroscopy
ERP	Event Related Potential
GUI	Graphical User Interface
MLNN	Multi Layer Neural Network

CHAPTER 1: INTRODUCTION

1.1 Overview

Emotion is defined as a complex state of feeling that results in physical and psychological changes that influence thought and behavior. Emotionality is associated with a range of psychological phenomena including temperament, personality, mood and motivation. Human emotion involves "...physiological arousal, expressive behaviors, psychological valence and conscious experience." Emotions play an important role in the daily life of human beings, the need and importance of automatic emotion recognition has grown with increasing role of human computer interface applications. Emotion recognition could be done from the text, speech, facial expression or gesture. In this thesis, main concentration was given towards recognition of “inner” emotions from electro-encephalogram (EEG) signals. The algorithm has been implemented and tested to recognize emotions along the valence axis. For this we use computer and artificial intelligence tools to recognize different emotions in EEG [1][2][3].

Since Electroencephalogram (EEG) is the reflection of brain activity and is widely used in clinical diagnosis and biomedical research so it is considered as the main signal for extraction. The features have been collected from the raw data available at enterface 06 website to determine the accuracy in emotional signals [4]. This raw data was considered to determined the accuracy of emotions in two classes- low valence (Negative) and high valence (positive). The obtained EEG data then processed, formatted and evaluated at a certain frequency range. Different machine learning techniques were used to classify EEG data associated with specific quantification/emotional states. Different methods were designed to format the dataset for EEG data. Formatted datasets were then evaluated to accurately classify EEG data according to associated affective/emotional states. In this thesis Brain signals occur during the activity of brain cells and have a frequency range of 1 to 100Hz. We consider the following frequency bands and event related potential features to interpret EEG signal: delta (0-4Hz), theta (4-8Hz), alpha (8-12Hz), and beta (12-30Hz) and gamma (> 30Hz); P100, N100, P200, N200 and P300.

1.2 Human Computer Interface

Human-Computer Interface (HCI) has so far not been able to correctly identify all human emotional states and perform processing upon the gathered information to infer the proper actions to be executed. The understanding of human emotions and an up to the mark human computer interface implementation can help bring a turnaround in medical profession, electronics, entertainment, and even the military and civil recruitments. This requires the study of human physiological and brain signals. A patient suffering from serious amyotrophic lateral sclerosis (ALS) like disease may lose the ability to exercise language and muscle functions, which are two common ways of human information output. The study of the brain and/or physiological variables of such persons and using them together in human computer implementation can help in understanding his emotions and needs, thus reducing the communication barrier with the outside world. Implicit assessment of emotion can be carried out by considering human expressions and physiological reactions. In first case, the human expression can be analyzed by using his images and taking the sample of his voice resulting due to a particular emotional stimulus. Then the emotional estimation can be performed using images and signal processing techniques. The analysis using physiological variables is gaining a lot of popularity nowadays. The common physiological variables being considered for emotion quantification are Galvanic Skin Response (GSR), Blood Pressure, and Heart Rate etc. Generally, physiological signals originate from the central nervous system (CNS) and the peripheral nervous system (PNS). Regarding the signals from the CNS, brain electrical activity has gained great interest for studying emotions. Among other physiological signals, EEG has gained special interest because emotion is considered as a psychological process which is directly related to the brain activities [5][6][8]. The advantage of studying EEG signals for brain computer interface is that the subject under observation cannot fake his feelings.

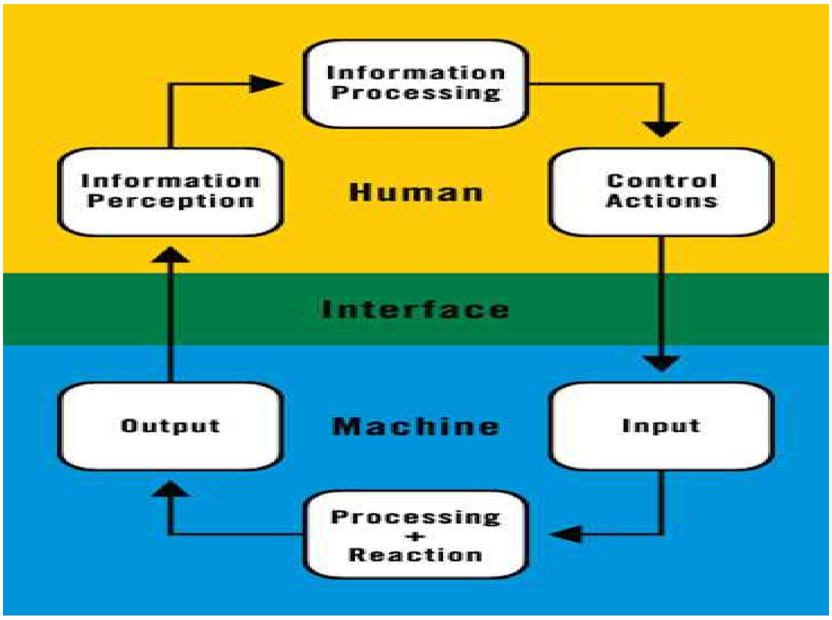

Figure 1.1: Including Emotion in the Human-Machine loop [7]

BCI system consists of several components: brain signals, signal acquisition, signal processing, operation of application and feedback presentation. Human intentions modulate the electrical brain signals which are detected and recorded by the signal acquisition block and then filtered by the signal preprocessing block. The signal processing block, which includes processes such as feature extraction and classification, subsequently analyses the captured signals and provides the corresponding instructions to appropriate devices. During the operation of these devices, some feedback may be returned to the users [9].

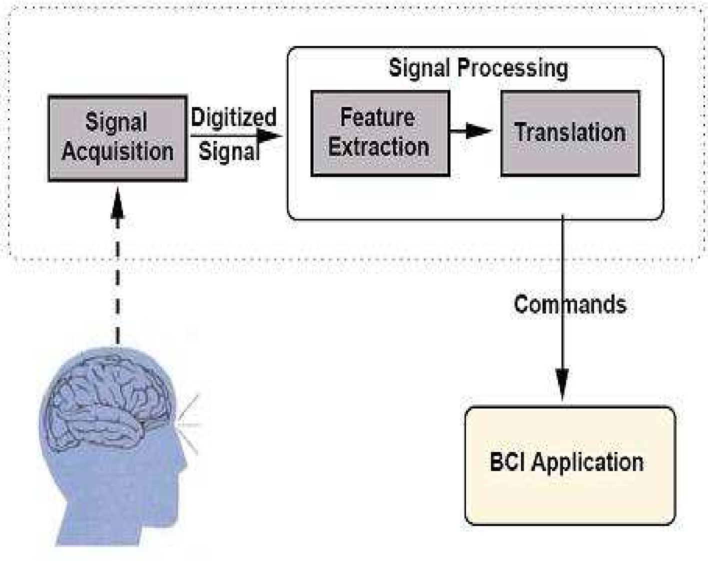

Figure 1.2: Typical Brain Computer Interface System [10]

1.3 Emotions

Emotion is an intense mental state of human being that shows the outward expression or feelings of anger, fear, happy, sad, and likening etc. In other words, emotion is a pleasant and unpleasant mental state of organized through neural mapping of human brain [11]. One of the emotion describe as-

1. It is an effective state of consciousness in which joy, fear, and like etc., is experience.
2. Emotion is a neural impulse that moves an organism to action.
3. Emotion is state of valence characterize by alteration of feeling and by psycho-logic behavioral.
4. Emotion is defined as a complex feelings state (affect) accompanied by characteristic motor and glandular activities, feelings, and mood.

1.4 Data Acquisition

To acquire data and create a relationship between EEG signals and emotion, dataset of EEG signals is required. To create dataset, user's emotions must be known at a specific moment. Since samples are required with different emotions, methods to elicit different kinds of emotions are needed[12].

Emotional behavior is organized along two psychological dimensions: (1) valence, varying from negative to positive, and (2) arousal, varying from low to high. The valence component is more difficult as it consists of cognitions. In order to build the valence-arousal space, the valence dimension has to be determined continually. This can be done using scale from unpleasant to pleasant task and vice-versa [2].

The raw EEG data is available at enterface 06 website. The data was collected by Savran et al on five participants, all were right handed males at an enterface workshop [4]. Enterface 06 website provides a set of data that contains four files, one containing the EEG and physiological variables data for all five participants in 3 sessions along with the corresponding mark files. The mark file for each session of a particular participant indicates the time of start and termination of an emotion stimulus to a participant. The data file is in Biosemi Data Format (BDF). The physiological variables that have been studied are respiration rate, Galvanic Skin Response (GSR) and blood volume pressure. The second one contains fNIRS information, the third one contains the set of images shown to the participants along with their mean arousal and mean valence values and fourth file indicates the self assessments done by the participants under observation. The emotions were elicited by using the stimulus provided by university of Florida called International Affective Picture System (IAPS) [13] in NIMH center. The participants were also asked to rate the images on the arousal and valence scale using self assessment manikin method (SAM) [14]. This work shows that images were shown to the participants after selected from IAPS based on three classes namely clam, positive exiting, and negative exiting. The data has been digitized and processed upon by using the open source software called EEG LAB [15].

Each image was shown for 2.5 seconds and total of 5 images were shown for evoking one emotion at a time. So to evoke one emotion the EEG data was collected for 12.5 seconds. The EEG data was collected at a sampling rate of 1024 Hz in the three sessions for each participant and the images were shown in a random order. To reduce the data set, the EEG data for participants 3, 4, and 5 has been down-sampled at a sampling rate of 256Hz.

CHAPTER 2: LITERATURE REVIEW

2.1 EEG and VEP signal processing

Daniel Novak et al (2001) in his thesis mainly focused on Visual Evoked Potentials (VEP) for processing the data extraction and classification with the help of cognitive process. Experiment was performed in two parts- First part contained the recorded data of EEG signals of young male persons having emphasis on artificial artifact generation such as blink, muscle and teeth etc. Then VEP was measured for more than 20 students by reversing the full-field of chessboard in biological laboratory. For data preparation each eye was tested separately. After data preparation, recorded file were processed using basic algorithms such as Fourier, wavelet transform, spectral analysis, mapping and spectral coherence.

For processing VEP, various neural activities were included like muscle activity (EMG), heart activity (EKG) and eye-movement artifacts (EOG), etc. Fresh data was prepared after rejecting the noise data from the entire recorded data. Finally after performing extraction process classification was done keeping the frame of Intelligent Human Computer Interface (iHCI) [6].

They provide this report for teaching purpose as well with the description of different algorithms[16].

2.2 Journal of Personality and Social Psychology

Russell, J.A. (1980) in his seminal work discussed that the feelings like joy, happiness, fear, angry, depressed, displeasure are not independent but are interrelated. The affective states were represented as a circle in a two dimensional space. Russell prescribed an affective space model for illustrating dimensional approach in which emotion is described through two dimension space of Valence and Arousal. In this approach arousal was given number one on the circle and emotion describing words or phrases were so placed that the similar meaning words were closer while the opposites lied diagonally. The circumflex model of affect as proposed in his study is shown below. Russell took pleased along the X-axis. However in Peter Lang's model valence replaces pleased along X-axis [17] [13].

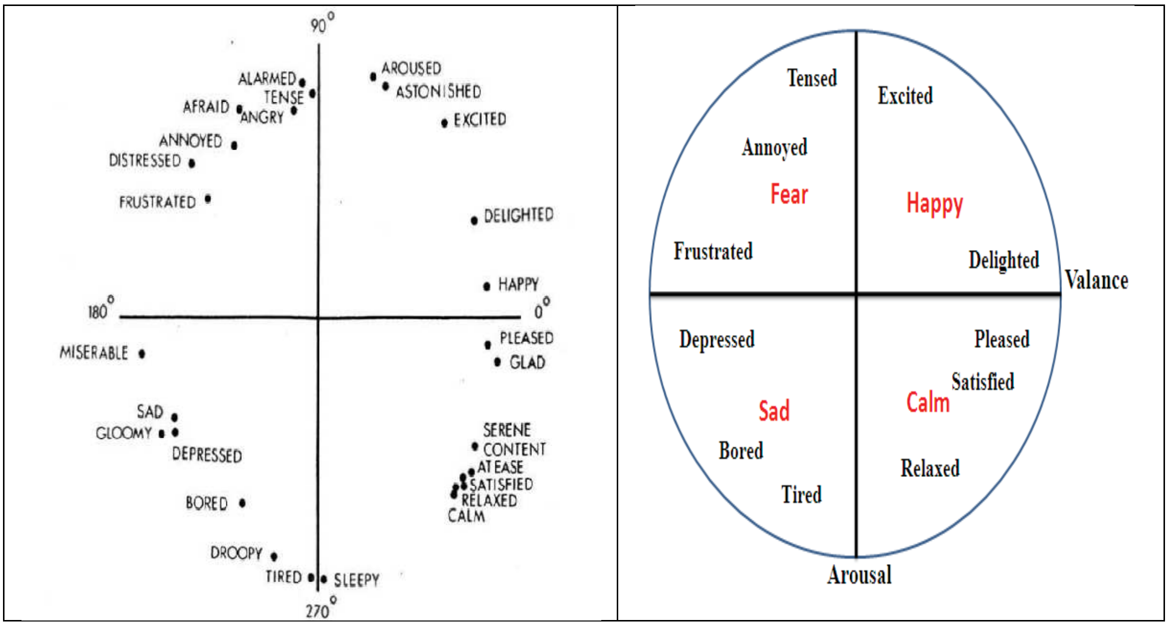

Figure 2.1: A circumflex model

2.3 A Database for Emotion Analysis using Physiological Signal

Sander Koelstra et al (2012) in his paper worked on multimodel dataset to prepare the database for the analysis of human affective states. To create database, EEG and peripheral signals were considered of 32 participants. They ask them to watch the 40 one-minute long music videos and at the same time video recording of emotions of the participants were taken. Frontal face video was also recorded for 22 participants out of 33 participants. Then participant's videos were rated on the basis on valence- arousal space, likes/dislikes, dominance and familiarity. Finally dataset was prepared after correlate the videos with EEG frequencies using different modalities [19].

2.4 Feature Extraction Techniques of EEG Signal for BCI Application

Abdul-Hameed Fatehi et al (2011) studied about the extraction of EEG signals using various time- frequency analysis methods for the field of BCI. The data was collected from 16 channels using various mental and motor tasks. After data collection the features were extracted using following extraction methods- Time analysis, Frequency analysis, Time- Frequency analysis, Time- Frequency space analysis at a cut off frequency of 0.5 Hz for high pass filtration and 40-70 Hz for low pass filtration. Then to classify these various datasets many classifiers were tried but on using artificial neural network with back propagation method 99% of accuracy was obtained between 2 tasks and 96% accuracy was obtained between 3 tasks. Other classifiers used by Abdul were FFT for time analysis, STFT for time-frequency analysis and space time-frequency analysis over multiple electrodes. In his study, two mental tasks and two motor tasks were considered i.e. baseline, and mental multiplication and baseline, and mouse click respectively by training the multi layer back- propagation neural network [8].

2.5 Short Time Fourier Transform

Naotoshi Seo in (2005) describe about his project which was based on STFT. In this, detail description of STFT algorithm was given. Using sampled signal comparison in data was performed using various windows and with various window length like rectangular window and hamming window at a sampled frequency of 400 Hz. On considering time-frequency, the hamming window had sharp low frequency response than rectangular window. To analyze the data Spectrogram function was used [20]. From this experiment it was concluded that the frequency resolution increases on decreasing the time resolution or vice-versa [20]. After this experiment one more experiment was conducted in which comparison between hamming window, rectangular window and hanning window was considered and verified that hamming and hanning will provide more precision on frequency domain than that of rectangular window.

2.6 Power Spectral Density

Jaime F. Delgado Saa et al in (2010) discuss about the two immediate challenges in which they were trying to find an appropriate frequency-domain description for a WSS random process. According to his first challenge, sample functions of individuals didn't have transforms that were ordinary, well-behaved functions of frequency. In second challenge, it was required to search the features of transforms that represents the whole class of sample functions as particular sample functions were obtained as the result of a probabilistic experiment. So his main focus was on the expected power in the signal using time domain in any realization[21].

2.7 Emotion Assessment: Arousal Evaluation Using EEG and Peripheral Physiological Signals

Guillaume Chanel et al (2005) discuss about the emotion recognization of human brain using EEG PET device using valence-arousal dimension and considering the facial and verbal emotion. For this, they conducted test on 5 participants on 39 stimuli. Three modalities and 4 emotions were consider to classify by splitting data into test, training and validation. In this case, the arousal and valence data of the IAPS and IADS databases was not used during training. By using the actual mean values provided by the databases, regression could be used to actually get a classification result on the two-dimensional emotion map [22].

2.8 Time-frequency analysis of EEG Signals Response due to simple Acupuncture Stimulation

Robinsar Suprijanto et al (2009) discussed about the quantification of EEG signals using Acupunture stimulation by giving the example of theory of pain and observed that during acupuncture stimulation, the higher power was seen in frequency band theta and alpha. The EEG power will tend decreasing until the needle acupuncture was released from body.

In theory of pain, they were curing the pain by blocking the pain signals from reaching brain, so that participant can't feel the pain. It was worked as traffic near construction zone, where two lanes merge into one. Slower car cannot move forward, caused by faster car go further and blocks the slower ones. Pain signal were represented by slower car. This theory is known as Gate control Theory of Pain. Acupuncture could help body in controlling stress and curing injury by stimulate the release of various hormones. Acupuncture influenced body by using body's ability to heal (self healing) [23]. After classification using power spectral in brain waves of delta, theta, alpha and beta they conclude that the simple acupuncture had a relaxation effect to the body, as the increased on the EEG power of alpha band was indicated of increasing relaxation of human brain. There were also viewed that the mean and variance of power spectral were decreased during and after acupuncture stimulation [23].

2.9 Toward Emotion Aware Computing: and Integrated Approach using Multichannel Neurophysiological Recordings and Affective Visual Stimuli last

Christos et al (2010) in the research study described about the classification of neurophysiological data for four emotional states obtained by observing International Affective Picture System (IAPS) images. They adopted valence-arousal dimension model for grouping the data using 2 step classification processes on the basis of gender. First classification involves arousal discrimination then valence discrimination was performed. With the help of Mahalanobis (MD) and support vector machines (SVMs) emotions were discriminated in arousal. After performing these operations he got the overall accuracy of 79.5% and 81.3% for MD and SVM respectively [24] [25].

After deriving the arousal dimension, the valence discrimination is performed by taking into consideration the obtained arousal and gender information [24].

2.10 Emotional stress recognition system using EEG and psychophysiological signals

Seyyed Abed Hosseini et al (2010) proposed a new emotional stress recognition system using multi-modal bio-signals. They chose EEG channels by using the cognitive model of the brain under emotional stress. They designed an efficient acquisition protocol to acquire the EEG and psychophysiological signals under pictures induction environment (calm-neutral and negative-excited) for participants. [1]. For this qualitative and quantitative evaluation of psychophysiological signals have been tried to select suitable segments of EEG signal for improving efficiency and performance of emotional stress recognition system. They used a Flexcom Infiniti biofeedback device for data acquisition. After that data from skin conductance, photoplethysmograph, respiratory rate and EEG signals were continuously recorded through bio-sensors. In this study, they recorded SC by positioning two dedicated electrodes on the top of left index and middle fingers. RR was recorded by a respiration belt, counting the chest cavity expansions over time. Finally, a photoplethysmograph was placed on the thumb of the participant to record his blood volume pressure. The sample rate of the psychophysiological acquisition was decided as 2048Hz. The scalp EEG was obtained at location FP1, FP2, T3, T4, Pz, as defined by the international 10-20 system at a sample rate of 256Hz [26]. Finally the classification accuracy in two emotional states was 82.7% by using the Elman classifier.

2.11 Classification of EEG for Affect Recognition

Omar AlZoubi et al (2009) study provides new data on EEG based affect recognition, and presents a performance comparison of K-Nearest Neighbor (KNN), Support Vector Machines (SVM), and Naïve Bayes using an adaptive classification technique. The performance of two classification methods, Naïve Bayes classifier and Fisher Discriminant Analysis (FDA) were evaluated on each EEG and physiological signal separately, and on combination of both. They considered 4 participants, and the EEG was recorded from 64 electrodes with a sampling rate of 1024 Hz. The EEG was then bandpass filtered between 4-45 Hz and removed from the signals. Using a 6s epoch length, the bandpower at six frequency bands were computed, using 6 features from the EEG. Using only EEG features and the one leave-out method, a classification accuracy of 72% for NaiveBayes was achieved and 70% for FDA for single participant. Their results suggested that EEG could be used to assess the arousal level of human affects. [27].

2.12 Toward Machine Emotional Intelligence: Analysis of Affective Physiological State

Jennifer Healey (2001) worked on the 8 emotional states namely no emotion, anger(High arousal negative valence), hate (Low arousal Negative valence), grief (High arousal negative valence or Low arousal Negative valence), love(Low arousal positive valence), romantic love(love for opposite sex- very high arousal positive valence), joy (high arousal positive valence)and reverence(for nature and God-low arousal and neutral valence) with the help of guidelines mentioned by Clynes [17]. To recognize 8 emotional states 5 sensors were used. The classification of these emotional states was done by using Fisher analysis and the accuracy lied between 80% and 90%. In his pioneer work Russell, J.A. (2003) discussed about the feelings like joy, happiness, fear, angry, depressed, displeasure and all were inter related. He worked on affective space model (Valence and Arousal) by representing them as a circle in a two dimensional space. He represented arousal dimension with pleased along the X-axis [28].

2.13 The International Affective Picture System: In the Study of Emotion and Attention

Bradley M.M et al (2005) discussed the development and use of emotional colored picture stimuli that was incorporated in International Affective Picture System (IAPS). These pictures include pleasure, arousal, and dominance ratings made by men and women. The IAPS was currently used in experimental investigations of emotion by facilitating the comparison of results across different studies in combination to control the emotions across psychological and neuroscience research laboratories [13].

The IAPS stimuli were standardized on the basis of ratings of pleasure and arousal which reflects both theory and data. After viewing the images, each picture was rated by a large group of people (both men and women) for the feelings of pleasure and arousal. Using these ratings, scientists can select and match pictures on the basis of the average reported emotional impact of that picture and are able to control for emotional arousal when investigating effects of hedonic valence and vice versa. The only requirements for appropriate stimuli were that the pictures should in color and at least 1024 x 768 pixels in resolution.

2.14 Emotion Detection in the Loop from Brain Signal and Facial Images.

Arman Savran et al (2006) developed various techniques for multimodal emotion detection. They considered internal as well as external look of EEG and fNIRS in which internal look follows the emotion generation process while external look consider video sequence. To get extra information about the information state they measured peripheral signals of the subjects. Their first goal was to build reliable data base that can be used for future research and second goal was to prove the ratability of multi modal approach to emotion recognition. Final long term aim was to create an integrated frame work for multimodal emotion recognition for both brain research and effective computing. For EEG and fNIRS recording together they consider data from five participants all are male as well as right handed. For each participant data they divided in three ambiguous parts one per session. They prepared the data in Biosemi Data format (BDF) and European Data Format (EDF). After creating data set they publish on enterface website 06 [4].

2.15 EEGLAB: an open source toolbox for analysis of signal-trial EEG dynamics including independent component analysis

Delorme, Arnaud et al (2003) describes the development of an open source toolbox that works on the MATLAB platform in which an EEG data from a channel can be imported for processing and analyzing operations. It includes the inbuilt functions to perform preprocessing operations like baseline removal, Artifact removal and filtering as well as operations like independent component analysis (ICA) and statistical analysis. The data analyzing operations can be performed by using a graphic user interface. Other flexible attributes are provided for the ease of users. EEGLAB is freely available at http://www.sccn.ucsd.edu/eeglab/ under the GNU public license for noncommercial use and open source development, together with sample data, user tutorial and extensive documentation [15].

CHAPTER 3: HUMAN BRAIN AND EEG

3.1 Human Brain

The Brain is a part of the central nervous system which is located in the skull and controls the mental processes and physical actions of a human being. The brain, along with the spinal cord and network of nerves, controls the information flow throughout the body, voluntary actions such as reading, talking, and involuntary reactions such as breathing and digestion. The human brain is a soft, grayish-white, mushroom-shaped structure. The four principal sections of human brain are: Cerebrum (divided into two large paired cerebral hemispheres), Diencephalon (Thalamus and Hypothalamus), Cerebellum and Brain stem [3][29].

The cerebrum is the largest and uppermost portion of the brain. It consist of four lobes-

Frontal lobe

Parietal lobe

Occipital lobe

Temporal lobe

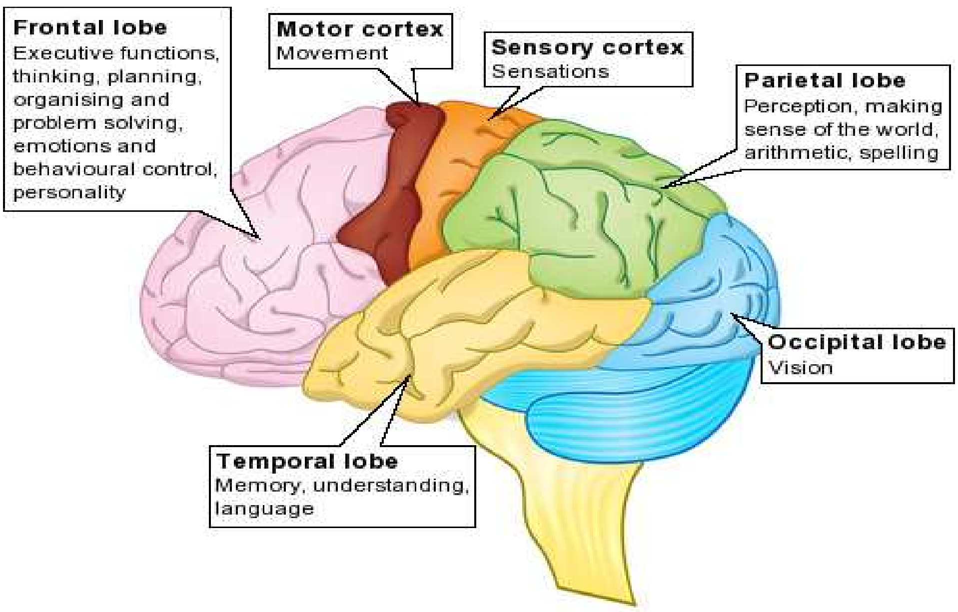

Figure 3.1: Brain Lobes [30].

3.2 Brain Lobes

Frontal lobe- It is the largest section of the brain located in the front part of the head. It receives information from various lobes and utilizes that information to carry out body movements. This lobe is responsible for conscious thoughts. Damage to the lobe can lead to the changes in mood, social differences etc.

Parietal lobe- It is the middle part of the brain and associated with processing sensory information such as pressure, touch, pain. Damage to the parietal lobe can result in problems with verbal memory, an impaired ability to control eye gaze etc.

Occipital lobe- The Occipital lobe is the back part of the cerebrum and is associated with interpreting visual stimuli and information. Damage to this lobe can cause visual problems such as difficulty in recognizing objects, in ability to identify colors.

Temporal lobe-The Temporal lobe is situated at the sides of the brain and is involved in memory speech and sense of smell. Damage to it can lead to problems with memory, visual perception and language skills [31].

3.3 Brain waves and EEG

Electroencephalography (EEG) is a recording of the electrical activity of the brain from the scalp. The first recordings were made by Hans Berger in 1929 although similar studies had been carried out in animals as early as 1870 [12].The waveforms recorded are thought to reflect the activity of the surface of the brain, the cortex. This activity is influenced by the electrical activity from the brain structures underneath the cortex. Single neuron activity is too small to be picked up by EEG. So, EEG reflects the summation of the synchronous activity of many neurons with similar spatial orientations. The nerve cells in the brain produce signals that are called action potentials. [23].

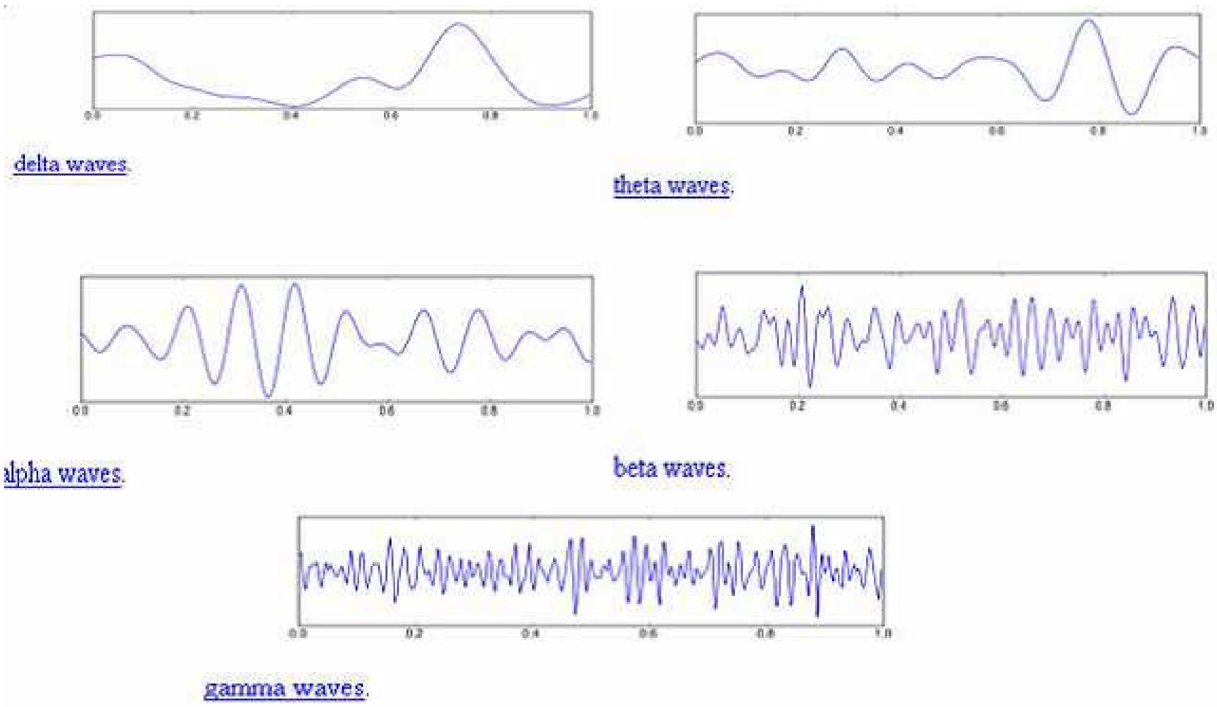

Figure 3.2: Brain waves [32].

There are mainly five types of Brain waves:

3.3.1 Delta: It has a frequency of 4Hz or below (0 to 4Hz). These are the slowest but loudest brain waves like a drum beat. These suspend external awareness and are the source of empathy. Healing and regeneration are stimulated in this state.

3.3.2 Theta: It has a frequency of 4 to 8 Hz and is classified as "slow" activity. It occur most often in sleep but are also dominant in the deep meditation.

3.3.3 Alpha: It has a frequency between 8 and 12Hz. It is usually best seen in the posterior regions of the head on each side, being higher in amplitude on the dominant side. They indicate resting state of the brain. Alpha waves aid overall mental coordination, calmness, mind/body integration and learning.

3.3.4 Beta: It has a frequency between 12 and 30Hz. Beta activity is "fast" activity. It is present when we are alert, attentive, engaged in problem solving, decision making etc. It dominates our normal waking state of consciousness.

3.3.5 Gamma: It has a frequency more than 30Hz. It is the fastest of the brainwaves and relate to simultaneous processing of information from different brain areas. It passes information rapidly and mind has to be quiet to access it [33].

3.4 Recording EEG

EEG recording records the electrical waves of activity that occurs in brain and across its surface. Electrodes are placed on different areas of person's scalp, filled with a conductive gel, and then plugged into a recording device. The electric potential arising out of the scalp is then attracted by the non invasive electrode, processed and amplified so that they can be more easily seen and examined. Both the intensity and the patterns of this electrical activity are determined by the level of excitation of different parts of the brain resulting from sleep, wakefulness, or brain diseases such as epilepsy or even psychoses [34].

3.5 Electrode

An electrode is placed on the scalp in special positions to record the summed signal from many cells. These positions are identified by the records which measure the head using the International 10/20 System. This relies on taking measurements between certain fixed points on the head. The electrodes are then placed at points that are 10% and 20% of these distances. Each electrode site is labeled with a letter and a number. The letter refers to the area of brain underlying the electrode e.g. F - Frontal lobe, T - Temporal lobe, C-Central lobe, P-Parietal lobe, and O-Occipital lobe, etc. Even numbers denote the right side of the head and odd numbers the left side of the head. There is a great variety of electrodes that can be used. The majority is small discs of stainless steel, tin, gold or silver covered with a silver chloride coating. These normally have a lead attached. The electrodes can be placed individually or a cap with electrodes already imbedded with the electrodes can be used [35].

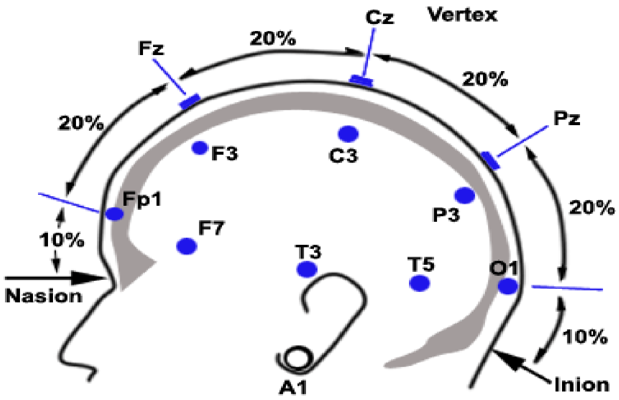

Figure 3.3:10-20 System [36].

Here the seven electrodes were considered to analyze the EEG data, three central electrode Cz, Fz, and Pz and four side electrodes F1, F2, FC1, and FC2 [37].

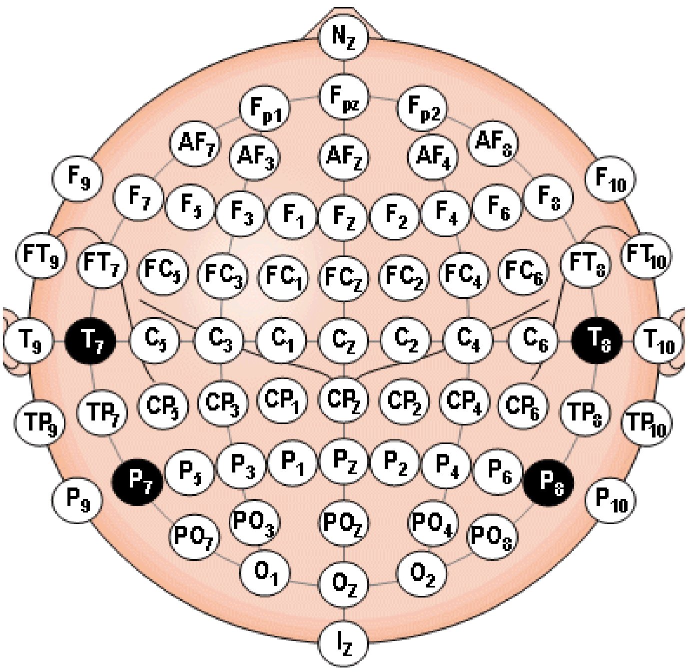

Figure 3.4: 10-20 Electrode Placement system [38].

CHAPTER 4: EMOTION

4.1 Definition of Emotion

As explained in introduction, an emotion is a mental and physiological state associated with a wide variety of feelings, thoughts, and behavior. It is a subjective experience depending on individual to individual basis and his past experiences, which makes studying emotions one of the most difficult and very open fields of research. There are more than 90 definitions of "emotion" and there is little consensus on the meaning of the term [3]. The reason why studying emotions is important is the fact that emotion is an important aspect in the interaction between humans. There are two models for theoretical emotion representation. The first model that is proposed by Darwin and after that followed by Plutchik and Ekman [39]. Ekman used the idea that all emotions can be composed of some basic emotions exactly like the white color can be composed of primary colors. Plutchik claims that there are eight basic emotions which all other emotions can be derived from. These eight emotions are anger, fear, sadness, disgust, surprise, curiosity, acceptance and joy. Ekman has chosen other emotions to be the basic emotions. He considered anger, fear, sadness, happiness, disgust and surprise as the basic emotions. Here objective is to quantification of emotion along valence axis. Following figure shows the different type of emotions such as Sad, happy, jealous, excited, sympathetic, regretful, grateful, angry and alarmed [3].

Figure 4.1: Emotions [40].

4.2 Psychology of Emotion

Psychology is the science of emotion which is closely linked to valence of the human brain with various states belongs to particular emotion. For example, the experience of fear usually occurs because of threat. Recognition of pleasant as substituent valence of human brain e.g. happiness, excited and anger etc., is an integral component and labeled as a one class of emotional state. Similarly for the perception of unpleasant and substituent valence of the human brain e.g. stress, sad, and depressed etc., is another integral component and labeled as second class of valence emotional state [19].

Various researches and theories done on emotion in over last two decades in many fields such as psychology, neuroscience, medicine, history, sociology, computer science and theories explain about the origin, neurobiology, experience, and function of emotion. To improve the result nowadays PET scans and fMRI scans are using at a large scale [41].

4.3 Classification of Emotion

Some theorists place emotions in a general category of "affective states" where affective states c include emotion-related phenomena such as pleasure and pain, modes and disposition [42][39].

To justify the emotional state following example was discussed - Imagine two car drivers, one being happy and the other being very sad. They will be driving totally different. Emotion also plays a crucial role in all-day communication. One can say a word like `OK' in a happy way, but also with anger [43] [8].

So, our objective is to quantify the emotion in two classes namely high valence (positive) and low valence (negative). In high valence emotion state following emotion are grouped such as happiness, pleasant, and excited and for emotion state low valence following emotion sad, depress, bore were grouped.

CHAPTER 5: METHODOLOGY

5.1 Signal acquisition

To create a relationship between EEG signals and emotion, dataset of EEG signals was required, for which what the emotion of the user at that moment must be known.

Different types of methodologies can be used like showing IAPS [13] images, IADS audio and videos stimuli (pictures) or by using Clynes method where in the user is asked to think about their respective experiences in part of life stimulating a corresponding emotion. With our understanding, the quantification of emotions with the third method is not possible using ERP as an attribute. Emotion quantification can be done using EEG signal as well as ERP attributes. So data set gathered by using IAPS images as stimuli was chosen for our analysis.

Since the objective is to quantify emotion along the valence axis, only those EEG signals gathered from different participants by showing IAPS images corresponding to the two emotions pleasant and unpleasant while ignoring the arousal dimension were processed upon.

5.2 Data collection

The data set chosen for the emotion quantification was obtained from enterface workshop in the year 2006 [4]. Here the data was gathered from five participants all are male and right handed in three sessions. A total of 150 images classified on the basis of mean arousal and mean valence values were shown to each participant in each session for the study of three emotions calm, exciting positive and exciting negative. A total of 3 sessions of approximately 15 minutes were conducted on each participant. Some of the images were repeating in the image set. Thus a total of 450 images were shown to each participant after the conclusion of the third session. The pictures related to sexual arousal were neglected. The data has been gathered using a Biosemi Active 2 device with 64 electrodes in BDF format (Biosemi Data Format) at a sampling rate of 1024 Hz [44].

On showing different images to the participants P1, P2, P3, P4, and P5, their emotions are recorded as on first looking at the image of blood the participant shows sad emotion. So that marked emotion cues on Self-Assessment Manikin (SAM) [14] chart and also on 2-D valence and arousal graph to mention the emotions that the participant in highly emotional state or not. Five emotional states are high arousal, low arousal, high valence, low valence and calm. These emotional states are defined according to the image seen by the participant in different sessions in the IAPS [13]. A particular time window is mentioned for each image so that the participant can relax or take break while seeing the images. To calculate the emotion the arousal and valence scales from 1 to 9 [3].

Calm: Mean Arousal < 4

4 < Mean Valence < 6

Exciting Positive: Valence > 6.8

Variance (Valence) < 2

Mean Arousal > 5

Exciting Negative: Mean Valence < 3

Mean Arousal > 5

The images shown for calm had a mean arousal value of less than 4 and mean valence value between 4 to 6, while the stimuli for positive exciting had a mean valence greater than 6, variance valence smaller than 2 and mean arousal greater 5, and for exciting negative the images had mean valence should smaller than 3 and mean arousal greater than 5.

Since fNIRS was also being conducted, some 10 frontal electrodes from the EEG cap were not used that were F5, F8, AF7, AF8, AFz, FP1, FP2, FPz, F7, and F6. Apart from this other physiological parameters like peripheral information were also determined from the subjects. In our study we considered participants 3, 4, and 5 as subjects for quantification to reduce the data set. Each image was shown for 2.5 seconds and total of 5 images were shown for evoking one emotion at a time so as to ensure stability of emotion over time. Such 30 image blocks were shown to each participant in each session. So to evoke one emotion the EEG data was collected for 12.5 seconds. A cross mark was shown for 3 seconds before the start of a stimulus and a black screen was shown for 10 seconds after the image set. The protocol followed in the acquisition of data is shown below.

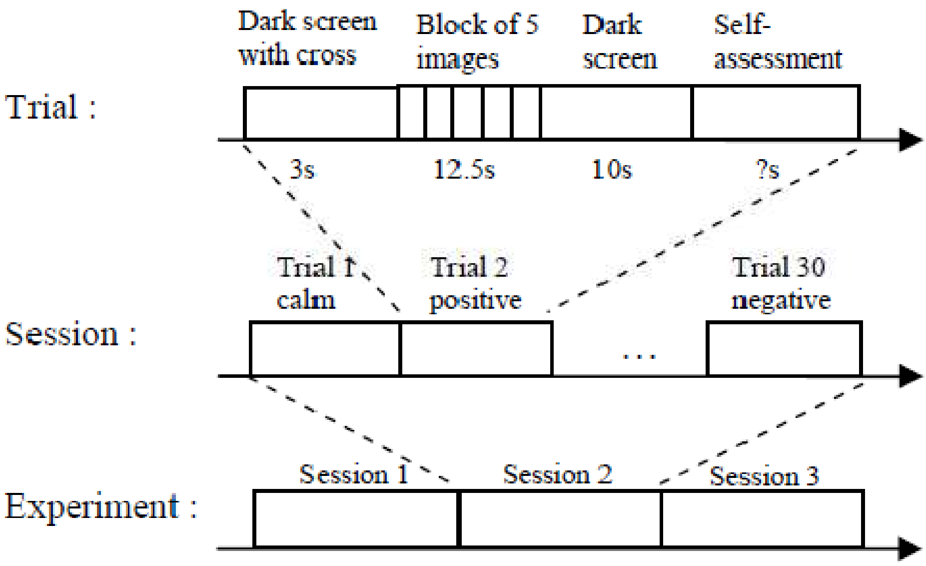

Figure 5.1: Protocol Description [4].

The EEG data was collected at a sampling rate of 1024 Hz in the three sessions for each participant and the images were shown in a random order. The acquired EEG data set contains four files, one containing the EEG and physiological variables data for all five participants in 3 sessions along with the corresponding mark files. The mark file for each session of a particular participant indicates the time of start and termination of an emotion stimulus to a participant. The format of these two files is:-

PART**A**_IAPS_SES**B**_EEG_fNIRS_**DDMMAAAA**.bdf

PART**A**_IAPS_SES**B**_EEG_fNIRS_**DDMMAAAA**.bdf.mrk

Where A is the participant number (1-5), B is the session number (1-3) and DDMMAAAA represents the date of the recording. To reduce the data set, the EEG data for participants 3, 4, and 5 has been down-sampled at a sampling rate of 256Hz.

Table 5.1: The table below shows the selected images from the IAPS image set that were selected for evoking the above said three emotions along with their values of mean arousal and mean valence.

mean arousal			mean Valence			images /sess1	2	3	Session-1	Session-2	Session-3
2.61	(N)6.24	5.09	5.19	2.19	7.91	7090.jpg	6570.jpg	2058.jpg	Calm	Neg	Pos
2.33	6.79	5.71	4.88	1.56	7.02	7006.jpg	3266.jpg	8090.jpg	Calm	Neg	Pos
2.99	6.83	6.14	4.69	2.19	7.02	7030.jpg	6540.jpg	8300.jpg	Calm	Neg	Pos
2.87	5.36	5.54	5.38	2.81	6.97	5530.jpg	6825.jpg	7570.jpg	Calm	Neg	Pos
3.21	5.36	5.1	4.77	2.92	7.29	9700.jpg	7359.jpg	4610.jpg	Calm	Neg	Pos
5.41	6.12	6.55	8.34	2.54	2.26	1710.jpg	6570.1.jpg	3150.jpg	Pos	Neg	Neg
5.76	5.92	5.52	7.53	2.67	2.49	7270.jpg	9425.jpg	3220.jpg	Pos	Neg	Neg
5.94	5.38	5.25	7.53	2.19	2.47	8210.jpg	9140.jpg	2053.jpg	Pos	Neg	Neg
5.18	7.35	6.44	7.18	2.37	2.7	8350.jpg	6230.jpg	6370.jpg	Pos	Neg	Neg
5.16	6.91	6.33	7.58	2.35	2.23	2160.jpg	3400.jpg	6360.jpg	Pos	Neg	Neg
2.95	(L)3.95	2.59	5.22	5.21	5.21	7053.jpg	1616.jpg	5740.jpg	Calm	Calm	Calm
2.79	3.98	2.75	5.71	5.29	4.93	2580.jpg	7058.jpg	7050.jpg	Calm	Calm	Calm
3.07	3.16	2.61	4.39	4.97	4.72	2221.jpg	7002.jpg	7150.jpg	Calm	Calm	Calm

1.76	2	3.43	4.94	5.04	4.73	7010.jpg	7004.jpg	7180.jpg	Calm	Calm	Calm
2.83	2.82	3.72	4.96	5.15	5.4	7235.jpg	5510.jpg	7546.jpg	Calm	Calm	Calm
5.95	5.69	5.68	1.95	7.12	7.35	3191.jpg	4599.jpg	2208.jpg	Neg	Pos	Pos
5.99	5.16	5.49	2.33	7.48	7.26	6243.jpg	8540.jpg	5270.jpg	Neg	Pos	Pos
6.64	5.28	6.02	1.98	7.05	7.35	9252.jpg	2346.jpg	5470.jpg	Neg	Pos	Pos
7.09	5.68	5.79	2.73	7.61	7.58	6550.jpg	5700.jpg	8496.jpg	Neg	Pos	Pos
6.35	5.67	5.12	1.49	7.19	6.82	3063.jpg	5623.jpg	8371.jpg	Neg	Pos	Pos
6.44	7.27	6.14	7.91	7.57	7.74	8501.jpg	8185.jpg	8470.jpg	Pos	Pos	Pos
6.55	5.91	6.65	7.03	7.75	7.73	5629.jpg	7502.jpg	8080.jpg	Pos	Pos	Pos
5.71	5.08	5.19	7.34	6.82	7.57	5260.jpg	4601.jpg	5600.jpg	Pos	Pos	Pos
6.14	5.22	5.14	7.02	7.02	7.69	8300.jpg	8503.jpg	7330.jpg	Pos	Pos	Pos
5.3	6.59	6.28	6.91	7.12	8.1	7220.jpg	8180.jpg	8190.jpg	Pos	Pos	Pos
6.05	3.57	6.38	2.04	5.88	2.31	9800.jpg	8311.jpg	6315.jpg	Neg	Calm	Neg
5.59	3.07	6.29	2.85	5.07	2.38	6571.jpg	7056.jpg	6821.jpg	Neg	Calm	Neg
5.64	2.17	6.97	1.96	4.97	1.58	9571.jpg	7020.jpg	3130.jpg	Neg	Calm	Neg
6.5	2.92	6.9	2.8	5.5	2.4	6250.jpg	7140.jpg	6260.jpg	Neg	Calm	Neg

4		3	3		4						
6.82	2.71	6.06	1.8	4.63	2.21	3530.jpg	7025.jpg	6021.jpg	Neg	Calm	Neg
3.01	6.6	2.66	5.33	2.57	4.98	7052.jpg	9250.jpg	7035.jpg	Calm	Neg	Calm
3.22	5.63	2.98	5.08	2.68	4.98	6150.jpg	9429.jpg	7161.jpg	Calm	Neg	Calm
3.44	5.2	2.96	5.42	2.93	4.23	7710.jpg	9530.jpg	7234.jpg	Calm	Neg	Calm
2.88	5.53	3.82	5.06	2	5.9	7179.jpg	9253.jpg	7495.jpg	Calm	Neg	Calm
3	5.98	3.71	5.42	2.73	4.06	5500.jpg	2688.jpg	2206.jpg	Calm	Neg	Calm
6.61	6.46	5.9	7.09	2.73	1.52	8400.jpg	8485.jpg	3015.jpg	Pos	Neg	Neg
6.12	5.02	5.06	7.63	2.99	2.3	8170.jpg	9180.jpg	3181.jpg	Pos	Neg	Neg
7.27	6.58	5.28	7.57	1.4	2.32	8185.jpg	3102.jpg	3061.jpg	Pos	Neg	Neg
5.43	6.77	6.21	7.2	1.8	2.62	4641.jpg	3068.jpg	2683.jpg	Pos	Neg	Neg
5.22	6.49	7.12	7.02	1.6	1.79	8503.jpg	3100.jpg	3060.jpg	Pos	Neg	Neg
5.82	5.56	3.18	1.9	7.76	5.21	3016.jpg	8420.jpg	7547.jpg	Neg	Pos	Calm
6.21	5.78	3.26	2.82	7.51	5.21	6830.jpg	8502.jpg	5471.jpg	Neg	Pos	Calm
5.25	6.44	2.89	1.79	7.91	5.24	2095.jpg	8501.jpg	7100.jpg	Neg	Pos	Calm
5.21	5.84	3.93	1.8	7.01	5.96	3301.jpg	5450.jpg	8465.jpg	Neg	Pos	Calm

5.6	5.48	2.51	1.91	7.53	4.45	3101.jpg	5480.jpg	5130.jpg	Neg	Pos	Calm
3.88	5.74	3.98	4.53	7.56	5.54	9401.jpg	8380.jpg	7096.jpg	Calm	Pos	Calm
2.71	6.35	2.63	4.63	7.54	4.03	7025.jpg	8200.jpg	9360.jpg	Calm	Pos	Calm
2.75	5.52	2.65	4.93	7.18	4.77	7050.jpg	4640.jpg	7705.jpg	Calm	Pos	Calm
2.63	5.83	3.8	4.03	7.57	4.75	9360.jpg	2216.jpg	7590.jpg	Calm	Pos	Calm
2.96	7.35	3.08	5.18	7.33	4.53	2880.jpg	8030.jpg	9210.jpg	Calm	Pos	Calm
6.92	6.37	6.76	2.63	2.48	1.91	6250.1.jpg	6312.jpg	3030.jpg	Neg	Neg	Neg
7.22	5.97	5.58	1.48	2.76	2.46	3080.jpg	2981.jpg	9900.jpg	Neg	Neg	Neg
5.88	6.28	6.04	2.46	2.91	2.03	7380.jpg	6834.jpg	9254.jpg	Neg	Neg	Neg
6.41	5.49	6	1.45	1.78	2.33	3064.jpg	2800.jpg	9902.jpg	Neg	Neg	Neg
5.62	5.19	6.06	2.3	2.55	2.96	3051.jpg	9419.jpg	9630.jpg	Neg	Neg	Neg
5.28	5.79	5.78	7.05	7.58	2.87	2346.jpg	8496.jpg	9424.jpg	Pos	Pos	Neg
5.09	6.73	5.75	7.02	7.77	2.71	7508.jpg	8370.jpg	9611.jpg	Pos	Pos	Neg
5.71	5.8	5.7	8.22	6.85	2.58	5833.jpg	8340.jpg	2717.jpg	Pos	Pos	Neg
5.41	6.3	5.03	7.03	7.06	2.49	8531.jpg	8034.jpg	9007.jpg	Pos	Pos	Neg
5.0	5.44	6.0	6.8	7.1	2.1	4601.jpg	4623.jpg	6022.jpg	Pos	Pos	Neg

8		9	2	3	4						
5.59	5.71	2.73	7.64	7.02	4.93	2209.jpg	8090.jpg	7059.jpg	Pos	Pos	Calm
5.97	5.59	3.01	6.82	7.8	4.82	8116.jpg	5910.jpg	7038.jpg	Pos	Pos	Calm
6.14	5.41	2.74	7.74	8.34	5.39	8470.jpg	1710.jpg	5731.jpg	Pos	Pos	Calm
5.12	5.11	3.07	7.62	7.21	4.39	1811.jpg	7260.jpg	2221.jpg	Pos	Pos	Calm
5.02	6.02	2.77	6.84	7.35	5.09	4624.jpg	5470.jpg	7233.jpg	Pos	Pos	Calm
3.18	3.02	5.41	5.21	4.9	8.34	7547.jpg	7055.jpg	1710.jpg	Calm	Calm	Pos
3.85	1.76	6.12	4.86	4.94	7.63	6570.2.jpg	7010.jpg	8170.jpg	Calm	Calm	Pos
2.92	2.69	5.16	5.5	4.69	7.58	7140.jpg	7040.jpg	2160.jpg	Calm	Calm	Pos
2.66	2.55	5.16	4.98	4.43	7.27	7035.jpg	7060.jpg	2352.1.jpg	Calm	Calm	Pos
2.89	3.39	5.42	5.24	5.35	7.41	7100.jpg	7057.jpg	2345.jpg	Calm	Calm	Pos
5.04	3.44	5.76	2.21	5.42	7.53	9421.jpg	7710.jpg	7270.jpg	Neg	Calm	Pos
6.62	3.83	5.16	2.09	5.39	7.48	9810.jpg	2445.jpg	8540.jpg	Neg	Calm	Pos
6.8	3.79	5.63	2.45	4.7	6.85	2730.jpg	2446.jpg	7501.jpg	Neg	Calm	Pos
5.41	3.84	5.56	2.02	5.55	7.76	3230.jpg	7190.jpg	8420.jpg	Neg	Calm	Pos
5.66	3.06	5.91	2.31	4.95	7.75	9428.jpg	7034.jpg	7502.jpg	Neg	Calm	Pos

3.39	6.61	2.96	5.35	7.09	5.18	7057.jpg	8400.jpg	2880.jpg	Calm	Pos	Calm
3.08	5.09	2.95	4.53	7.91	4.95	9210.jpg	2058.jpg	2890.jpg	Calm	Pos	Calm
3.71	5.14	2.83	4.81	7.69	4.96	7037.jpg	7330.jpg	7235.jpg	Calm	Pos	Calm
2.03	5.12	3.83	4.52	7.62	5.67	7031.jpg	1811.jpg	7285.jpg	Calm	Pos	Calm
3.26	5.07	3.22	5.21	7.27	5.08	5471.jpg	5660.jpg	6150.jpg	Calm	Pos	Calm
5.6	2.88	5.26	6.96	5.06	2.63	8500.jpg	7179.jpg	9430.jpg	Pos	Calm	Neg
5.67	3.32	5.78	7.19	4.88	1.91	5623.jpg	7036.jpg	2703.jpg	Pos	Calm	Neg
5.06	2.88	5.76	7	5.59	2.34	7400.jpg	5390.jpg	9006.jpg	Pos	Calm	Neg
5.48	3.01	6.29	7.53	5.33	2.35	5480.jpg	7052.jpg	3550.1.jpg	Pos	Calm	Neg
5.09	3.94	6.96	7.91	4.69	2.46	2058.jpg	7044.jpg	6510.jpg	Pos	Calm	Neg
3.79	2.95	5.8	5.64	4.25	6.85	7236.jpg	7700.jpg	8340.jpg	Calm	Calm	Pos
3.43	3.33	6.99	4.73	5.82	7.57	7180.jpg	1670.jpg	5621.jpg	Calm	Calm	Pos
3.58	3.01	6.73	5.77	4.93	7.77	7192.jpg	7009.jpg	8370.jpg	Calm	Calm	Pos
3.35	3.57	6.84	4.77	5.15	7.01	7130.jpg	7207.jpg	8186.jpg	Calm	Calm	Pos
3.98	1.72	5.87	5.29	4.87	7.33	7058.jpg	7175.jpg	5460.jpg	Calm	Calm	Pos
2.1	5.59	7.0	4.9	2.8	1.7	7020.jpg	9925.jpg	3069.jpg	Calm	Neg	Neg

7		3	7	4							
3.26	5.72	5.89	5.33	1.88	1.84	7500.jpg	3350.jpg	9433.jpg	Calm	Neg	Neg
3.57	5.35	5.86	5.15	2.63	2.91	7207.jpg	3160.jpg	6213.jpg	Calm	Neg	Neg
2.81	5.82	6.61	4.45	2.42	2.59	7224.jpg	9500.jpg	6300.jpg	Calm	Neg	Neg
3.8	5.99	6.36	4.75	2.5	2.43	7590.jpg	9400.jpg	9050.jpg	Calm	Neg	Neg
5.83	6.14	2.93	7.57	1.68	5.56	2216.jpg	9570.jpg	7205.jpg	Pos	Neg	Calm
5.11	7.29	3.85	7.21	1.9	4.86	7260.jpg	6350.jpg	6570.2.jpg	Pos	Neg	Calm
5.54	6.54	2.6	6.97	1.9	4.99	7570.jpg	9635.1.jpg	7041.jpg	Pos	Neg	Calm
5.63	7.34	2.95	6.85	1.59	5.33	7501.jpg	3000.jpg	5520.jpg	Pos	Neg	Calm
6.84	6.13	2.03	7.01	2.79	4.52	8186.jpg	4664.2.jpg	7031.jpg	Pos	Neg	Calm
3.12	2.28	5.71	5.31	4.94	7.34	5533.jpg	7950.jpg	5260.jpg	Calm	Calm	Pos
3.78	3.95	6.35	5.58	5.27	7.54	7183.jpg	7550.jpg	8200.jpg	Calm	Calm	Pos
2.59	2.43	7.35	5.21	4.91	7.33	5740.jpg	2840.jpg	8030.jpg	Calm	Calm	Pos
2.27	3.76	6.44	4.55	5.04	7.91	7110.jpg	2749.jpg	8501.jpg	Calm	Calm	Pos
3.83	3.68	6.55	5.67	5.17	7.03	7285.jpg	7043.jpg	5629.jpg	Calm	Calm	Pos
6.36	5.5	2.79	1.83	2.12	5.71	3140.jpg	9560.jpg	2580.jpg	Neg	Neg	Calm

5.18	6.99	3.14	2.67	2.21	4.84	2751.jpg	3500.jpg	5534.jpg	Neg	Neg	Calm
5.28	5.16	3.09	2.26	2.41	5.61	9301.jpg	9340.jpg	2980.jpg	Neg	Neg	Calm
6.2	5.7	2.27	2.06	2.27	4.55	9910.jpg	9901.jpg	7110.jpg	Neg	Neg	Calm
5.66	5.82	3.35	2.61	3.2	4.77	9423.jpg	6200.jpg	7130.jpg	Neg	Neg	Calm
6.65	5.09	3.81	7.73	7.02	5.5	8080.jpg	7508.jpg	7283.jpg	Pos	Pos	Calm
5.19	5.68	2.81	7.57	7.35	4.45	5600.jpg	2208.jpg	7224.jpg	Pos	Pos	Calm
5.59	5.97	2.39	7.8	6.82	4.82	5910.jpg	8116.jpg	7491.jpg	Pos	Pos	Calm
5.56	5.43	3.21	7.76	7.2	4.77	8420.jpg	4641.jpg	9700.jpg	Pos	Pos	Calm
6.07	5.71	3.26	7.63	8.22	5.33	8499.jpg	5833.jpg	7500.jpg	Pos	Pos	Calm
6.9	3.07	6.18	2.17	5.02	2.76	2811.jpg	7160.jpg	6530.jpg	Neg	Calm	Neg
6	2.95	5.39	2.26	5.22	2.26	9300.jpg	7053.jpg	9181.jpg	Neg	Calm	Neg
7.26	3.69	5.5	1.79	5.15	2.89	3010.jpg	5531.jpg	9427.jpg	Neg	Calm	Neg
5.09	3.29	6.52	2.45	5.93	2.04	2900.jpg	7039.jpg	9921.jpg	Neg	Calm	Neg
5.44	2.43	7.34	2.51	4.82	1.59	3215.jpg	7217.jpg	3000.jpg	Neg	Calm	Neg
6.2	5.06	5.74	2.21	7	7.56	6415.jpg	7400.jpg	8380.jpg	Neg	Pos	Pos
5.7	6.07	6.5	2.3	7.6	7.1	9903.jpg	8499.jpg	8180.jpg	Neg	Pos	Pos

1		9	6	3	2						
5.46	5.94	5.69	2.52	7.53	7.12	2710.jpg	8210.jpg	4599.jpg	Neg	Pos	Pos
5.91	5.42	5.59	2.95	7.41	7.8	8230.jpg	2345.jpg	5910.jpg	Neg	Pos	Pos
6.25	6.28	5.59	2.09	8.1	7.64	2352.2.jpg	8190.jpg	2209.jpg	Neg	Pos	Pos
3.81	3.83	3.26	5.5	5.28	5.31	7283.jpg	7242.jpg	2745.1.jpg	Calm	Calm	Calm
3.26	3.31	3.79	5.31	5.67	5.19	2745.1.jpg	2518.jpg	5532.jpg	Calm	Calm	Calm
3.16	3.07	3.88	4.97	4.39	4.53	7002.jpg	5120.jpg	9401.jpg	Calm	Calm	Calm
3.09	3.58	3.79	5.61	5.77	5.64	2980.jpg	7192.jpg	7236.jpg	Calm	Calm	Calm
2.28	3.77	2.42	4.94	4.55	5.52	7950.jpg	7595.jpg	7490.jpg	Calm	Calm	Calm
6.28	6.34	5.52	8.1	2.95	7.18	8190.jpg	6210.jpg	4640.jpg	Pos	Neg	Pos
5.84	5.43	5.78	7.01	2.69	7.6	5450.jpg	6242.jpg	4626.jpg	Pos	Neg	Pos
5.12	7.07	5.41	6.82	1.51	7.03	8371.jpg	9410.jpg	8531.jpg	Pos	Neg	Pos
5.78	5.77	5.3	7.6	1.92	6.91	4626.jpg	3180.jpg	7220.jpg	Pos	Neg	Pos
5.68	5.92	5.71	7.61	2.54	8.22	5700.jpg	3550.jpg	5833.jpg	Pos	Neg	Pos
5.1	5.78	5.44	7.29	1.87	7.13	4610.jpg	3062.jpg	4623.jpg	Pos	Neg	Pos
5.87	6.2	5.6	7.33	1.63	6.96	5460.jpg	3005.1.jpg	8500.jpg	Pos	Neg	Pos

6.3	5.34	5.78	7.06	2.45	7.51	8034.jpg	3017.jpg	8502.jpg	Pos	Neg	Pos
5.16	5.95	5.52	7.27	1.82	7.38	2352.1.jpg	3225.jpg	7230.jpg	Pos	Neg	Pos
6.73	5.76	5.07	7.77	2.5	7.27	8370.jpg	9920.jpg	5660.jpg	Pos	Neg	Pos
6.7	5.02	5.76	1.79	6.84	2.3	3110.jpg	4624.jpg	9911.jpg	Neg	Pos	Neg
5.69	5.52	5.75	2.31	7.38	1.82	9420.jpg	7230.jpg	3261.jpg	Neg	Pos	Neg
6.08	5.18	6.11	1.83	7.18	2.7	9405.jpg	8350.jpg	9620.jpg	Neg	Pos	Neg
6.86	5.49	6.46	1.88	7.26	2.48	3071.jpg	5270.jpg	9600.jpg	Neg	Pos	Neg
6.94	6.99	5.8	1.98	7.57	2.45	6313.jpg	5621.jpg	6838.jpg	Neg	Pos	Neg
6.01	2.32	6	2.19	5.27	1.56	6212.jpg	7080.jpg	3168.jpg	Neg	Calm	Neg
5.02	3.21	6.53	2.42	5.14	2.16	2799.jpg	7170.jpg	6560.jpg	Neg	Calm	Neg
6.84	2.33	5.82	1.56	4.88	1.67	3120.jpg	7006.jpg	9040.jpg	Neg	Calm	Neg
5.41	2.61	5.55	2.46	5.19	2.59	9520.jpg	7090.jpg	6831.jpg	Neg	Calm	Neg
6.91	2.42	7.26	1.31	5	1.79	3053.jpg	7000.jpg	3010.jpg	Neg	Calm	Neg

5.3 Data Analysis

The data of electrodes Cz, Pz, Fz, Fc1, Fc2, F1, and F2 available on enterface 06 website was a raw data in BDF (Biosemi Data Format) format obtained at a rate of 1024Hz, except the first session of participant 1 that was recorded at sampling rate of 256Hz. In order to reduce the data set, the EEG data was loaded into the EEG lab [15] which is an open source software and then down-sampled to 256Hz. The sampled output for all 64 electrodes and the physiological variables were then saved into the memory of computer for further analysis in case of each participant. The features have been extracted by acquiring the data for 20 marks for each session of a participant. Thus the data acquired from a total of 180 marks of the three participants (P3, P4, and P5) was processed upon for the classification into two classes

5.3.1 Artifact Removal

Here no algorithm or an inbuilt feature of EEG lab or any other source has been used. The program for baseline removal has been written in MATLAB. From the excel file obtained from EEG LAB for each participant and for each session, the sample values of the selected electrode were individually loaded in MATLAB for the baseline removal. No other filtering operation or component analysis operation has been performed.

5.4 Feature Extraction

After getting sample values and performing the operation like baseline removal, the objective of quantification of emotions using three different classifiers has been achieved. To work with these classifiers the following features were extracted from the sampled data:

5.4.1 Power Spectral Density

The features were extracted in PSD using MATLAB function [Pxx,w] = periodogram (x) returns the power spectral density (PSD) estimate Pxx of the sequence x using a periodogram. The power spectral density is calculated in units of power per radians per sample [21].

$$\max(\omega) = 1/n(|X(\omega)|^2$$

Table 5.2: Table shows the Extracted features of Power Spectrum Density (PSD).

PSDmax(0-4Hz)	PSDmin(0-4Hz)	PSDmax(4-8Hz)	PSDmin(4-8Hz)	PSDmax(8-12Hz)	PSDmin(8-12Hz)	PSDmax(12-30Hz)	PSDmin(12-30Hz)	PSDmax(above 30Hz)	PSDmin(above 30Hz)
1410.6	2.0762	3.6139	0.393	3.7092	0.4198	0.9748	0.0795	0.2554	0.0255
1789.1	1.6237	7.3439	0.2766	2.944	0.4882	1.55	0.2094	0.4813	0.0345
1537.2	2.0848	7.1874	0.3017	3.4974	0.6252	1.896	0.1864	0.5571	0.0603
1445.4	1.2259	5.0482	0.3971	2.1705	0.5489	1.1263	0.171	0.4233	0.016
567.2	1.3499	3.6605	0.3781	3.8674	0.4867	1.0258	0.1147	0.4082	0.0516
3549.1	2.5372	8.4205	0.4624	4.2253	0.711	1.7289	0.2605	0.5332	0.0418
1399.5	1.0213	1.3784	0.1991	0.3856	0.094	0.1679	0.0125	0.0545	0.0049
7012.2	8.5287	11.285	1.0683	3.4257	0.5107	1.3088	0.1072	0.4147	0.0429
3485.6	2.4329	9.1132	0.7426	4.4962	0.3105	2.0317	0.1885	0.5942	0.0814
5159	4.8448	10.859	0.8418	3.8488	0.3914	1.8832	0.2495	0.5844	0.0681
3548.3	3.1614	7.3596	0.7563	2.9136	0.2506	1.3657	0.1765	0.4722	0.0498
3953.4	3.3413	8.4199	0.63	3.1929	0.2433	1.2195	0.0703	0.4538	0.0461
7317.3	5.9247	11.51	1.2352	4.6491	0.26	2.286	0.1882	0.6198	0.0548
2598.5	1.9376	2.3725	0.3948	0.8288	0.17	0.3182	0.0236	0.0716	0.0107
3089.3	3.291	7.4928	0.7864	2.5117	0.5364	1.6008	0.0829	0.408	0.0252
2045.4	2.8153	8.5901	0.8829	4.9665	0.5856	3.3367	0.242	0.9328	0.0315
3187.5	3.2884	12.434	1.0224	4.9961	0.9742	3.2182	0.321	0.7851	0.0359
2059	2.3477	6.9662	0.903	3.8245	0.4591	2.2066	0.1944	0.6705	0.013
1878.6	2.602	7.3527	1.0195	3.3321	0.827	1.852	0.2286	0.5728	0.0423
12485	11.681	20.758	3.9548	7.4481	1.7575	4.2575	0.3608	1.4094	0.081
2449.4	1.9159	4.7307	0.4067	1.2019	0.2694	0.5445	0.0393	0.1098	0.0153
2130.9	1.077	2.5957	0.4043	1.9214	0.1896	1.0887	0.099	0.2906	0.021
1328.7	2.6225	5.9014	0.8515	3.9707	0.51	2.3858	0.2417	0.6453	0.0423
2475.1	3.8872	7.4418	0.6516	3.4758	0.4739	2.9459	0.2321	0.6966	0.0333
1287.2	1.6658	3.4048	0.737	2.445	0.4038	1.6554	0.1189	0.7561	0.0187
553.31	1.0061	2.415	0.4655	1.9599	0.1721	1.7987	0.0752	0.5108	0.0171

14092	13.859	20.842	2.1274	7.1232	1.1394	3.7057	0.3209	1.3111	0.0834
863.98	0.9746	1.1047	0.1573	0.3197	0.0458	0.171	0.0081	0.0359	0.0024
289.02	0.9737	2.0474	0.1312	1.1623	0.1561	1.1221	0.0472	0.2212	0.0124
504.92	4.5816	4.7223	0.4989	3.6153	0.4301	2.0217	0.1408	1.0048	0.0428
955.41	4.1725	4.5356	0.5914	3.1305	0.4621	2.7091	0.1727	0.9873	0.0626
443.36	2.4027	3.2245	0.4662	2.2735	0.3878	1.5821	0.0924	0.7426	0.0204
649.4	2.1321	2.7785	0.5048	1.58	0.3283	1.8974	0.0978	0.4815	0.0364
726.28	4.0807	4.5644	0.5247	2.3503	0.5359	2.4409	0.1293	0.9383	0.0466
519.65	0.2372	0.4462	0.0232	0.1031	0.0317	0.1086	0.0096	0.0297	0.0031
4230.1	4.2606	4.9111	0.8532	2.6843	0.559	1.6358	0.1027	0.3591	0.0235
2355.5	4.9316	8.9376	1.0931	3.0584	0.9661	2.4145	0.2515	0.7484	0.0556
2356.6	4.6214	10.263	1.3011	3.0492	0.8211	2.5822	0.1981	0.6311	0.0537
4920.4	5.6759	11.116	1.121	2.7713	1.0171	2.3204	0.244	0.5681	0.0678
3151	4.7021	6.4179	1.3267	2.7667	0.7862	1.9401	0.1369	0.4152	0.0244
2397.4	4.2298	7.8486	1.0721	3.194	0.9456	2.5174	0.2228	0.5667	0.0331
3322.4	2.6779	3.0787	0.4808	0.6544	0.1726	0.3202	0.029	0.0809	0.0059
563.26	1.346	4.0208	0.2603	3.02	0.2967	1.3832	0.1059	0.2555	0.0333
1012.3	1.9832	5.2985	0.478	3.0253	0.9212	2.0307	0.2097	0.7109	0.0378
1593.4	2.2799	8.0063	0.3103	4.1957	0.893	1.8909	0.2014	0.8309	0.0489
1137.7	2.6953	4.8599	0.2917	1.9063	0.6485	1.8008	0.1346	0.726	0.0314
904.01	2.1245	4.8956	0.1734	3.405	0.3216	1.7135	0.1639	0.4176	0.0185
472.16	2.9913	6.2116	0.585	3.0685	0.8969	1.8235	0.1877	0.5999	0.0488
454.96	0.324	0.7685	0.0519	0.2092	0.0303	0.1738	0.0121	0.0548	0.0036
3427.5	5.5659	7.0275	1.4611	3.3676	0.3168	2.1412	0.1416	0.7424	0.0284
2974.4	4.0014	5.3458	1.2096	3.0572	0.495	2.2947	0.1881	1.1356	0.0695
2885.7	4.1344	5.4837	1.6748	3.4659	0.8482	3.2107	0.1833	1.3494	0.0537
3264.3	2.5767	4.2432	0.9723	2.7782	0.3963	2.0798	0.1493	1.0071	0.0508
5580.6	5.5074	8.3114	2.3625	4.0868	0.6582	2.8925	0.2336	1.3069	0.0518
5181.4	4.1553	6.7906	1.6944	3.8921	1.0829	2.6883	0.2553	1.1309	0.0412
3980.7	5.1989	5.3287	1.4323	1.4847	0.475	0.7661	0.0841	0.1778	0.0339
272.04	0.9358	2.3356	0.5179	1.4811	0.3823	1.3995	0.0758	0.2809	0.0254

152.72	2.8081	5.1496	1.159	5.2949	0.5354	2.6138	0.1859	0.7467	0.0345
130.76	2.4328	5.5195	0.9665	4.9332	0.791	3.3945	0.1959	0.6774	0.0363
168.57	2.6351	2.6479	0.6998	3.6614	0.6182	2.5356	0.1375	0.4686	0.041
1023.3	1.6107	3.1242	0.7316	2.6287	0.4141	2.3313	0.1255	0.3737	0.0262
226.55	3.1641	5.1497	1.0872	5.493	0.5665	3.0978	0.2234	0.6355	0.0454
1106.5	0.2921	0.3812	0.061	0.1641	0.0373	0.0982	0.0102	0.036	0.0034
203.62	0.6368	1.7206	0.2433	2.0625	0.1286	1.0963	0.0544	0.8734	0.0193
289.43	1.5972	2.2567	0.646	2.8669	0.467	2.8185	0.0951	8E+07	0.0141
370.48	1.7172	1.783	0.4587	3.5977	0.1416	2.7478	0.1426	0.7598	0.0318
559.86	1.9454	2.1113	0.8036	2.017	0.3911	2.3599	0.1354	0.5972	0.0192
362.66	1.1597	1.1599	0.3275	2.3403	0.1938	1.8103	0.0819	0.7448	0.0359
611.74	1.4965	1.7112	0.4721	3.1052	0.271	2.8403	0.076	0.7929	0.0173
173.62	0.2245	0.278	0.0454	0.1247	0.0422	0.1037	0.0049	0.0889	0.0034
178.09	0.3292	2.4975	0.1946	1.7039	0.2404	0.8356	0.0.6844 3553	0.2444	0.0156
214.22	2.7942	3.486	0.2494	3.1876	0.4311	1.3759	0.1206	1.0147	0.043
740.68	2.9472	4.5107	0.3377	3.6789	0.1788	1.4535	0.1548	1.0553	0.0485
147.39	1.7867	2.5642	0.2872	2.1078	0.2123	0.9925	0.0798	0.8687	0.0245
57.764	1.8084	3.1551	0.1655	2.0924	0.1182	0.9712	0.0435	0.592	0.0318
418.2	2.6669	4.5245	0.3898	3.0893	0.2973	1.314	0.0776	0.962	0.0341
25.589	0.1802	0.2695	0.0592	0.1162	0.0251	0.0973	0.0058	0.0531	0.0035
1374.4	1.2604	4.1725	0.6002	2.3305	0.2918	0.7612	0.0624	0.35	0.0223
3562.5	1.6542	4.4183	1.5089	2.0429	0.5812	1.9349	0.2632	0.6339	0.0561
2824.5	2.4719	4.0132	1.1821	2.4518	0.2993	2.5243	0.2002	0.6231	0.0468
441.46	1.0769	2.069	0.5339	1.5223	0.4322	1.3319	0.1424	0.5109	0.0458
1539.3	1.7875	5.2665	0.7365	2.2537	0.4022	1.4281	0.128	0.4527	0.0349
309.61	1.6314	3.1948	0.8217	1.8739	0.5911	1.6477	0.1791	0.6724	0.0561
1789.6	1.0948	2.1543	0.4456	0.4624	0.1191	0.2394	0.0084	0.0762	0.0049
81.441	0.514	3.5109	0.1569	2.3842	0.2672	0.7567	0.0683	0.2854	0.0182
3197.2	1.4709	2.9432	0.3192	3.4451	0.5546	1.8875	0.1104	0.8183	0.0396
2526.9	1.9933	4.3965	0.7226	4.6597	1.0197	2.7254	0.137	0.528	0.0362

150.48	0.662	2.0422	0.3445	2.435	0.7057	1.3176	0.1173	0.472	0.036
163.34	1.3064	4.8667	0.2981	2.7057	0.35	1.3099	0.1249	0.3213	0.0378
1065.3	1.7313	3.9032	0.6017	4.5749	1.0527	2.0585	0.1474	0.7231	0.0434
94.26	0.3101	0.2789	0.0335	0.1197	0.033	0.1006	0.005	0.0449	0.0043
848.81	1.3317	2.0784	0.3212	2.4388	0.2546	1.0327	0.1014	0.3339	0.0259
13514	2.0587	2.9357	0.5296	6.5056	0.7232	2.8929	0.2247	0.4233	0.0393
473.39	3.2208	2.7915	0.6301	3.7731	0.8465	3.1838	0.2455	0.5304	0.0357
2179.2	2.2225	2.474	0.5931	4.2758	0.4462	1.9385	0.1288	0.5218	0.0271
1431.9	2.0078	2.1325	0.2423	3.8173	0.5389	1.7115	0.1997	0.4082	0.0204
735.71	2.6355	2.9496	0.4669	5.3474	0.5074	2.4646	0.1886	0.5264	0.027
449.25	0.4093	0.4163	0.055	0.2151	0.0577	0.1442	0.0106	0.0408	0.0046
409.79	1.0472	3.7375	0.2329	1.9601	0.2913	0.9324	0.0706	0.3085	0.012
4406.8	2.5966	8.3828	0.8754	2.5246	0.9188	2.5006	0.1178	0.4004	0.0371
510.95	2.0956	3.405	0.6021	3.0951	0.7304	3.0158	0.1578	0.3855	0.0359
185.05	1.7111	2.766	0.4239	2.1446	0.4864	2.3465	0.1569	0.3999	0.0241
190.95	1.3644	3.6626	0.3455	2.5038	0.4846	1.7791	0.1221	0.3063	0.0326
676.15	2.5302	3.9042	1.2946	2.9043	0.3572	2.4621	0.1789	0.5379	0.0456
439.25	0.3102	0.5307	0.1219	0.3107	0.0463	0.125	0.0072	0.0499	0.004
1451.7	0.4266	1.4841	0.358	1.3093	0.1296	1.1404	0.0459	0.2993	0.0257
675.39	1.2167	6.6136	0.7249	3.4568	0.6321	2.2311	0.1727	0.6718	0.0494
165.18	1.8998	6.1544	0.931	6.1659	0.9353	2.1426	0.1943	0.9166	0.031
1041.1	0.7334	3.7837	0.6069	2.3656	0.2927	2.1053	0.1271	0.5456	0.0392
1230.4	0.5392	1.9665	0.4783	2.748	0.4803	1.7216	0.1458	0.6068	0.0295
84.489	1.2303	5.2655	0.9346	5.3395	0.33	2.373	0.1835	0.8405	0.0548
479.08	0.2939	0.3601	0.0871	0.232	0.0469	0.1605	0.0095	0.0616	0.0042
429.96	0.8673	2.3348	0.2328	1.0316	0.2029	1.0917	0.0329	0.2126	0.0208
5890.3	1.2692	2.8976	0.7644	3.7428	0.584	3.4032	0.1401	0.3351	0.0207
43162	12.961	14.643	1.0643	8.0968	0.9316	5.5641	0.41	1.2338	0.0971
8859.2	2.1065	3.4528	0.7193	1.7815	0.1569	2.1338	0.1313	0.4126	0.0312
2412.3	1.3309	3.6569	0.3876	2.091	0.415	1.771	0.0852	0.3924	0.0338
68536	36.724	34.661	9.5161	11.373	3.2817	8.874	0.5827	1.5779	0.176

1171.7	0.8035	1.2469	0.1803	0.3861	0.0422	0.1811	0.0166	0.0637	0.0058
504.99	1.1161	3.9887	0.2766	1.4954	0.1563	0.5994	0.0586	0.2757	0.0168
3578.7	2.7612	4.3178	0.953	3.0726	0.9298	1.3747	0.1835	0.5506	0.0309
1080	2.827	5.422	0.673	3.6019	0.7167	2.5468	0.1566	0.5058	0.0357
424.61	1.0761	2.2496	0.2455	1.8934	0.4829	0.9345	0.1872	0.5219	0.0225
1466.5	2.308	4.8134	0.5851	2.7723	0.4207	1.0832	0.0581	0.3961	0.0226
3037.6	5.0244	8.2026	1.2379	3.1626	0.4562	2.3262	0.1666	0.7233	0.0244
502.29	0.4871	0.8855	0.1924	0.2921	0.042	0.1809	0.0159	0.0825	0.0059
458.08	0.933	1.3158	0.8867	1.5212	0.327	0.7797	0.0566	0.2318	0.0106
5483.4	9.2202	13.096	1.4097	6.3948	1.0647	3.1109	0.3272	0.7093	0.0925
1147.3	2.2718	7.5553	0.5444	5.9137	0.6452	2.9376	0.1923	0.4329	0.0697
588.3	2.4084	4.3704	0.313	3.4586	0.5274	1.6366	0.1314	0.4614	0.027
169.87	1.0401	2.9514	0.2421	3.382	0.7669	1.6346	0.0739	0.2967	0.0126
905.26	3.0314	4.8196	0.558	4.5509	1.0462	2.4949	0.2302	0.5782	0.5661
1238	1.1216	1.1177	0.2775	0.4179	0.0737	0.356	0.0141	0.0516	0.0059
266.66	0.8399	1.2362	0.1096	2.0152	0.3162	1.1267	0.0414	0.3719	0.0273
12714	11.604	19.555	1.7183	5.4363	1.3258	4.6978	0.1912	1.1094	0.0543
8965.8	7.7911	15.028	1.3408	5.3501	1.0611	5.2921	0.1934	1.0649	0.0598
586.62	2.3654	2.0032	0.3223	2.0905	0.3931	2.7909	0.062	1.077	0.0389
300.29	2.0865	2.5748	0.236	2.5712	0.5047	2.7754	0.0699	0.4218	0.0362
4908.6	7.1718	5.6936	1.3888	3.8549	1.3771	4.3641	0.1666	1.2547	0.0329
1460.4	0.1523	0.6027	0.0826	0.2026	0.0307	0.1724	0.0054	0.0681	0.0046
203.64	0.3159	1.353	0.1492	1.3365	0.2473	0.7657	0.0281	0.1826	0.0183
680.62	2.3877	6.8069	0.6683	3.1661	0.9652	1.3657	0.2394	0.3924	0.0413
449.53	1.0788	3.7535	0.6176	2.6983	0.5686	1.9872	0.1786	0.4309	0.0438
574.39	0.7629	3.0631	0.3762	1.9997	0.5252	1.0233	0.1115	0.276	0.0228
437.04	0.5138	2.2578	0.4717	2.4223	0.3675	1.5097	0.1264	0.3056	0.0365
1459.4	2.1782	5.5669	0.8568	3.603	0.992	1.7007	0.1735	0.4558	0.0349
332.57	0.3451	1.0566	0.042	0.3253	0.0892	0.2041	0.0158	0.0947	0.0047
921.91	2.0467	3.3148	0.2724	2.74	0.2255	1.1948	0.0547	0.1989	0.0337
2315.1	5.14	3.9886	1.0328	2.6922	0.9327	1.558	0.1592	0.5045	0.0359

2141	4.3819	9.6635	1.1697	4.5449	0.4928	3.7746	0.192	0.5802	0.0436
1258.3	2.6682	2.7606	0.5054	1.8562	0.413	1.1235	0.1115	0.3495	0.0272
1073	2.8993	8.2329	0.7355	5.2445	0.2816	3.1103	0.1344	0.3727	0.0381
2335.4	3.9747	6.8802	0.9623	4.2614	0.364	2.9849	0.2144	0.5093	0.0461
1772	1.849	2.5543	0.2576	1.2176	0.1072	0.3889	0.0309	0.0677	0.0096
1042.3	1.2668	3.2844	0.1487	2.575	0.3234	1.1374	0.0152	0.3132	0.0231
219.4	1.8307	4.3681	0.8514	2.6686	0.7141	2.495	0.1259	0.6041	0.0333
386.43	2.5915	8.3217	0.5941	4.2037	0.6688	2.7856	0.0831	0.4623	0.0311
447.46	1.6282	3.6353	0.311	1.9818	0.4821	1.7835	0.089	0.6357	0.0276
181.16	1.8868	4.4911	0.3481	5.6058	0.5185	2.7373	0.0791	0.3912	0.0258
1699.7	3.9917	7.0467	0.8399	5.4711	1.2281	3.044	0.1375	0.7876	0.0407
480.62	0.3407	1.0397	0.0913	0.1997	0.0642	0.1217	0.0193	0.073	0.0066
374.56	0.8731	2.4573	0.2148	1.0552	0.2368	0.7342	0.0822	0.1781	0.0129
214.05	2.5076	5.5886	0.4933	2.4791	0.405	1.495	0.0538	0.5771	0.0153
512.04	3.5095	5.5158	0.6776	2.7755	0.3851	2.4231	0.1558	0.5453	0.0221
246.63	1.9877	3.5049	0.4243	1.6604	0.2453	0.9974	0.0875	0.4293	0.0084
223.92	1.9502	4.3423	0.3022	1.8753	0.5096	2.2065	0.1357	0.4224	0.0267
1310.4	2.7778	6.6344	0.7707	3.0348	0.507	2.2844	0.2013	0.6342	0.0231
663.3	0.3524	0.5618	0.1337	0.2256	0.5479	0.1373	0.0067	0.0475	0.0037
1563.1	2.8946	4.4211	0.3931	3.3424	0.1863	0.8659	0.0628	0.2543	0.0108
2001.8	6.1225	9.5489	0.8099	5.6327	0.9775	1.7414	0.154	0.8125	0.0355
1285	5.004	11.443	0.7369	6.6002	0.7087	2.2593	0.1624	0.703	0.0226
1940.3	4.2842	6.6334	0.5178	5.072	0.62	1.421	0.1261	0.5709	0.023
1412.1	4.0979	6.5977	0.5329	7.2054	0.4381	2.139	0.1143	0.4786	0.0074
3928.9	9.8257	13.3	0.9787	10.921	1.141	2.4859	0.2045	1.036	0.0549
1522.7	1.6433	1.6888	0.1391	0.4205	0.0751	0.2213	0.0154	0.058	0.0095
485.14	1.2181	3.3759	0.5501	1.4494	0.1564	0.9149	0.0563	0.1788	0.0133
800.49	2.2821	7.6345	0.6846	2.2035	0.4412	2.1274	0.296	0.6222	0.0124
982.55	2.0019	7.5221	1.0704	2.8502	0.3894	2.7883	0.1084	0.3743	0.0292
340.22	1.4563	4.3767	0.653	1.4673	0.3052	1.8063	0.1495	0.3472	0.0191
747.42	2.2453	5.4998	0.9183	3.2775	0.1844	2.6939	0.1051	0.2675	0.0119

2794.3	3.7475	10.383	1.0185	3.9234	0.7363	3.1329	0.1864	0.5113	0.0166
368.07	0.2643	0.954	0.0366	0.1897	0.0767	0.144	0.0086	0.0488	0.0045
164.01	1.3337	1.3988	0.3955	2.2289	0.1338	1.0837	0.0604	0.1814	0.0174
371.07	1.587	3.913	0.4399	2.4606	0.3244	2.3923	0.0845	0.4367	0.0174
562.86	2.3195	4.3846	0.6741	2.7283	0.3584	1.8624	0.142	0.4214	0.0096
221.29	1.3843	2.6567	0.4008	1.6463	0.2637	1.5247	0.0479	0.414	0.0113
177.88	1.7841	3.2045	0.5497	3.5327	0.3891	1.7997	0.0757	0.2996	0.0261
1122.8	4.2465	6.1656	0.7378	4.829	0.5245	2.6183	0.1314	0.5668	0.0082
127.21	0.2638	1.0355	0.0925	0.2731	0.0557	0.1138	0.0133	0.0317	0.0047
96.843	0.6095	1.0154	0.1606	1.1977	0.1573	0.7622	0.0473	0.1322	0.0118
182.66	1.8657	3.5017	0.4145	1.7008	0.4927	1.2816	0.1306	0.3663	0.0136
103.43	1.3453	4.383	0.6553	3.1465	0.5117	1.5171	0.1482	0.3406	0.0173
129.6	1.2288	2.1253	0.3955	1.7654	0.4165	0.9984	0.0873	0.1874	0.0149
86.688	1.4464	2.5545	0.5015	3.9263	0.2601	1.696	0.0829	0.2586	0.022
360.62	2.0502	4.3607	0.6415	4.0614	0.624	1.5848	0.1381	0.2967	0.0252
77.656	0.3031	0.4137	0.0153	0.2068	0.0278	0.1315	0.0084	0.0319	0.0042
687.6	0.594	2.1887	0.2589	2.4113	0.2869	0.879	0.0739	0.1435	0.0137
188.64	0.2532	6.2485	0.8225	2.6117	0.6186	1.488	0.0992	0.4555	0.0225
292.59	1.1198	4.2641	0.7466	2.938	0.6623	1.7357	0.0791	0.3774	0.0181
418.28	0.5089	3.4309	0.5879	1.8925	0.5219	1.2717	0.0638	0.3878	0.0176
72.309	1.0893	4.854	0.6925	3.9687	0.5469	1.4461	0.0866	0.293	0.0257
2148.4	1.8021	6.9707	0.7951	5.0034	0.8036	2.448	0.1255	0.4634	0.0189
427.07	0.7233	0.9597	0.0843	0.2314	0.0765	0.1333	0.0071	0.0424	0.0047
303.69	0.5288	1.1539	0.4073	1.7108	0.2306	0.7601	0.044	0.3751	0.0163
528.99	4.7005	3.4007	0.4333	2.3535	0.4723	1.608	0.0983	0.7109	0.0292
45.701	1.1114	3.0696	1.0475	3.1246	0.4333	1.662	0.147	0.6911	0.021
138.66	1.4975	1.8146	0.4881	1.6572	0.3263	1.3765	0.0581	0.7859	0.0109
53.277	0.8267	3.4414	0.6913	4.7323	0.3702	1.4459	0.0896	0.4979	0.0297
870.06	2.644	2.9758	0.8864	4.3301	0.6242	2.21	0.0982	0.9	0.0222
460.57	0.3666	0.8962	0.1408	0.4273	0.0514	0.1597	0.012	0.057	0.0054
379.86	0.8879	1.6612	0.141	2.9466	0.3342	0.7126	0.0463	0.1996	0.0136

70.378	1.3543	1.9469	0.6998	3.0327	0.5654	1.5418	0.0816	0.4453	0.032
161.81	1.1975	2.8333	0.8143	3.5256	0.5216	1.5968	0.0982	0.4292	0.0512
46.826	0.6817	2.226	0.4333	2.1621	0.3321	1.1654	0.0879	0.3252	0.0195
122.94	0.6563	3.0164	0.4672	5.0498	0.7074	1.3381	0.0689	0.319	0.0336
638.08	1.1028	3.888	0.9495	5.8068	1.0637	2.0729	0.0902	0.5616	0.0518
112.26	0.3756	0.6454	0.1109	0.2601	0.0227	0.1725	0.0099	0.0502	0.0038
605.77	0.6828	2.0146	0.2606	3.0075	0.1347	0.6426	0.0321	0.1538	0.0165
453.69	1.8984	2.954	0.3608	1.9419	0.4261	1.1471	0.0849	0.5638	0.0166
64.05	1.3381	3.4229	0.3799	2.9068	0.5022	1.4259	0.1732	0.5702	0.0058
502.91	1.2245	2.1362	0.3005	1.1224	0.3666	0.9769	0.0576	0.3964	0.0132
298.67	1.2388	3.8681	0.3343	5.4143	0.2724	1.5648	0.0732	0.4306	0.0141
2124.3	3.0138	4.016	0.5228	5.8613	0.4198	2.3638	0.1442	0.5756	0.0327
1164.6	0.5191	0.6097	0.1096	0.2672	0.0211	0.1419	0.0125	0.037	0.0048
298.59	0.8384	1.1931	0.3972	1.7471	0.2534	0.721	0.0492	0.2394	0.0067
531.95	3.4662	6.0037	0.9056	3.3073	0.3851	1.5431	0.1232	0.5034	0.0221
255.91	3.2608	6.3043	0.9659	3.6465	0.442	1.8153	0.1401	0.542	0.0266
631.88	2.1136	3.7971	0.4427	2.2885	0.2403	1.2601	0.0719	0.4623	0.0138
358.89	2.4757	3.7742	0.7661	4.115	0.4552	1.854	0.1244	0.4949	0.0235
349.34	3.6849	6.1506	0.6281	4.9601	0.3248	1.743	0.1099	0.6703	0.03
182.42	0.2074	0.356	0.082	0.1627	0.0349	0.1454	0.0087	0.0498	0.0038
204.99	0.9855	1.492	0.305	2.1702	0.1161	0.5952	0.0386	0.2553	0.0251
420.62	3.5818	4.5866	0.7523	2.7387	0.8977	1.9427	0.114	0.5106	0.0362
631.36	3.5718	7.5416	0.7273	2.8829	0.5871	2.3843	0.1518	0.5232	0.0295
347.18	1.3498	3.3484	0.681	1.8764	0.3943	1.4192	0.0894	0.2879	0.0216
409.44	1.9616	4.0703	0.6934	5.7524	0.374	1.6114	0.0759	0.4776	0.0429
451.46	2.5471	5.0045	0.5238	6.6628	0.9298	2.1725	0.1217	0.5631	0.0191
168.42	0.1491	0.3713	0.0392	0.2597	0.0228	0.1104	0.005	0.0602	0.002
240.93	0.91	1.7657	0.3883	2.7532	0.256	0.5721	0.0265	0.1486	0.0198
164.53	2.4612	2.97	0.4926	2.7484	0.2441	1.5865	0.1192	0.6829	0.0428
80.443	1.9809	3.4024	0.8167	3.4179	0.4958	1.8587	0.1201	0.3509	0.0162
132.64	1.1686	2.8784	0.3713	1.9766	0.4053	1.0231	0.0843	0.3886	0.0169

130.37	1.8264	3.7421	0.6464	5.4872	0.4768	1.5945	0.0934	0.2195	0.0144
274.6	2.2783	4.5136	0.7284	4.0589	0.6184	1.9828	0.0965	0.4897	0.0185
154.83	0.2273	0.4982	0.071	0.1622	0.04	0.1481	0.0128	0.0396	0.0042
970.7	1.1177	2.2581	0.1978	1.6241	0.3043	0.7211	0.0943	0.2053	0.0278
182.82	1.4874	4.0947	0.4207	2.2595	0.4791	1.3	0.0955	0.4368	0.0308
661.56	2.2214	3.9991	0.1823	3.0277	0.7643	1.2783	0.1336	0.3742	0.0184
237.82	0.9606	2.7367	0.2264	1.7075	0.3637	0.9841	0.0735	0.3709	0.0106
760.02	1.951	2.3239	0.2288	3.3058	0.6335	1.1702	0.0737	0.341	0.0311
304.6	1.4003	4.2221	0.269	3.3918	0.6928	1.4426	0.1233	0.4205	0.0278
683.28	0.1994	0.6377	0.0159	0.3006	0.0276	0.1961	0.0114	0.0525	0.0047
91.005	0.5361	1.9403	0.3118	2.6422	0.098	1.1573	0.03	0.2214	0.0116
229.52	2.0005	4.1342	0.168	2.062	0.5559	1.724	0.1206	0.29	0.0261
112.43	1.4123	3.7618	0.6985	2.8336	0.4201	1.8238	0.1373	0.4395	0.0203
148.41	1.1942	2.8583	0.2349	1.4995	0.1699	1.3642	0.0668	0.2653	0.0199
446.81	0.7449	4.2393	0.5459	6.0774	0.2374	1.77	0.0368	0.3871	0.0217
357.25	2.3567	5.7035	0.7152	6.1703	0.4275	2.0316	0.0832	0.4437	0.0217
472.23	0.1384	0.3679	0.0286	0.1362	0.0152	0.1365	0.0041	0.0319	0.0036
144.09	0.4521	1.6874	0.2813	2.3744	0.1965	0.7944	0.0592	1.4976	0.0134
345.5	1.6888	3.507	0.6533	2.1879	0.8085	1.6397	0.1136	0.4974	0.043
1047.1	1.8861	4.5249	1.1673	2.8888	0.4632	1.87	0.1912	0.4154	0.0443
34.968	1.3883	2.1142	0.457	1.6677	0.4387	1.0988	0.0479	0.3687	0.0186
130.13	1.145	4.3357	0.7221	5.7052	0.3388	1.5585	0.1008	0.3206	0.0239
989.93	2.516	4.7536	1.3031	6.6682	0.6831	1.6437	0.1838	0.438	0.0355
453.02	0.4268	1.059	0.0854	0.2505	0.0655	0.1795	0.012	0.051	0.0038
163.05	1.1877	2.1086	0.3168	1.649	0.2682	0.9499	0.0363	0.1527	0.0249
1170.9	1.8478	2.8043	0.361	2.3493	0.4419	1.5897	0.1695	0.4086	0.0315
1083.7	2.6255	5.1943	0.9923	2.4433	0.7035	1.7674	0.1013	0.6406	0.0345
694.34	1.8246	2.0967	0.4099	1.3638	0.2358	1.1932	0.0697	0.2933	0.0152
1253	1.9317	5.1085	0.6136	3.5415	0.4624	1.4256	0.0756	0.4479	0.0191
483.31	3.0682	5.9434	0.82	3.5912	0.5799	1.6577	0.102	0.5111	0.048
78.391	0.0535	0.328	0.0355	0.145	0.0219	0.0686	0.0075	0.038	0.0036

767.81	0.6351	1.7512	0.4202	1.6104	0.2462	0.8929	0.0725	0.2645	0.0111
383.03	1.5214	3.7999	0.4148	2.2132	0.1616	1.6405	0.1197	0.4613	0.0118
781.47	2.4459	3.6447	0.5931	2.6066	0.4392	2.1564	0.1564	0.6034	0.0205
255.29	1.312	2.2221	0.1918	1.5094	0.1773	0.9994	0.0893	0.319	0.0153
494.94	1.2156	2.5093	0.4671	3.858	0.3073	1.5343	0.126	0.489	0.0093
287.5	1.6351	3.7026	0.5596	5.2662	0.3234	1.618	0.1841	0.5621	0.0202
205.32	0.1155	0.708	0.0994	0.2856	0.0262	0.1121	0.0097	0.0493	0.0034
672.44	0.5869	2.3625	0.4264	2.3329	0.2074	1.0723	0.0708	0.2021	0.0136
130719	93.188	92.611	21.208	21.692	8.9812	11.834	1.2945	2.4768	0.6534
21737	10.025	13.676	1.8645	4.1183	0.7088	3.2027	0.1853	0.6961	0.0384
519.57	1.6488	2.2161	0.4114	1.4372	0.1993	1.2645	0.1115	0.2713	0.0238
246.24	1.305	2.4233	0.3216	1.8015	0.2599	1.2159	0.1234	0.1937	0.0133
333.56	3.1827	3.0387	0.6189	2.5256	0.3846	1.9772	0.172	0.3698	0.0157
485.63	0.6216	2.2765	0.1529	0.5065	0.0916	0.2458	0.0256	0.0862	0.0072
950.91	0.5691	2.1426	0.1108	1.7734	0.1733	0.877	0.0619	0.2239	0.0258
5201.3	3.7048	3.872	1.2596	3.323	0.5296	1.7622	0.1419	0.4043	0.0269
4331	5.253	5.1263	0.665	4.5163	0.9033	1.8524	0.0709	0.3398	0.0316
171.07	0.2113	0.4952	0.0635	0.244	0.0161	0.1166	0.0089	0.0458	0.0055
574.04	2.2194	2.4191	0.4996	1.8912	0.4361	1.148	0.0758	0.3347	0.0159
124.1	1.7797	1.9855	0.4863	2.4527	0.3351	1.2046	0.0386	0.2284	0.0157
303.99	2.69	3.2198	0.7757	3.1505	0.4258	1.6626	0.1465	0.385	0.0275
105.83	0.8825	1.3778	0.3435	1.2045	0.1424	1.1938	0.0463	0.2126	0.007
6953.2	7.8955	15.268	2.3382	5.2418	1.334	2.4958	0.1088	1.3143	0.0865
4922.8	3.225	10.484	1.3855	5.1002	1.3542	2.3989	0.0668	0.4688	0.034
239.21	1.636	1.951	0.4361	1.7528	0.2812	0.7484	0.1135	0.6207	0.0117
320.59	1.0912	1.7545	0.36	2.0953	0.4316	1.172	0.0351	0.2726	0.0057
451.53	2.2479	4.067	0.284	3.1322	0.7208	1.4197	0.1709	0.7868	0.0245
134.99	0.3518	0.3632	0.0575	0.201	0.0531	0.1711	0.0134	0.042	0.0073
642.64	0.7358	8.079	0.6613	2.7365	0.2884	1.7142	0.0614	0.3022	0.019
6041.7	1.1762	3.6475	0.4865	2.7277	0.323	1.7737	0.1587	0.7322	0.0395

2271.1	2.5798	5.8366	0.7198	3.034	0.9225	2.2921	0.1176	0.444	0.039
448.33	0.8005	2.3123	0.5079	1.6141	0.4547	1.5082	0.0829	0.4453	0.0181
570.98	0.9705	2.4891	0.5108	1.655	0.5551	1.5202	0.0484	0.3119	0.0227
795.77	1.1946	3.7669	0.6366	2.8896	0.814	2.0576	0.1493	0.6556	0.0275
1089.4	0.9187	1.4407	0.1983	0.5016	0.1525	0.3573	0.0126	0.0804	0.0064
419.14	1.185	2.0408	0.4418	1.1385	0.0597	0.5367	0.0559	0.334	0.0156
11218	11.841	17.907	1.2534	6.0168	0.7842	3.7439	0.2643	0.6259	0.0457
9803.3	7.0327	15.79	1.7019	5.3742	0.2896	4.0587	0.1664	0.6233	0.0336
295.95	1.5128	3.1113	0.5652	1.8666	0.258	0.9608	0.051	0.3983	0.0125
99.681	1.4994	3.5016	0.3533	1.6974	0.3973	0.9835	0.018	0.4858	0.0157
724.52	3.1522	6.5457	0.7738	3.1332	0.4587	2.1222	0.1206	0.6952	0.0381
526.4	0.2193	0.4354	0.0754	0.2084	0.0228	0.2005	0.0095	0.0485	0.0048
481.55	1.2476	1.1614	0.3091	1.1722	0.2931	0.6016	0.0407	0.2278	0.0025
34699	7.5144	10.591	1.7998	5.7811	1.0275	2.5577	0.3211	0.4717	0.057
18331	2.4833	2.7281	0.4831	3.4163	0.8516	1.7851	0.1481	0.5797	0.05
229.66	2.2655	1.7567	0.3589	1.9228	0.501	0.8956	0.1525	0.2642	0.0224
718.5	1.0608	1.6384	0.3764	2.0544	0.712	1.0567	0.0935	0.2896	0.0205
109.71	3.4215	2.8081	0.8774	2.9064	0.6622	1.4549	0.2191	0.3614	0.0356
905.52	0.519	0.7388	0.1086	0.2555	0.0732	0.1515	0.0102	0.0495	0.004
3438.6	1.2945	2.1893	0.3014	1.2852	0.2716	0.7249	0.0622	0.3059	0.0129
4915.7	2.2622	4.2341	0.2149	2.9476	0.7018	1.8245	0.043	0.4526	0.0261
7185.8	3.3351	2.6053	0.5265	2.8819	0.4884	2.0505	0.0893	0.4855	0.0385
4719.5	1.7922	1.6117	0.2989	1.4258	0.3496	1.2897	0.0605	0.4291	0.0219
5423.1	1.6167	1.5528	0.238	1.6822	0.3039	1.5245	0.0536	0.3875	0.014
6979.2	2.3895	2.104	0.3929	2.1295	0.4922	1.7544	0.0995	0.5508	0.0224
6075.2	0.2427	0.8191	0.1252	0.3171	0.0507	0.1393	0.0161	0.045	0.0056
167.74	0.7946	2.6017	0.2213	1.7252	0.2168	0.9478	0.0581	0.2168	0.0225
3322.3	6.2066	14.178	1.441	3.2089	0.9976	2.9946	0.122	0.6881	0.0592
340.71	3.4205	7.0404	0.4777	3.7152	0.7024	1.9653	0.1031	0.6483	0.0391
337.67	0.7777	3.0441	0.4477	2.5558	0.2265	1.3536	0.0804	0.376	0.0211
223.48	7.4006	13.571	2.4661	4.302	1.1618	2.4625	0.0894	0.4916	0.0512

580.14	1.6344	4.1507	0.5758	4.3377	0.3578	2.3153	0.0961	0.4636	0.0256
271.31	0.8263	1.6224	0.1501	0.3034	0.0513	0.1763	0.0127	0.0576	0.0036
4867.2	6.0707	8.0926	1.2053	2.8819	0.3977	1.3645	0.0853	0.4692	0.0329
46327	15.735	24.53	4.7267	9.5921	2.5052	4.7151	0.2485	1.3249	0.1428
50056	23.689	35.773	7.4595	12.58	3.354	6.5492	0.3658	1.6832	0.1953
1043	2.151	4.5083	0.5105	2.1234	0.5044	1.3733	0.0722	0.73	0.0249
5037.3	5.3017	10.137	1.2922	3.7569	0.5558	2.2339	0.0978	0.7105	0.0425
728.99	2.7811	5.1285	0.5101	3.551	0.7328	1.8486	0.123	0.9444	0.0363
299.75	0.3509	0.6449	0.0786	0.2592	0.0648	0.1365	0.0139	0.0584	0.0044
303.37	0.8657	2.5247	0.2592	0.8478	0.2383	0.8636	0.0656	0.2812	0.0178
4395.9	4.6564	8.3847	1.4387	4.7632	0.7011	2.7044	0.1424	0.6475	0.0511
3540.8	2.761	7.8931	1.3891	3.1754	0.6005	2.5959	0.1281	0.6018	0.0378
249.06	0.9111	2.3916	0.3832	1.7242	0.259	1.4466	0.0432	0.3117	0.0275
73.968	0.6823	3.8492	0.2986	1.3112	0.2983	1.6303	0.0372	0.372	0.0153
115.92	0.5895	4.2216	0.5397	2.6157	0.3894	2.0732	0.0289	0.4921	0.04
57.923	0.3656	0.525	0.0437	0.1122	0.0274	0.1436	0.0023	0.0636	0.0636
1861.3	1.8777	1.7928	0.4575	1.9623	0.2115	1.026	0.0281	0.3186	0.0222
509.67	2.505	4.0383	0.9985	2.3178	0.3129	2.2131	0.1425	0.5499	0.0332
275.95	2.7694	6.0958	0.3831	2.7325	0.7447	2.0326	0.1326	0.5399	0.0317
1218.3	1.8624	2.9646	0.5144	1.5727	0.2737	1.8043	0.1133	0.5147	0.0331
2380.5	2.5831	2.5771	0.3887	1.9495	0.4178	1.6761	0.1372	0.4486	0.0262
551.08	1.9799	3.5006	0.558	2.4522	0.4621	2.0504	0.1277	0.643	0.0426
1764.9	1.2686	1.7967	0.3695	0.8863	0.0955	0.2587	0.0163	0.0898	0.0094
3128.3	3.4764	8.4536	0.4464	2.0673	0.5431	1.3598	0.0718	0.2784	0.0272
3395.2	3.1636	12.476	0.353	2.6977	0.7413	2.353	0.2018	0.5268	0.0371
4507.6	5.4639	13.641	0.5325	3.7659	1.077	3.9036	0.0918	0.5157	0.0638
2892.3	1.6123	8.5079	0.3832	2.8175	0.4544	2.167	0.1204	0.4307	0.0415
3001.9	1.3901	7.6778	0.1539	2.203	0.6114	2.2603	0.0866	0.2808	0.0309
3346.9	1.8297	14.133	0.4025	3.8148	1.0854	2.9153	0.0879	0.5375	0.0624
2575.3	2.1388	2.8804	0.4534	0.8181	0.2142	0.3665	0.0281	0.0879	0.0125
8271.3	3.2751	5.1829	0.9483	1.9993	0.6218	1.1024	0.0825	0.2137	0.0395

2667.6	2.0797	3.9108	0.7401	3.3111	0.4233	2.2385	0.0814	0.4465	0.0334
298.95	2.6962	5.9675	0.7219	4.433	0.6082	2.1556	0.102	0.3829	0.0509
132.21	0.5748	1.8827	0.301	2.1376	0.3357	1.0139	0.1029	0.2504	0.0365
75.524	1.9003	3.9499	0.3334	2.7734	0.2713	1.0978	0.064	0.2704	0.0241
475.23	2.2893	5.9073	0.7084	4.2455	0.6056	1.7148	0.1058	0.4764	0.0368
17.213	0.1649	0.2496	0.0374	0.1461	0.0486	0.1173	0.0119	0.0376	0.0034
1455.9	2.063	4.7665	0.4961	2.2163	0.4238	0.9603	0.1194	0.2778	0.0367
2096.5	3.6865	7.3944	0.7877	3.7062	0.6541	2.2103	0.173	0.5187	0.0363
5547.3	4.8204	13.803	1.4435	4.9971	0.9877	3.5611	0.2492	0.5418	0.0597
1029	1.8812	3.0403	0.5097	2.2081	0.4888	1.5471	0.1258	0.4901	0.0235
273.74	1.3158	3.6745	0.3727	2.0666	0.4024	1.4861	0.1138	0.3707	0.0331
1491.5	1.8666	4.5548	0.5552	3.3464	0.6148	2.0056	0.1657	0.5829	0.0453
30.233	0.1451	0.2311	0.0203	0.175	0.0445	0.1542	0.0158	0.0518	0.0032
999.19	0.6545	7.0061	0.1553	4.1807	0.278	2.9582	0.0732	0.257	0.02
8113.6	2.1954	5.9428	0.3222	2.3997	0.3137	2.2499	0.1399	0.4329	0.0254
10907	3.0736	5.3971	0.4408	2.5026	0.2899	4.419	0.0789	0.5461	0.0452
233.85	0.6517	2.2253	0.2319	1.7616	0.1248	1.2214	0.1053	0.4805	0.0333
623.53	1.279	3.6354	0.2523	2.1949	0.371	1.6205	0.1062	0.3299	0.0386
547.94	2.4309	3.9712	0.2421	2.7497	0.298	2.2429	0.0833	0.5071	0.0091
299.46	0.2368	0.3982	0.0849	0.1971	0.0417	0.1267	0.0092	0.073	0.0046
4820.2	1.9106	11.417	0.5843	4.648	0.228	2.0616	0.0612	0.3929	0.0278
10013	15.471	29.979	2.714	6.5278	1.1109	2.9418	0.3224	0.9096	0.0819
30727	57.756	53.648	11.27	20.137	5.6495	8.9743	0.8823	1.7302	0.2173
3666.5	2.4225	6.0088	0.5133	1.8005	0.4923	1.0574	0.0944	0.5636	0.038
6517.9	1.1686	6.9419	0.7649	2.4547	0.3906	1.4445	0.1169	0.4504	0.0551
4170.4	2.1899	5.9556	1.0321	2.6574	0.7915	1.5387	0.151	0.623	0.0425
3819.9	1.8849	3.2501	0.1769	0.4577	0.1729	0.3	0.0116	0.053	0.0051
144.09	0.4521	1.6874	0.2813	2.3744	0.1965	8E+08	0.0592	0.1498	0.0134
345.5	1.6888	3.507	0.6533	2.1879	0.5699	1.6397	0.1136	0.4974	0.043
1047.1	1.8861	4.5249	1.1673	2.8888	0.4632	1.87	0.1912	0.4154	0.0443
34.968	1.3883	2.1142	0.457	1.6677	0.4387	1.0988	0.0479	0.3687	0.0186

130.13	1.145	4.3357	0.7221	5.0516	0.3388	1.5585	0.1008	0.3206	0.0239
989.93	2.516	4.7536	1.3031	6.6682	0.6831	1.6437	0.1838	0.438	0.0355
453.02	0.4268	1.059	0.0854	0.2505	0.0655	0.1795	0.012	0.051	0.0038
163.05	1.1877	2.1086	0.3168	1.649	0.2682	0.9499	0.0363	0.1527	0.0249
1170.9	1.8478	2.8043	0.361	2.3493	0.4419	1.5897	0.1695	0.4086	0.0315
1083.7	2.6255	5.1943	0.9923	2.4433	0.7035	1.7674	0.1013	0.6406	0.0345
694.34	1.8246	2.0967	0.406	1.3638	0.2358	1.1932	0.0697	0.2933	0.0152
1253	1.9317	5.1085	0.6136	3.5415	0.4624	1.4256	0.0756	0.4479	0.0191
483.31	3.0682	5.9434	0.82	3.5912	0.576	1.6577	0.102	0.5111	0.048
78.391	0.0535	0.328	0.0355	0.145	0.0219	0.0686	0.0075	0.038	0.0036
767.81	0.6351	1.7512	0.4202	1.6104	0.2462	0.8929	0.0725	0.2645	0.0111
383.03	1.5214	3.7999	0.4148	2.2132	0.1616	1.6405	0.1197	0.4613	0.0118
781.47	2.4459	3.6447	0.5931	2.6066	0.4392	2.1564	0.1564	0.6034	0.0205
255.29	1.312	2.2221	0.1918	1.5094	0.1773	0.9994	0.0893	0.319	0.0153
494.94	1.2156	2.5093	0.4671	3.858	0.3073	1.5343	0.126	0.489	0.0093
287.5	1.6351	3.7026	0.5596	5.2662	0.3234	1.618	0.1841	0.5621	0.0202
205.32	0.1155	0.708	0.0994	0.2856	0.0262	0.1121	0.0097	0.0493	0.0034
1116.2	0.7607	2.7952	0.0926	2.0752	0.3625	1.4164	0.0807	0.1979	0.0169
771.87	1.4593	3.0662	0.4464	3.7033	0.5557	4.728	0.1628	0.513	0.0259
2235.6	1.8531	5.4897	0.3936	3.974	0.3939	5.3035	0.1045	0.3553	0.0364
1948.3	1.2213	3.2834	0.1841	2.5119	0.6034	3.4509	0.1185	0.3923	0.3923
1087.8	0.8249	3.2687	0.3211	3.8346	0.8416	3.5709	0.1223	0.3415	0.015
1983.7	1.8502	4.3741	0.3838	3.7994	0.3615	5.0226	0.1483	0.4506	0.0356
880.1	0.3473	0.4228	0.043	0.1821	0.0265	0.1067	0.0062	0.0506	0.0015

5.4.2 Short Time Fourier Transform

The STFT feature was extracted by using MATLAB function Spectrogram, this features were computed from EEG signals by applying the FFT algorithm on the whole duration of a trial. This could be done reliably under the assumption that the EEG signals were stationary for the duration of each trial. However this is rarely true since EEG signals can only be considered as stationary on short periods of time. This comment also applies for the computation of mean and variance features. To solve this issue the following feature set was defined under the assumption that EEG signals are stationary on short time windows of 0.5 seconds [20][8].

$$S(\omega, T) = Fs(t)w(T- t)$$

The obtained features of PSD and STFT were analyzed by Naïve Bayes classifier.

Table 5.3: Table shows the Extracted Features of Short Time Fourier Transform (STFT).

STFT(0 to 4Hz)	STFT(4to 8Hz)	STFT(8 to 12Hz)	STFT(12 to 30Hz)	STFT(above 30Hz)
-8.88E-06	-1.86E-05	3.54E-04	-1.23E-05	-7.25E-07
-3.62E-05	2.26E-04	6.90E-05	-2.12E-04	-9.24E-05
1.54E-05	6.55E-05	2.83E-05	-1.56E-04	-1.82E-04
3.40E-06	8.23E-05	4.09E-07	2.40E-05	2.00E-05
4.88E-05	3.58E-05	1.72E-04	2.41E-05	-6.69E-07
-3.27E-05	-1.22E-04	1.49E-04	3.86E-05	-9.47E-06
6.03E-06	-1.50E-05	2.07E-05	5.53E-05	-6.35E-05
-2.63E-05	-1.47E-05	1.39E-04	8.00E-05	-6.68E-05
3.22E-07	-7.27E-07	-8.63E-05	1.92E-04	2.20E-05
8.60E-05	-1.29E-05	2.18E-04	-2.90E-04	2.86E-05
-3.37E-05	-1.66E-05	-4.58E-04	-3.97E-05	3.37E-05
5.48E-06	-1.35E-04	2.43E-04	-4.87E-05	4.94E-05
4.30E-05	-1.88E-06	7.98E-05	-1.45E-04	-9.25E-05
-3.58E-06	-5.79E-05	7.00E-05	-1.36E-05	7.16E-05
-2.72E-06	4.99E-05	2.32E-05	2.72E-04	-2.71E-05
-1.87E-05	-2.02E-04	6.40E-05	4.16E-04	-3.34E-04
7.93E-05	-1.11E-04	-0.0012	-1.25E-04	-6.96E-04
1.13E-05	-3.44E-05	4.34E-05	3.55E-04	3.59E-05
-9.31E-06	-7.90E-05	-5.65E-04	5.30E-05	4.92E-05

1.72E-06	1.77E-05	1.18E-04	1.03E-04	7.11E-05
-2.50E-06	-3.85E-07	8.15E-05	-6.43E-05	-1.97E-05
1.46E-05	-2.29E-05	-6.63E-06	-1.78E-04	2.46E-04
-3.99E-05	-1.48E-04	-2.10E-04	5.56E-04	-6.19E-04
3.00E-05	-1.98E-05	5.34E-05	1.32E-06	1.18E-04
1.39E-05	-5.14E-06	-2.92E-04	-3.95E-05	-2.67E-04
-1.50E-05	-1.13E-04	4.49E-05	-5.05E-05	1.26E-05
-4.10E-05	-1.60E-04	-3.12E-05	-4.73E-05	-2.38E-04
1.78E-05	7.48E-05	3.24E-05	2.19E-05	1.16E-04
-9.30E-06	-4.67E-05	1.95E-05	3.92E-05	1.06E-05
8.49E-06	-8.21E-05	9.52E-05	-7.89E-05	8.95E-05
-8.79E-06	-4.83E-05	5.42E-05	-3.89E-05	-3.27E-05
1.04E-05	-8.24E-05	1.72E-04	1.65E-04	-2.09E-04
-1.88E-05	7.56E-05	5.72E-04	2.53E-04	1.21E-04
5.36E-05	-4.57E-05	-5.26E-04	-3.62E-04	-9.67E-05
-1.51E-05	-1.12E-05	-1.13E-05	-4.64E-05	1.11E-04
1.70E-06	-6.95E-05	-6.63E-05	2.74E-04	3.53E-06
-1.38E-06	-1.16E-04	5.22E-04	-1.23E-04	2.97E-04
2.33E-05	4.28E-05	-2.33E-04	-4.39E-04	-1.02E-04
-1.72E-05	-6.53E-05	-2.79E-05	-1.77E-04	4.67E-05
-2.59E-05	-5.66E-05	-1.13E-04	-4.94E-04	-1.83E-04
-1.63E-06	8.89E-05	-1.00E-05	-1.34E-04	3.55E-05
-1.75E-06	1.87E-05	-1.89E-04	-1.83E-05	1.43E-05
-2.64E-05	1.69E-05	-1.27E-04	5.26E-06	-9.44E-06
-2.30E-05	-2.84E-04	8.64E-05	1.00E-05	9.93E-05
8.39E-06	7.41E-05	-1.43E-04	-2.01E-04	2.03E-05
-2.03E-05	-4.67E-05	-9.56E-05	-1.33E-05	8.45E-06
3.55E-05	-1.70E-04	1.61E-04	6.31E-05	-4.50E-06
1.27E-04	2.13E-04	4.37E-05	6.51E-04	-2.01E-04
-8.89E-06	2.20E-05	1.31E-05	-2.49E-05	9.22E-05
4.37E-05	-4.06E-05	1.21E-04	-1.05E-04	9.42E-05

1.96E-05	-2.32E-04	-5.29E-06	7.15E-04	-2.35E-05
-4.39E-05	-1.21E-04	3.88E-04	3.99E-05	-1.37E-05
8.78E-06	1.83E-05	-8.42E-06	-4.57E-06	2.93E-04
-2.01E-05	1.65E-04	1.48E-04	2.89E-04	9.78E-05
3.48E-05	6.37E-06	2.34E-04	2.14E-04	6.10E-05
5.68E-06	-1.78E-05	1.09E-04	2.68E-05	7.99E-06
-1.39E-05	-4.84E-05	-3.46E-05	4.37E-05	-4.28E-04
1.03E-05	1.45E-04	4.33E-04	-5.24E-05	3.29E-05
-4.95E-05	4.09E-05	-2.80E-04	-9.63E-04	-4.81E-05
-9.22E-06	2.50E-05	4.77E-05	1.15E-05	-3.66E-04
3.77E-05	-2.73E-05	8.22E-05	3.80E-04	3.74E-05
5.31E-06	-1.32E-04	-1.89E-04	1.12E-04	1.99E-04
-6.11E-06	9.32E-06	5.15E-06	1.47E-05	-1.26E-05
-1.59E-05	2.07E-05	-4.27E-05	-9.88E-05	1.23E-04
-3.25E-05	1.92E-04	-1.32E-05	6.85E-04	2.58E-04
-2.83E-05	-4.35E-05	3.11E-05	3.59E-05	-2.35E-04
-3.69E-07	-2.43E-04	-5.52E-05	-5.88E-05	2.59E-05
-8.74E-06	1.22E-04	2.64E-05	-4.23E-05	-1.38E-04
2.26E-05	-2.16E-05	2.05E-05	-2.02E-04	-1.53E-04
1.30E-05	-5.76E-06	1.24E-05	1.45E-04	-3.07E-05
-3.76E-09	1.13E-04	-1.15E-04	-7.13E-05	6.76E-05
-7.17E-05	4.81E-04	-1.20E-04	-0.0011	-6.85E-06
3.89E-05	2.18E-05	-2.21E-04	2.05E-05	2.75E-04
-4.57E-06	3.78E-05	-1.05E-05	-5.23E-05	-4.05E-05
-7.82E-06	-2.41E-05	-1.43E-05	2.41E-05	3.86E-05
-4.94E-05	1.05E-04	-3.00E-06	-8.96E-05	1.20E-04
6.99E-06	-5.88E-05	8.31E-06	-5.38E-06	7.71E-05
-2.18E-06	4.26E-05	1.12E-04	-1.41E-04	-1.45E-04
2.95E-05	1.19E-04	-7.20E-06	-3.12E-04	-3.40E-04
7.58E-05	-9.40E-05	3.06E-04	-3.15E-04	-0.0011
6.25E-06	-2.84E-05	-7.04E-05	-2.81E-04	1.90E-05

-2.00E-05	6.29E-05	1.27E-04	1.32E-04	2.82E-04
-2.01E-05	-1.91E-04	-1.84E-04	5.08E-05	-1.88E-04
-7.98E-06	-4.22E-05	-5.69E-05	-7.84E-05	4.03E-05
2.33E-06	-1.33E-06	-3.14E-05	1.07E-05	-3.86E-05
-2.03E-05	1.46E-05	8.23E-05	-2.27E-04	-5.15E-04
-5.73E-05	1.57E-04	-2.21E-04	-1.63E-04	-7.91E-07
-1.94E-05	1.03E-04	9.03E-05	-3.66E-04	8.16E-06
-6.26E-06	1.02E-04	-2.51E-04	-2.07E-04	1.67E-05
-3.92E-05	2.20E-04	-3.52E-04	2.89E-04	2.51E-04
4.08E-06	-4.33E-06	9.55E-05	-1.94E-05	-4.29E-05
-9.35E-06	-7.95E-05	-1.11E-04	-5.69E-05	6.65E-06
6.27E-05	-6.94E-05	4.90E-05	1.23E-06	7.40E-04
5.23E-05	-9.77E-06	4.96E-04	7.79E-05	6.71E-04
1.86E-05	-5.56E-05	8.15E-05	-2.77E-05	4.22E-05
1.66E-05	9.75E-05	3.47E-04	2.78E-04	5.17E-04
6.17E-05	-4.34E-05	-2.44E-05	7.84E-04	-1.16E-04
1.49E-05	4.51E-05	-5.01E-05	-8.51E-05	3.14E-05
-4.29E-06	-3.06E-05	6.74E-06	4.12E-05	2.18E-05
2.10E-05	-2.05E-04	-2.16E-05	-7.91E-05	1.49E-04
8.22E-05	2.50E-04	1.21E-05	-1.87E-04	3.78E-05
-6.07E-06	3.08E-05	3.22E-04	-9.79E-05	-5.03E-06
-3.36E-05	5.20E-05	-2.23E-04	-6.91E-05	1.10E-04
3.27E-06	-1.92E-04	-2.75E-04	-3.93E-05	1.49E-06
-3.98E-06	-8.33E-05	7.06E-05	-7.33E-06	1.79E-04
1.52E-05	-1.62E-05	-7.48E-05	-1.13E-05	8.60E-05
2.62E-05	-1.14E-04	2.65E-04	-2.78E-04	-1.73E-04
-3.70E-05	8.64E-05	5.82E-04	-1.16E-05	1.79E-04
3.80E-07	-1.57E-05	4.09E-05	-2.89E-04	-1.62E-05
-7.45E-06	1.16E-04	5.37E-04	1.91E-04	-5.78E-06
-8.76E-05	-8.18E-05	1.76E-04	1.19E-04	6.25E-05
-1.46E-06	-1.32E-05	4.22E-05	3.97E-06	-7.27E-06

1.61E-05	9.49E-06	-2.59E-05	2.38E-05	2.80E-06
2.23E-05	-4.12E-04	5.56E-05	4.61E-04	-9.18E-06
3.60E-05	-1.46E-04	3.16E-04	2.62E-04	1.21E-04
-1.72E-05	-3.36E-05	5.24E-05	-1.30E-04	-1.33E-05
-4.26E-06	-5.59E-05	-7.91E-05	1.51E-04	2.94E-06
-4.57E-05	-2.61E-05	2.76E-04	1.06E-04	1.82E-05
-6.19E-06	-2.87E-06	-5.43E-05	-7.38E-06	-1.03E-04
-2.96E-05	7.18E-05	1.17E-04	1.10E-04	-1.73E-05
2.34E-05	4.35E-05	1.12E-04	3.62E-04	-9.61E-05
2.43E-05	-1.01E-04	6.81E-04	5.02E-04	2.93E-04
3.54E-06	-7.64E-06	-9.30E-06	-2.51E-05	1.56E-05
1.78E-05	3.35E-05	4.97E-04	5.53E-05	1.03E-04
-5.04E-05	9.54E-05	4.72E-04	7.03E-05	-4.04E-05
1.29E-05	-1.97E-06	-9.80E-05	-2.54E-05	8.21E-05
-1.42E-05	-1.59E-05	-8.18E-05	9.97E-05	-1.16E-05
3.07E-06	1.10E-04	9.76E-05	8.98E-06	-1.10E-04
-1.00E-05	-1.22E-04	-1.74E-04	-1.76E-04	-3.23E-05
7.84E-06	-1.25E-05	7.85E-05	-1.93E-05	-4.17E-05
-3.50E-05	4.55E-06	5.05E-05	-5.88E-06	1.00E-05
6.00E-05	6.39E-05	-6.35E-05	-1.10E-04	0.0011
4.30E-06	3.56E-05	5.93E-05	-7.25E-05	1.07E-04
2.17E-07	9.49E-06	1.47E-05	-1.22E-04	-7.05E-05
-2.08E-05	1.03E-04	-6.20E-05	-1.57E-04	-3.27E-04
-2.11E-05	1.25E-04	-2.89E-04	2.71E-05	3.90E-04
2.03E-05	-2.46E-05	-6.17E-05	8.49E-06	-1.12E-04
-1.94E-05	1.96E-04	-2.44E-04	-3.26E-04	1.63E-04
-3.58E-05	5.24E-05	3.90E-04	1.15E-04	-0.0015
9.26E-06	-9.39E-06	-1.44E-04	-5.71E-05	3.29E-05
-2.12E-05	1.58E-05	-2.13E-05	3.34E-05	-9.00E-05
-5.23E-06	-5.07E-05	-3.52E-04	1.60E-04	3.26E-04
5.48E-06	-1.05E-04	-2.94E-05	2.89E-05	-2.54E-04

1.67E-05	2.02E-04	1.03E-07	-8.98E-07	5.20E-04
1.86E-05	-2.76E-05	4.81E-05	2.25E-04	4.82E-04
-3.10E-05	2.12E-04	-5.71E-05	-4.09E-05	1.34E-04
-1.13E-05	-1.17E-04	7.51E-06	2.10E-04	2.24E-04
1.54E-05	5.20E-06	-8.16E-06	3.36E-04	-1.93E-04
-9.82E-06	1.45E-04	-1.73E-04	-4.68E-04	1.89E-04
-2.07E-05	2.14E-05	-2.48E-04	1.46E-04	-1.10E-04
3.07E-05	3.72E-05	4.93E-04	-6.93E-04	3.17E-05
-2.24E-05	-5.17E-05	3.17E-04	-9.54E-04	-3.01E-04
6.99E-05	-1.37E-05	1.44E-04	1.90E-04	3.57E-05
1.59E-05	7.71E-05	5.31E-06	-4.61E-04	3.42E-04
-1.44E-05	-4.63E-05	8.08E-06	1.23E-04	3.39E-04
-1.28E-05	-8.17E-07	-6.43E-05	-7.49E-05	3.88E-04
-7.31E-06	-8.19E-05	2.53E-04	9.15E-05	1.16E-04
7.56E-06	-5.44E-06	4.32E-05	-4.96E-07	-2.12E-04
-2.43E-05	5.59E-05	2.52E-05	-1.07E-04	-1.29E-05
-7.36E-05	3.97E-05	-8.81E-05	1.29E-04	1.51E-06
1.76E-05	2.13E-06	8.13E-05	-2.42E-05	1.72E-04
2.02E-05	2.07E-05	-4.90E-05	1.99E-05	-2.94E-04
-3.25E-05	1.60E-05	1.11E-04	8.88E-05	3.42E-05
3.04E-05	2.16E-05	-3.76E-04	1.72E-04	3.42E-04
3.25E-05	8.78E-05	4.13E-06	-1.40E-05	6.32E-05
1.70E-05	-3.13E-05	2.43E-05	6.98E-06	2.95E-04
2.68E-05	-2.74E-04	-8.69E-05	1.14E-04	-5.68E-05
-2.86E-05	6.07E-05	4.21E-04	1.35E-04	1.93E-06
-2.08E-06	-3.62E-05	1.61E-04	1.64E-04	2.49E-05
6.52E-06	-2.58E-05	7.89E-05	-3.02E-04	2.15E-05
-1.26E-05	1.18E-04	9.10E-05	-0.001	-7.63E-05
5.13E-05	6.62E-05	-1.50E-04	-4.44E-04	-5.40E-05
-8.03E-06	-7.22E-05	-1.47E-04	-1.25E-05	2.09E-04
4.05E-05	6.94E-05	6.82E-05	-1.77E-04	-8.78E-04

1.65E-05	6.08E-06	-7.62E-05	-9.46E-05	1.21E-04
5.00E-06	1.41E-05	-6.69E-05	9.76E-05	9.98E-05
-1.26E-05	-1.27E-04	-4.85E-05	-1.19E-04	5.01E-04
-9.99E-06	4.48E-05	-2.88E-05	1.45E-04	6.20E-05
1.96E-05	-2.33E-05	-1.58E-04	3.57E-04	5.43E-04
-1.48E-05	7.62E-06	-2.19E-04	-2.62E-04	-1.47E-05
5.24E-05	-6.17E-05	3.73E-05	5.02E-04	6.46E-05
2.47E-05	-1.44E-06	1.51E-06	-1.08E-04	-3.65E-05
-7.74E-06	6.67E-05	-2.35E-04	-2.34E-05	5.39E-06
1.17E-05	8.94E-05	7.59E-05	-6.08E-05	-4.12E-04
-1.35E-05	1.03E-04	-2.07E-04	3.37E-05	3.64E-04
-1.69E-05	-2.74E-05	-7.31E-06	-5.34E-05	-3.29E-04
1.74E-05	5.53E-05	-3.83E-05	-7.24E-05	-8.43E-05
1.76E-05	-1.43E-05	-3.54E-04	2.48E-04	1.36E-04
-8.68E-07	-4.08E-05	1.95E-05	-1.24E-05	-1.92E-04
-5.67E-06	4.63E-06	-6.12E-06	1.09E-04	-5.03E-06
4.00E-05	-1.34E-05	-4.36E-05	4.01E-05	-1.61E-04
5.21E-06	-1.77E-05	-2.71E-04	1.73E-05	4.92E-05
9.45E-06	4.26E-06	7.49E-06	-8.71E-05	1.06E-04
2.10E-05	-3.14E-05	-3.78E-05	1.91E-05	-1.64E-07
-2.04E-05	1.87E-05	-1.74E-05	-8.28E-05	-2.64E-05
9.95E-06	7.91E-05	7.10E-05	-4.93E-05	-7.09E-05
6.62E-06	-1.57E-05	1.28E-04	-6.09E-05	5.80E-05
1.84E-05	-1.71E-04	-3.78E-04	-4.53E-05	-5.48E-05
-4.11E-06	4.30E-05	-7.27E-05	-1.90E-04	1.05E-04
3.81E-05	7.78E-05	1.05E-04	7.47E-05	1.42E-04
-1.81E-05	9.12E-06	-6.54E-06	3.82E-04	-8.54E-05
1.36E-05	-2.25E-05	4.24E-04	1.52E-04	-3.28E-05
2.04E-05	6.49E-05	4.06E-05	-2.86E-04	1.23E-05
-9.30E-06	9.95E-05	-3.50E-05	2.08E-06	2.02E-04
1.88E-06	-6.67E-06	4.75E-05	-1.32E-04	-2.18E-05

-1.28E-05	-4.71E-05	-1.84E-05	-1.81E-04	-2.96E-05
-4.11E-06	-5.21E-05	-2.47E-04	-1.83E-04	4.56E-04
1.26E-06	-2.82E-05	1.25E-05	7.35E-05	-3.80E-04
-2.44E-05	-1.16E-04	5.29E-06	-2.29E-04	3.73E-04
1.57E-05	-4.61E-05	-1.17E-05	1.26E-04	7.77E-04
3.64E-06	-2.65E-05	1.44E-04	2.24E-05	1.52E-04
-1.36E-05	1.38E-04	-3.63E-05	7.42E-05	-2.70E-04
1.56E-05	-6.83E-05	1.57E-04	-7.51E-05	-2.43E-04
-1.94E-05	4.27E-06	1.74E-04	1.84E-04	-4.19E-04
1.00E-05	8.10E-05	3.39E-05	-1.08E-04	-1.23E-06
4.10E-05	-8.84E-05	-1.50E-04	2.23E-04	3.46E-04
-8.89E-06	-8.99E-05	-2.93E-05	-6.52E-05	-1.25E-05
9.49E-06	-2.10E-05	1.75E-05	1.33E-04	7.93E-06
1.97E-05	7.90E-06	9.26E-05	1.64E-05	-5.62E-04
2.02E-05	-7.61E-05	-1.34E-05	1.22E-04	1.13E-04
4.85E-06	-1.70E-04	-5.60E-05	2.30E-05	2.06E-04
4.85E-06	-1.70E-04	-5.60E-05	2.30E-05	2.06E-04
-3.38E-05	6.28E-05	4.71E-05	1.79E-05	-2.13E-04
3.40E-05	1.04E-04	5.06E-05	-1.44E-04	-3.88E-05
4.32E-05	5.43E-06	1.74E-04	-2.79E-05	1.32E-04
-2.71E-06	-1.54E-05	1.46E-04	-2.22E-04	1.76E-06
-7.98E-06	-1.72E-05	9.76E-06	-1.41E-04	1.08E-04
-1.38E-05	-1.18E-04	3.94E-04	-2.65E-04	-1.76E-04
2.90E-05	8.48E-05	3.18E-05	-4.86E-05	-3.35E-04
1.53E-05	4.04E-05	-2.26E-05	1.93E-04	4.16E-05
-2.82E-05	5.27E-05	2.80E-05	3.94E-05	1.94E-06
1.66E-05	9.38E-05	-1.30E-05	1.43E-05	-2.13E-04
-4.53E-07	1.08E-04	8.75E-05	-2.44E-04	1.05E-04
-2.42E-06	-2.10E-04	1.53E-05	3.56E-05	-1.36E-05
7.25E-06	8.04E-05	8.70E-06	3.94E-05	8.21E-04
-1.95E-06	-6.67E-05	-8.91E-05	1.11E-05	-5.06E-05

1.18E-05	1.23E-05	-3.36E-05	5.25E-05	-2.16E-04
-2.52E-05	4.88E-05	-1.82E-05	4.24E-05	1.00E-04
-1.42E-06	-1.83E-05	3.07E-05	-1.12E-04	-1.35E-04
2.11E-05	-4.40E-05	1.08E-04	2.42E-04	2.99E-04
-1.26E-06	5.17E-06	-2.41E-05	-1.58E-05	-2.80E-06
-2.98E-05	1.14E-05	-1.66E-05	2.73E-05	-5.33E-05
-1.28E-05	1.73E-05	7.33E-05	-8.19E-05	9.73E-05
-6.08E-06	3.86E-05	3.33E-05	-6.46E-05	-4.07E-04
-5.35E-05	6.93E-05	-4.90E-05	-2.03E-04	-1.02E-04
-1.11E-05	-6.49E-05	1.46E-05	2.46E-06	1.26E-06
7.63E-06	3.03E-04	-2.66E-05	-1.86E-05	-1.58E-05
-1.30E-05	1.30E-05	1.08E-04	-2.04E-06	-1.51E-05
-8.19E-06	1.20E-04	4.60E-04	-2.19E-04	-1.43E-04
2.19E-05	9.23E-05	1.79E-04	-6.04E-05	-4.60E-06
-1.78E-05	-4.41E-05	-3.34E-05	-1.05E-04	-1.28E-04
-9.50E-06	6.36E-05	3.91E-05	-3.36E-05	6.42E-06
1.54E-05	-3.51E-06	4.28E-05	4.05E-06	-2.78E-04
-3.86E-05	-7.24E-05	-1.96E-05	6.29E-06	-2.09E-04
2.29E-05	2.56E-05	-6.76E-05	-1.72E-04	2.96E-04
-4.11E-05	4.28E-05	-7.08E-05	1.56E-04	2.38E-05
-2.15E-05	-8.11E-05	3.24E-05	-4.25E-06	2.52E-05
-6.55E-06	1.75E-04	-4.95E-05	2.80E-04	8.24E-04
-1.43E-05	-5.27E-05	-2.91E-05	3.61E-05	-1.64E-04
5.82E-06	-6.06E-05	-5.61E-05	-9.76E-05	-1.36E-05
1.95E-06	-4.21E-05	-1.97E-05	-4.91E-06	-7.87E-05
-8.05E-08	1.35E-05	8.50E-05	8.46E-05	-2.43E-05
-2.52E-05	-9.02E-06	-1.49E-05	-3.09E-05	-1.66E-04
3.25E-05	1.09E-04	8.88E-06	4.37E-06	-5.00E-05
3.11E-05	1.53E-05	-3.05E-05	-1.27E-06	2.56E-04
-1.19E-05	-5.64E-05	-1.24E-04	-3.52E-05	4.70E-05
-1.02E-06	-6.06E-05	-2.17E-05	6.16E-05	-1.73E-04

-2.14E-05	1.47E-05	-2.72E-05	-5.97E-05	9.13E-05
-2.45E-05	-6.99E-05	1.71E-06	-2.15E-04	6.82E-05
1.69E-05	2.78E-05	3.45E-05	1.44E-04	7.85E-05
2.55E-06	-9.28E-06	4.34E-05	2.09E-05	1.09E-05
-4.34E-05	2.79E-05	-2.11E-05	7.61E-05	3.05E-05
9.86E-06	-8.23E-05	3.72E-05	1.33E-05	5.89E-05
-4.46E-06	6.43E-05	-6.94E-05	-9.60E-06	-1.90E-04
2.39E-05	9.14E-05	1.10E-04	2.23E-04	-3.86E-05
1.04E-05	1.08E-04	5.45E-05	-5.82E-06	4.85E-05
2.59E-06	-1.35E-05	-8.55E-05	5.43E-07	-3.27E-05
1.29E-05	-1.39E-04	-8.65E-05	1.93E-05	-1.56E-04
-6.82E-06	1.20E-04	1.66E-04	6.04E-05	-7.03E-05
-2.44E-05	-2.57E-05	-1.16E-04	-1.09E-04	2.47E-05
1.36E-05	9.02E-05	7.38E-05	-1.67E-04	-3.27E-04
3.85E-05	-5.87E-05	-1.26E-04	1.83E-04	-1.71E-04
9.41E-06	-3.13E-04	4.07E-04	2.40E-04	5.27E-06
-3.73E-06	5.02E-05	4.56E-05	-1.17E-05	-3.15E-05
4.86E-06	-8.47E-06	1.36E-05	-1.41E-04	1.48E-04
-7.02E-06	-9.53E-05	6.39E-05	-2.92E-04	9.47E-05
1.97E-05	6.02E-06	2.72E-06	1.31E-04	-6.03E-05
3.32E-06	2.80E-05	-8.62E-05	-1.53E-05	-2.50E-06
3.24E-05	1.64E-04	3.82E-05	2.09E-04	5.53E-04
-1.60E-06	-9.23E-05	-3.36E-05	-2.01E-04	2.68E-04
-1.02E-05	4.08E-05	1.66E-04	-1.59E-05	5.70E-05
3.48E-05	-1.85E-05	2.44E-05	-8.76E-05	3.50E-04
1.58E-05	-3.29E-05	8.06E-05	-3.79E-05	2.97E-05
2.43E-05	5.10E-06	2.10E-04	-3.46E-05	-6.62E-04
1.77E-05	7.93E-05	3.51E-05	-2.81E-05	-7.27E-05
-4.83E-05	-1.35E-04	6.16E-05	4.31E-05	3.59E-04
-8.44E-05	1.68E-04	-8.03E-05	4.11E-05	-7.40E-04
7.19E-06	2.87E-05	8.63E-05	-1.04E-06	-4.05E-05

5.32E-05	2.02E-05	2.72E-04	1.01E-04	-5.24E-04
-1.19E-05	1.58E-05	-1.25E-04	-1.92E-05	9.31E-06
-5.79E-06	-2.07E-04	-2.73E-05	1.54E-04	-2.65E-04
8.79E-07	1.92E-05	-7.76E-05	1.60E-05	-1.76E-04
1.08E-06	-1.65E-04	4.05E-05	-2.32E-04	-1.66E-04
2.52E-05	1.21E-05	1.17E-04	3.43E-04	-1.76E-04
1.45E-05	8.48E-06	8.12E-06	2.61E-06	9.68E-06
-5.75E-07	2.77E-05	-2.91E-04	-7.88E-05	3.83E-04
-7.19E-06	-5.25E-05	-6.33E-06	6.51E-05	1.52E-04
1.33E-05	1.66E-05	7.04E-05	2.56E-04	-8.22E-05
1.44E-05	-7.10E-05	1.08E-04	-1.28E-05	6.76E-05
3.50E-05	-9.16E-05	-8.47E-04	1.27E-04	-5.51E-05
-6.38E-05	2.16E-05	4.24E-05	1.38E-04	-3.67E-04
9.05E-06	3.90E-05	1.59E-04	1.75E-04	2.96E-06
1.76E-05	3.74E-06	-4.42E-05	-6.30E-04	1.29E-04
7.97E-06	1.95E-05	-1.21E-04	3.20E-04	-1.04E-04
2.98E-05	-3.33E-05	1.84E-04	1.37E-04	-1.38E-05
3.46E-05	2.39E-05	-3.70E-05	-1.14E-04	-1.34E-04
7.44E-05	-2.23E-04	2.50E-05	3.63E-04	1.45E-04
5.59E-05	-3.28E-04	-1.69E-05	1.70E-04	-2.10E-06
-6.57E-06	-4.45E-05	3.67E-05	5.31E-05	-8.98E-04
1.47E-05	-8.36E-05	-2.64E-04	-3.09E-04	4.83E-05
-2.28E-05	-7.72E-05	1.06E-05	2.37E-04	4.49E-05
1.14E-05	-1.48E-05	8.67E-06	-5.10E-05	-1.17E-04
1.80E-05	2.00E-05	-2.01E-05	4.70E-05	-6.48E-05
-7.37E-06	-1.19E-04	4.31E-05	-2.00E-05	-5.70E-04
-5.46E-06	-4.20E-04	2.50E-04	2.04E-04	9.16E-05
1.46E-05	2.40E-05	2.07E-05	6.48E-05	-1.40E-04
-6.74E-07	-7.46E-05	-1.13E-04	7.87E-05	-1.85E-04
1.23E-05	-1.85E-05	-7.36E-05	-2.31E-04	2.63E-04
2.29E-05	-2.78E-05	2.21E-04	1.27E-04	-4.69E-05

-7.93E-07	-7.86E-05	2.04E-04	3.15E-04	-4.59E-05
-6.72E-05	-1.83E-04	-9.37E-05	-2.56E-04	4.04E-04
-2.15E-05	5.23E-05	-2.38E-04	7.47E-06	2.32E-04
1.30E-05	4.87E-05	1.36E-04	6.05E-06	3.59E-05
2.48E-05	2.94E-05	1.31E-05	5.93E-05	-9.94E-05
1.46E-05	-1.02E-04	1.70E-04	-2.61E-04	1.47E-04
-1.66E-05	9.41E-05	8.22E-05	5.77E-05	3.38E-04
-3.49E-05	-8.61E-05	-4.40E-04	-9.82E-06	4.41E-06
-4.07E-05	1.68E-04	-5.76E-05	-3.42E-06	6.47E-04
1.92E-05	-6.12E-05	-1.79E-04	-8.84E-05	-4.04E-05
3.68E-06	-8.64E-05	-6.26E-06	-1.20E-04	-4.78E-05
-3.69E-05	7.19E-06	-2.50E-04	-1.62E-04	-9.38E-05
4.34E-06	1.72E-04	1.16E-04	-1.55E-04	4.38E-05
-2.53E-06	4.24E-06	-2.44E-04	-4.12E-04	5.05E-04
4.46E-07	-2.47E-04	9.62E-05	-6.66E-05	2.22E-04
5.23E-05	-1.03E-04	1.52E-06	-1.45E-04	1.70E-04
8.72E-05	-7.46E-05	-9.27E-06	3.56E-04	2.66E-04
5.37E-06	-1.01E-04	4.66E-05	9.32E-05	3.81E-05
5.14E-05	-6.35E-05	4.87E-07	1.78E-04	-7.84E-05
2.64E-05	-2.40E-05	2.00E-05	4.87E-05	1.25E-04
-3.09E-05	-7.08E-05	-5.14E-04	-7.06E-05	-7.05E-05
-3.89E-05	-7.33E-05	-2.41E-04	-2.32E-04	-1.30E-05
1.80E-04	1.68E-04	7.37E-05	6.68E-05	-5.67E-06
8.93E-05	1.37E-04	-7.36E-05	-3.67E-05	5.42E-05
-9.72E-06	2.42E-05	-2.03E-04	-4.36E-05	1.99E-04
2.13E-05	1.32E-05	-2.06E-05	5.67E-04	-5.41E-04
2.99E-05	2.39E-05	1.60E-04	-1.22E-04	3.55E-05
7.35E-06	-1.09E-04	-7.95E-05	1.09E-05	-2.79E-05
7.82E-06	-1.19E-05	-3.16E-05	-3.23E-05	-4.09E-04
2.77E-05	-1.07E-04	-3.40E-04	-3.48E-04	-0.002
3.46E-05	-5.25E-05	1.96E-04	7.44E-06	-0.002

-4.63E-06	2.18E-05	-6.64E-05	-2.29E-04	1.80E-04
-4.22E-06	5.23E-05	-6.08E-05	3.32E-04	-0.001
1.05E-05	-1.92E-04	-9.32E-05	1.38E-04	-5.60E-04
3.15E-05	5.48E-05	-7.00E-06	-8.63E-05	3.18E-04
-2.96E-05	-4.96E-05	-2.27E-04	-5.27E-05	7.55E-05
1.56E-05	1.44E-04	3.14E-04	-1.81E-05	8.52E-05
2.02E-05	-1.69E-04	-1.62E-04	6.97E-05	2.51E-04
3.42E-05	-2.86E-05	-7.21E-05	-1.09E-05	2.27E-04
-3.83E-05	-3.31E-05	-3.70E-04	-2.15E-04	-6.54E-05
-1.82E-06	-2.11E-05	4.99E-05	1.30E-04	1.85E-04
1.76E-05	-8.93E-05	-5.35E-04	2.46E-04	-5.66E-05
4.85E-07	6.78E-05	-1.84E-05	3.14E-05	4.29E-05
1.16E-04	-2.51E-04	-3.74E-04	-8.45E-05	1.79E-04
5.48E-05	9.35E-05	-2.42E-04	3.32E-04	-3.74E-04
3.35E-05	-1.19E-04	3.96E-06	-2.02E-05	-1.07E-04
4.23E-05	-3.10E-04	1.14E-06	-1.06E-04	-1.69E-04
-4.41E-06	-1.79E-04	-6.91E-05	-3.44E-05	4.71E-04
-6.34E-06	-9.57E-05	-4.41E-06	6.63E-05	-2.75E-04
2.46E-05	2.39E-05	2.29E-04	3.39E-05	0.0012
8.76E-05	3.39E-04	-3.75E-04	-1.55E-04	-1.86E-04
2.43E-05	3.85E-05	-2.03E-04	0.0011	-1.19E-04
3.93E-05	-1.60E-04	-4.34E-05	-2.56E-04	7.17E-05
1.19E-05	-1.55E-04	-1.37E-04	-1.11E-04	-2.58E-04
4.37E-06	-1.66E-04	3.35E-05	-2.01E-04	-2.19E-05
-1.54E-05	6.35E-05	9.12E-05	-4.52E-04	2.41E-05
-1.39E-05	-7.24E-05	8.85E-05	-1.30E-04	2.41E-05
-6.38E-05	-6.64E-06	3.11E-04	-5.52E-04	0.0014
2.98E-05	2.46E-05	3.74E-04	-8.93E-05	-9.56E-04
-2.12E-05	3.64E-05	2.43E-04	-2.30E-06	-3.57E-05
2.72E-06	-2.42E-04	-1.68E-04	6.12E-05	-7.87E-08
6.37E-06	2.62E-04	-2.31E-04	1.45E-04	-1.08E-05

2.93E-05	-9.77E-05	-8.39E-05	-1.35E-05	-2.02E-04
5.82E-06	-6.06E-05	-5.61E-05	-9.76E-05	-1.36E-05
1.95E-06	-4.21E-05	-1.97E-05	-4.91E-06	-7.87E-05
-8.05E-08	1.35E-05	8.50E-05	8.46E-05	-2.43E-05
-2.52E-05	-9.02E-06	-1.49E-05	-3.09E-05	-1.66E-04
3.25E-05	1.09E-04	8.88E-06	4.37E-06	-5.00E-05
3.11E-05	1.53E-05	-3.05E-05	-1.27E-06	2.56E-04
-1.19E-05	-5.64E-05	-1.24E-04	-3.52E-05	4.70E-05
-1.02E-06	-6.06E-05	-2.17E-05	6.16E-05	-1.73E-04
-2.14E-05	1.47E-05	-2.72E-05	-5.97E-05	9.13E-05
-2.45E-05	-6.99E-05	1.71E-06	-2.15E-04	6.82E-05
1.69E-05	2.78E-05	3.45E-05	1.44E-04	7.85E-05
2.55E-06	-9.28E-06	4.34E-05	2.09E-05	1.09E-05
-4.34E-05	2.79E-05	-2.11E-05	7.61E-05	3.05E-05
9.86E-06	-8.23E-05	3.72E-05	1.33E-05	5.89E-05
-4.46E-06	6.43E-05	-6.94E-05	-9.60E-06	-1.90E-04
2.39E-05	9.14E-05	1.10E-04	2.23E-04	-3.86E-05
1.04E-05	1.08E-04	5.45E-05	-5.82E-06	4.85E-05
2.59E-06	-1.35E-05	-8.55E-05	5.43E-07	-3.27E-05
1.29E-05	-1.39E-04	-8.65E-05	1.93E-05	-1.56E-04
-6.82E-06	1.20E-04	1.66E-04	6.04E-05	-7.03E-05
-2.44E-05	-2.57E-05	-1.16E-04	-1.09E-04	2.47E-05
1.39E-05	1.08E-04	-2.67E-06	-1.13E-04	9.92E-07
2.09E-05	8.90E-05	-5.52E-05	4.91E-05	7.47E-05
7.27E-06	-6.34E-05	-9.13E-06	9.54E-05	-7.57E-05
2.50E-05	-2.50E-05	-5.43E-05	6.18E-05	5.16E-05
5.54E-06	3.50E-06	-1.37E-04	3.68E-05	-8.29E-05
-1.44E-05	2.19E-05	-2.52E-04	2.42E-04	-4.18E-05
3.43E-06	-2.40E-05	2.64E-04	2.18E-05	4.13E-05

5.4.3 Event Related Potential (ERP)

After analyzing the STFT and PSD features using Naïve Bayes classifier we found that the accuracy for quantification into two classes was very low to improve the results, it was decided to work with ERP features and other classifiers also. To reduce the dataset the latencies of the ERP features were ignored and only the potential values were considered. The chosen features for emotion quantification are P100, N100, P200, N200, and P300 [45].

P100 is also called P1 as it first positive peak observed from 80 to 120ms after the onset of stimuli, we took P100 as the maximum ERP of the subject in the time limit of 80 to 120ms. For the corresponding electrode, the P100 of the subject was determined manually. N100 was just reverses of P100. Here the minimum of ERP value was chosen as an attribute for classification. The N100 was also classified within the time limit of 80 to 120ms. P200 is a second positive peak observed about 200ms varying between about 150 and 275ms. N200 in particular is a negative-going wave that peaks 200-350ms post-stimulus and is found primarily over anterior scalp sites. P300 is a positive peak observed at 300 ms varying between 250 to 500ms.

The coefficients of PSD, STFT and ERP were collected with seven electrode Cz, Pz, Fz, FC1, FC2, F1, and F2 cap in the delta (0 to 4hz), theta (4 to 8hz), alpha (8 to 12hz), beta (12 to 30hz), and gamma (above 30hz) frequency bands corresponding to unpleasant and pleasant classes.

The obtained ERP features were then analyzed both by Naïve Bayes, ANN single layer, Feedforward single layer, and Multilayer 2-Hidden Layer Neural Network classifier.

Table 5.4: Table Shows the Extracted Features of ERP.

P(100)	N(100)	P(200)	N(200)	P(300)
43.19457	-4.97343	32.19457	-9.77523	30.13057
87.03264	-21.8678	87.55414	3.265044	111.7943
280.389	225.5023	264.7152	210.3968	230.2386
-1.86665	-92.8334	-19.0151	-82.2514	-2.08155
57.70061	10.36861	40.13811	-3.06109	32.27091
181.3342	117.0705	169.3459	121.7522	178.0354

27.21785	-23.2404	25.07055	-26.5083	25.91575
18.90131	-17.0684	22.28311	-13.8189	20.32561
-57.1614	-143.154	-55.1888	-118.3	-35.6751
-118.755	-200.296	-137.348	-223.067	-161.061
6.799346	-56.4918	8.752446	-50.9175	11.71335
-34.4617	-98.6102	-59.368	-101.751	-60.6492
-48.7265	-93.0019	-40.7324	-94.621	-41.6054
24.21955	-22.5474	23.23015	-25.1175	25.25085
38.32767	-12.8818	36.59527	-3.49513	39.00047
21.8778	-41.6534	17.1805	-20.0695	33.0575
-39.5513	-82.6411	-33.4048	-77.3911	-16.3071
-35.0885	-93.0748	-34.6276	-88.3033	-22.5416
-32.0721	-91.7479	-46.3104	-87.1639	-47.4158
8.721081	-48.0738	6.971081	-39.1422	14.29338
19.71125	-20.2205	19.69045	-29.5707	23.48475
18.39815	-21.1429	23.46545	-18.2596	17.70715
69.9672	-21.2262	69.1742	-1.0387	38.2504
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28.61804	-31.2784	39.47554	-20.6027	16.21184
-14.0078	-56.7656	-7.70697	-50.8554	-23.5254
39.85636	-11.2686	42.79966	-10.9093	22.07116
26.24362	-17.5162	27.21012	-23.0751	24.62372
40.93178	1.162276	38.21888	-0.48962	47.86488
83.99098	1.162276	38.21888	-0.48962	47.86488
194.5209	133.1948	183.7319	135.9936	325.1694
159.2609	102.2277	167.7042	111.466	153.0548
279.3092	117.1875	270.2272	234.9675	306.9323
235.3501	175.6665	238.7348	191.1704	255.0454
20.09653	-28.4604	15.95263	-29.3936	19.75483
25.50402	-15.6591	48.31702	10.65052	25.59192
118.0191	57.10108	13.56208	-52.9692	49.47418

68.14354	18.14164	229.3857	150.2529	95.16694
28.74039	-28.8553	6.931792	-54.244	0.156392
-231.825	-272.941	-157.235	-214.073	-222.788
28.91821	-17.576	63.33031	8.523609	11.86151
24.81554	-23.3448	28.78414	-15.1684	23.21044
46.63083	6.313427	40.56293	2.022427	42.42813
11.60811	-54.3509	-6.62239	-78.4251	-2.88609
-21.1803	-79.2897	-25.0885	-86.7057	-16.3326
18.25905	-39.8074	9.749345	-55.0671	13.83725
21.68451	-14.5343	11.42081	-32.4366	26.49311
29.38173	-28.8058	11.49693	-42.9816	22.69223
21.91362	-25.6021	24.66762	-19.4313	22.88692
66.46573	26.52243	44.57123	-11.4664	25.93603
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132.8036	71.88952	22.37392	-21.6358	16.14152
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18.76812	-31.0022	13.15552	-32.973	15.48592
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126.4145	57.18976	124.5805	66.75426	127.9887
23.2196	-31.2609	24.3993	-42.7081	20.4091
57.11763	-7.40387	56.40083	2.37153	58.62933
130.1561	89.04279	129.0779	79.97829	75.07599
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28.4215	-18.2935	26.7967	-19.7937	28.1539
13.97725	-36.6575	43.90605	-7.11935	-7.86155
3.769275	-59.2444	-163.627	-258.119	-51.6389
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16.68011	-37.4781	43.72701	-9.54249	-29.5816
30.80289	-16.9401	34.64669	-13.3912	32.20119
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56.5889	-6.9287	85.5752	16.6338	71.1748
15.53037	-36.1004	26.65737	-37.9442	8.581168
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12.1958	-24.1265	28.2505	-24.5561	8.287605
38.95687	-11.6349	58.72057	-0.84003	49.61507
26.47453	-17.0483	28.12313	-14.9464	25.04133
24.63911	-14.5797	32.99751	-12.5328	48.89641
110.2201	39.87236	109.4173	49.53646	-101.145
31.56779	-28.6216	13.66349	-23.3658	315.5366
42.8451	-9.8483	44.0521	-5.5338	-26.0592
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22.10209	-18.0032	21.76059	-21.2726	25.05939
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46.28528	-5.31822	49.10958	-13.9393	-23.2459
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42.94594	-3.64786	65.39514	-8.78846	56.61194
24.26479	-19.5254	26.11289	-16.7374	27.30659
74.45264	20.39654	41.76324	-9.66016	27.83544
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363.7717	107.8713	-64.7322	-148.199	-77.9666
-44.7288	-116.871	59.4841	7.939101	68.9704
167.0092	42.71044	1.644038	-52.4009	0.659638
70.02496	-44.6156	18.96446	-35.7484	18.16176
13.21509	-29.4171	9.747288	-32.8334	8.063188
11.44231	-19.4717	15.55801	-23.1685	11.15471

103.6292	45.77772	100.7972	38.72692	31.71712
42.53439	-16.116	48.57929	-3.53591	39.02069
115.4597	70.28778	112.7722	57.35618	117.5984
46.3404	3.443895	43.8384	10.7232	41.6646
72.8764	29.1967	67.1967	23.7416	61.6791
19.37165	-27.8142	22.92945	-23.1106	22.45935
12.22953	-29.23	66.04643	18.94773	-0.17967
105.9636	42.66276	-163.169	-286.685	97.12756
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70.02169	9.642788	-16.074	-73.5603	59.43379
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46.5036	-13.889	121.9235	57.9274	34.7204
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122.8805	45.39026	22.65976	-23.6761	19.53476
30.51239	-12.2876	27.73189	-13.2065	23.45279
49.30035	15.56645	36.27935	183.5938	35.29245
297.2825	233.47	257.6457	185.7961	249.0989
301.0855	239.396	267.4097	210.2535	255.0699
132.515	78.95443	110.6321	54.10683	105.097
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96.39183	46.54023	65.42113	13.65353	59.80583
14.9515	-29.8613	14.5062	-30.3152	14.2994
27.66393	-5.67347	25.48823	-12.4332	20.61753
25.93602	-34.1343	56.12942	1.846225	35.66652
129.547	84.09575	96.55675	48.56455	85.10355
74.759	21.7023	75.8664	27.0402	68.3547

3.570917	-34.7162	-3.23568	-43.1654	-12.5111
29.22412	-14.4243	29.10502	-18.1509	15.29442
21.01775	-21.5446	16.54025	-27.432	21.38355
-24.0055	-61.064	-28.9283	-62.3687	-21.2681
26.21454	-33.5883	15.97424	-47.4222	1.503543
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27.62809	-28.3329	10.57529	-41.2567	0.344889
29.03165	-13.4498	31.84925	-11.876	27.81985
47.7056	-37.9634	55.3413	-50.1694	39.8853
48.63821	-13.6665	54.29441	-15.4234	41.14891
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39.08123	-15.5016	35.64153	-27.8124	24.33823
96.02543	6.119731	105.9639	-3.29287	101.063
64.37043	-32.5662	56.43443	-48.6811	47.44713
981.1508	-1022.98	1026.073	-897.38	881.1644
67.81999	-13.013	54.62669	-27.7855	66.00459
45.53868	-19.9994	58.51518	-28.6586	70.07378
37.7741	-48.1092	34.6008	-44.7054	52.4606
19.19055	-62.5062	1.415154	-60.9073	8.335054
23.36715	-57.9023	8.655753	-71.5629	32.15425
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821.2211	-820.148	864.6791	-793.04	877.9145
48.17979	7.927887	36.90539	-3.53891	41.36339
88.60434	26.97744	81.10534	19.62484	90.93054
184.0423	121.285	170.9706	119.3622	182.0052
62.11583	14.09873	51.34723	2.902734	57.83313
45.95516	-3.55754	31.41706	-20.2567	44.91566
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44.21618	-14.4273	43.04918	-13.3541	36.89788
231.0376	165.8193	231.833	173.5107	220.0078
44.28765	-6.60465	46.31775	1.731055	45.54085
39.85233	-15.8996	42.68053	-6.41377	40.49783
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16.43471	-46.147	23.21501	-43.9941	11.66881
883.5653	-854.115	914.3143	-761.705	786.7284
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79.9649	-4.1884	75.1153	14.7364	91.1632
3.505658	-65.8488	5.193158	-53.067	0.520558
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-50.6145	-139.283	-58.2439	-127.145	-57.7924
694.0615	-1076.61	852.7637	-922.243	798.6485
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79.9649	-4.1884	75.1153	14.7364	91.1632

3.505658	-65.8488	5.193158	-48.296	0.520558
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694.0615	-1076.61	852.7637	-994.812	798.6485
-49.2412	-91.7715	-45.456	-93.8105	-43.248
40.99035	-30.3759	50.00105	-31.1288	37.93855
20.66427	-37.865	37.49287	-35.7093	30.95767
36.93626	-11.5703	49.60696	-18.1843	40.86646
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34.69295	-25.9164	49.04825	-29.3332	41.13815
901.0517	-884.183	766.1943	-998.854	900.5195
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37.4039	-34.0394	37.0241	-35.1615	17.9606
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37.27148	-14.1692	39.72358	-21.6304	33.06758
36.28498	-17.072	28.00518	-30.2834	16.08768
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872.3361	-1007.81	882.3224	-951.727	792.2316
-30.725	-71.8979	-22.2621	-67.5648	-33.1195
27.40733	-51.8027	35.37993	-31.8496	12.94833
31.36934	-41.0296	37.87224	-23.6751	24.32144
62.56059	1.90319	68.66659	10.09799	46.67759
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38.14799	-38.6265	44.94519	-20.8899	30.61949
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101.0975	-98.8151	114.8343	-64.1735	118.307
84.79033	33.72273	89.02693	40.27573	89.61483
34.29371	-116.503	24.48021	-111.344	15.48611
75.61254	-134.123	91.18554	-113.011	64.70034

785.3552	-1015.19	835.3484	-966.215	819.8454
274.7908	162.3767	275.6892	163.4158	254.0505
291.0291	227.0223	283.9686	224.0359	283.3875
331.7878	175.0422	339.4846	186.862	302.0656
284.6791	222.1938	284.0639	235.0324	282.7553
311.3894	196.5637	318.0779	200.1272	287.5085
347.3893	188.9452	360.6847	198.0489	292.7055
1166.633	-820.717	1262.217	-777.995	1251.564
223.0523	114.7505	230.4571	124.125	208.5352
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324.9005	163.6954	318.8243	163.4512	286.6963
259.5733	201.4834	250.5957	206.6621	243.7149
315.9413	188.9755	307.9198	182.7802	282.0165
274.5053	105.32	273.4142	103.0583	242.6181
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41.08758	-21.8709	109.375	-15.9456	41.76728
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47.48774	-85.9976	42.35884	-83.2242	46.01024
54.35224	-124.564	54.42404	-106.534	52.55734
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122.6891	3.809192	128.5094	4.152392	118.3673
88.47501	6.356807	92.09801	19.61461	79.54431
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171.0798	146.7048	179.2727	135.7487	159.3483
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63.93832	-32.0185	64.30822	-33.0502	64.90922
287.1022	-423.663	327.7052	-397.138	327.3903
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32.75034	-6.54706	29.76304	-5.98996	36.80254
1.386034	-79.2653	29.77473	-90.1774	4.897834
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358.7108	-261.221	331.8802	-390.339	362.0316
36.42205	-35.1726	32.80485	-40.6121	58.10665
42.74499	-0.94941	37.31239	-8.46991	64.84799
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378.6878	-361.459	399.8011	-307.256	335.5145
7.556	-68.0476	3.6995	-67.1599	1.3079
43.75823	-1.25397	46.66883	-17.1779	24.62633
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10.82539	-19.1766	11.95669	-24.1732	-6.71861
-62.4958	-137.053	-59.7663	-133.849	-60.3103
42.94614	-49.2817	31.97964	-55.9016	41.75054
364.8179	-368.9	385.149	-331.916	331.8243
64.61363	-13.7819	80.01303	-11.943	67.00723
44.11012	2.977316	50.49732	7.401616	29.93972
212.4389	108.0815	223.4282	120.5356	214.1684
128.4585	101.3056	135.5786	100.2197	115.2324
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129.3723	21.01237	132.3626	24.42327	110.5589
366.8327	-310.919	322.0012	-342.444	365.3649
104.4826	33.49922	114.5695	22.80972	105.88
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83.41771	60.61881	106.7307	76.16131	109.5622
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145.4917	52.90141	164.2471	47.89091	139.9446
347.1501	-320.015	342.6945	-342.688	310.8723
72.60582	1.887623	71.46472	1.837323	67.25872
47.66903	12.50273	50.64463	7.719535	37.78623
17.75354	-65.8763	20.39034	-71.2406	33.04264
93.08318	67.76238	90.31408	60.60558	76.44498
107.8853	34.58346	105.0865	28.39796	103.6929
108.2183	21.65241	102.5579	7.384314	100.2327
388.9451	-292.743	360.2737	-336.914	381.1297
-11.8808	-101.816	-13.5595	-87.3813	-22.9037
50.95332	-6.30398	46.00482	3.986322	29.48902
110.7884	-4.06714	110.9105	10.22396	82.40656
65.14012	16.50632	61.20652	25.88812	52.33832
39.65598	-62.8225	38.78398	-47.5461	17.94018
32.78616	-83.0358	35.74006	-65.5949	13.19196
358.3909	-342.858	317.533	-378.13	350.199
39.56872	-33.8639	42.36222	-6.82388	38.36512
52.00588	8.252978	33.93428	-6.97172	50.64818
52.46801	-36.2976	77.28441	-22.8982	50.73171
65.67157	32.73207	56.66667	28.41177	61.67057
58.93639	-21.3468	67.62979	-22.4366	50.89829
61.72207	-33.6739	69.67957	-37.0213	54.13907
362.2221	-334.748	400.6621	-276.854	375.3974
-0.35547	-80.3457	-17.0142	-82.854	-14.6548

93.91024	38.92654	86.43954	51.65364	74.09744
67.15332	-30.0958	42.33302	-41.7696	37.33002
70.847	30.432	63.2269	34.6839	51.0531
55.96706	-29.7615	31.51686	-36.5036	27.29316
96.53974	-10.7406	85.27774	-4.99716	70.14714
335.1215	-359.802	353.1395	-342.319	316.2001
-9.69537	-80.1221	-14.4092	-83.9825	-19.9854
43.76088	13.30308	37.69808	6.258176	37.97688
132.8235	45.15357	123.1223	37.65157	111.8548
102.0051	82.611	93.8986	77.8312	102.0676
48.22774	-24.7596	42.54814	-30.0515	30.64674
90.3323	5.0242	77.1944	-10.8173	69.0035
340.0991	-351.26	288.3291	-387.335	337.0698
-28.694	-99.8669	-29.1559	-107.55	-28.863
57.16966	15.33466	38.82106	12.56856	33.79836
30.02578	-66.4312	17.72208	-77.6305	18.74548
-21.5658	-51.4173	-31.5658	-53.4613	-34.6888
1.787355	-74.7087	3.463155	-81.2351	3.242455
19.90686	-68.2217	20.87176	-79.0792	13.27776
282.9191	-390.293	325.257	-360.328	301.1198
60.07626	-17.8446	55.85456	-19.288	49.03226
3.713903	-41.0561	-2.1999	-32.061	-0.7995
143.459	23.05081	110.2178	22.31941	116.251
-36.2704	-64.5278	-33.9872	-57.7119	-37.0253
20.59117	-74.9146	1.14297	-71.5718	-0.09723
64.0598	-7.9289	75.763	-17.322	74.4392
353.997	-320.804	321.8173	-344.641	367.8456
109.765	31.34995	111.179	41.68005	109.3265
-2.60864	-43.98	-0.32134	-45.0288	14.53706
-210.339	-304.692	-207.82	-297.032	-206.944
-32.6135	-68.9587	-34.1755	-66.2809	-15.1481

77.77584	-8.70266	81.15864	5.052143	80.46434
78.47886	-18.5875	88.00136	-9.19714	85.24456
368.2872	-326.878	362.0475	-348.559	347.8629
40.50231	-27.0661	37.40271	-39.4713	45.27961
24.85413	-4.54797	16.87263	-20.8276	27.70643
-85.4744	-172.256	-90.2557	-195.27	-73.9441
-70.7601	-94.0487	-73.1097	-102.56	-57.89
-10.7691	-79.5689	-7.96736	-95.9849	4.986741
23.20964	-61.2995	19.88564	-80.5526	36.37074
325.4298	-357.501	365.1978	-318.373	347.5855
41.38621	-34.0425	30.72801	-41.1216	28.49261
71.69002	33.90242	74.40852	30.39362	61.61482
101.644	-22.8345	62.13234	-20.8306	56.86184
-28.2962	-60.4036	-29.823	-59.0511	-40.4334
32.15162	-63.2733	9.481618	-65.9109	2.342018
9.950503	-93.5637	-8.6699	-93.8965	-18.7133
363.0395	-333.106	320.9272	-359.856	369.3618
2.277477	-70.5311	-3.86312	-74.0271	4.675977
-11.5583	-56.7526	-7.63302	-58.9636	-25.8068
141.8787	45.27216	117.1501	40.77026	125.4275
19.33173	-18.7743	6.102232	-29.0722	-2.68297
39.7151	-42.9333	22.6194	-46.5827	32.513
56.9092	-39.5371	42.6189	-39.5793	43.6887
312.1177	-353.688	303.6744	-406.137	301.9586
-5.13928	-75.2828	-8.83748	-76.6559	-14.5368
-44.9175	-70.3465	-30.689	-64.7032	-51.3313
53.67019	-30.491	73.55099	-5.97831	63.44259
43.09011	21.23021	62.44801	35.76731	65.13601
-19.948	-89.8045	-2.69711	-72.9949	-8.52711
37.79595	-46.0591	59.24805	-21.8081	44.90485
280.4066	-421.462	275.8919	-404.985	241.0233

14.63321	-55.9996	17.73571	-56.9772	8.521911
21.12497	-22.0465	27.00997	-16.1505	15.99937
-25.6434	-106.821	-30.6717	-116.049	-47.3124
45.85718	16.24588	50.60868	18.00858	43.47348
0.325942	-73.0491	1.961642	-81.0325	-10.5569
80.80581	-7.97399	80.28841	-8.61759	71.06941
340.9299	-371.276	309.9944	-387.237	341.9812
76.30651	7.191309	73.66591	-3.78139	72.94421
23.28451	-14.2928	13.71871	-41.2314	4.065809
-5.30379	-91.1329	7.189409	-101.954	-8.04399
-78.7955	-104.387	-70.4039	-109.387	-68.2051
8.403988	-62.5774	16.57589	-67.971	24.24189
15.68458	-69.7014	23.99288	-79.6958	35.53708
354.2208	-330.112	392.3624	-315.358	381.7027
69.13439	-7.41341	62.66659	-2.67711	60.18909
33.83733	-12.6799	22.21163	-14.8243	20.85363
-35.9846	-131.052	-38.8059	-129.245	-36.1096
70.09593	36.34053	64.96413	29.98703	55.00563
53.50576	-29.0938	41.94226	-35.4552	38.98916
89.06744	-10.988	69.41774	-17.7397	64.26764
360.91	-372.226	361.1493	-368.967	386.3553
82.18124	3.558243	74.60704	7.622143	80.52604
84.32137	51.03797	75.88577	34.93357	78.67287
80.24302	-7.89948	87.39542	-12.755	88.90322
29.24548	6.987183	29.36268	2.177183	30.55848
57.14666	-21.0623	59.41526	-22.4031	60.08516
79.98061	-16.5114	80.79381	-16.7799	79.15811
417.7357	-318.05	436.8324	-297.334	401.4618
26.73158	-25.9745	13.57238	-37.0326	19.90638
51.38926	14.79176	39.62486	16.81786	38.41186
212.8466	145.3134	214.6308	151.3925	202.2538

249.6089	221.0445	239.8443	217.9634	231.0801
176.1215	118.6928	163.1547	106.8569	167.7993
151.626	85.64307	136.0425	69.44537	130.0992
117.9951	-178.488	132.3911	-175.29	130.2988
6.029748	-53.6031	1.705548	-46.4518	8.837848
36.76488	16.77418	49.44028	18.29908	45.46458
-10.0665	-73.2257	0.5301	-66.3673	9.8104
77.94316	58.55256	79.69416	58.92366	76.75366
18.22196	-41.9166	13.70636	-37.7291	15.52476
54.35006	-11.6811	56.37056	-13.9058	49.10106
153.7614	-157.609	161.5123	-137.64	146.569
45.28552	24.65902	43.97542	25.40722	33.56012
51.19755	22.71905	41.94075	19.12285	37.08035
40.25276	16.84606	38.06136	14.35586	30.37826
48.68386	24.76096	45.42586	21.75006	37.86066
28.86774	4.991244	26.40674	4.148044	11.49854
59.36491	35.86321	58.44121	35.53501	45.62851
27.61133	-16.0636	34.63833	-9.09647	31.62963
82.72488	62.79498	85.22638	67.11098	68.47538
62.87756	36.36336	62.22226	34.31796	58.59876
79.64018	53.37798	72.66218	49.90678	62.43958
57.76209	33.75819	56.74699	31.22929	47.39929
61.74275	40.02595	61.74805	39.64265	49.47075
79.81601	55.79281	79.34661	57.85441	74.80971
67.15445	28.82825	65.12305	23.71015	62.51415
107.5225	82.98396	105.1611	82.72396	96.87086
92.67534	60.36774	85.02014	51.78764	78.54644
113.1499	83.1147	101.5361	69.8731	88.4399
97.17268	68.11858	85.53048	55.91708	77.84718
93.8105	67.8745	88.0893	62.1938	78.8481
163.9829	137.9245	148.7888	128.2409	146.3452

98.61118	61.24878	99.52738	60.87738	99.87468
27.71868	-0.88972	8.440081	-11.0363	-1.59352
53.35646	16.60406	33.95906	2.724162	18.20466
70.23171	31.83571	46.62141	20.02371	23.67661
44.57794	14.14584	29.41714	4.32944	15.01544
31.79602	-1.97298	8.695425	-13.1551	-4.18738
139.6142	103.0094	108.0109	85.09511	90.15671
14.10748	-23.8998	14.38738	-25.8444	15.48468
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11.40872	-11.6342	0.687118	-39.2973	-10.8247
7.185751	-15.1023	-6.13165	-41.4202	-18.5603
9.662466	-13.9644	-1.36923	-37.2271	-12.9926
4.029063	-15.0627	-6.87084	-42.1091	-23.3049
12.98336	-8.48784	-0.73394	-36.614	-22.998
6.591473	-30.4261	-1.55623	-36.5721	-0.40533
50.81532	67.55682	39.74802	67.50102	42.99152
39.62367	59.98157	27.35027	50.09147	32.46597
43.24971	62.70821	22.14271	45.63831	29.39611
58.35476	77.46746	43.82426	65.87836	47.29556
42.93872	62.20192	29.24242	57.29662	37.92302
36.1805	57.4615	19.9844	43.4927	28.2374
25.31924	59.20464	21.80064	57.18874	21.34534
16.25293	37.63653	0.355226	21.46473	24.30513
13.29684	46.32124	22.18544	-7.53766	39.71864
37.23561	62.27611	41.43531	191.4063	56.72971
19.65694	50.67724	31.29164	4.621041	44.02914
17.35592	39.49612	22.29542	-1.08648	31.68162
40.46993	11.97803	17.37253	-9.66647	34.23613
6.530727	39.23333	38.34313	5.016327	42.09013
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-88.511	-109.607	-97.8142	-125.719	-90.8547
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-100.467	-135.339	-99.9346	-135.057	-92.2695
11.24731	-8.47309	12.18591	-8.62579	20.06421
2.161671	-28.3256	18.03667	-14.9765	7.620671
6.267034	-23.0274	17.89353	-12.4186	19.31783
24.22996	-2.79254	33.19296	7.712963	30.87836
-15.4487	-39.9487	-9.38911	-33.3954	-4.19131
0.520303	26.2043	14.8215	14.8215	38.8191
9.84821	-26.8649	-0.30679	-31.8661	5.85201
6.261341	-10.5622	4.683641	-9.79896	19.76414
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-3.26691	-26.3745	-11.3905	-32.6242	-10.9051
17.81509	0.052386	13.09529	-1.18251	20.17539
16.82786	-2.88944	9.981661	-6.17024	9.770261
17.97077	-15.732	17.68697	-14.7191	22.21837
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61.02256	29.96936	42.84486	14.74376	47.68026
74.94789	42.29599	48.10219	27.25349	51.75739
46.67615	19.27435	32.03245	7.591953	33.45725
35.3028	10.1582	14.0596	-4.4887	13.8413
47.97635	21.38215	27.84015	2.854349	27.57795
21.95653	-8.71067	20.03553	-8.25867	17.69193
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24.04933	10.35263	32.57223	13.10083	19.19463
26.89039	6.655587	25.84359	1.155087	17.64289
73.95736	57.96616	78.82556	54.78546	65.99246
29.1968	10.8466	32.3934	7.702295	21.3546
10.91473	-3.08337	23.88833	0.495225	10.23163
59.50929	46.62059	73.41649	49.82079	56.03659
25.63082	0.588716	25.30882	-0.13818	25.35702
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28.74404	6.544842	20.36124	-7.96446	7.017942
-23.2083	-46.2955	-29.8005	-53.453	-39.7771
-25.9093	-41.5236	-26.673	-49.5622	-38.6706
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25.81041	10.42611	24.48261	4.754913	4.210313
52.47676	29.79556	54.60126	20.91086	38.13346
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16.57883	-5.48307	16.08093	-14.3781	-1.78657
22.88395	3.746753	20.49235	-0.90315	3.997253
10.01484	-10.4115	8.699342	-20.8099	-13.5804
40.41104	12.25624	39.17174	13.47744	34.08674
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38.861	12.6198	29.8024	7.440102	17.2872
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32.31398	13.15718	29.79148	6.640578	20.43698
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15.04862	-5.44938	-1.24968	-30.4494	-13.468
147.1184	126.8064	136.5852	109.9661	125.4427
38.17865	22.10375	23.36585	-1.45085	11.04625
10.02676	-7.80334	-6.30334	-28.0855	-13.7291
102.8203	91.75145	97.61075	74.03415	88.43405
17.60779	-5.74191	16.00779	-8.91071	13.17589
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91.06732	63.90622	77.54682	45.44232	61.20312
23.19892	-2.89638	10.28552	-18.8315	-1.59898
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115.1727	95.1287	105.9486	77.1976	91.3157
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23.52018	2.034279	18.64448	6.464179	15.55458
102.4912	82.66413	80.27983	61.38283	70.50543
44.48903	19.76933	36.54673	19.17563	24.69123
39.80495	9.287354	24.00235	6.486054	19.71535
26.5188	4.864003	19.0813	3.975803	16.1702
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36.43425	14.31345	32.94555	7.349448	30.47465
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112.1152	86.69037	96.87147	64.80757	84.00577
80.84441	56.94891	67.47521	41.48791	59.94501
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70.0893	26.6078	66.2941	18.2996	46.3606
45.87005	7.093653	50.50965	9.775753	38.70005
57.56995	14.08655	59.76235	13.59395	40.07095

39.59533	2.581331	44.66073	5.493231	31.99593
71.40882	29.59822	73.19002	28.52012	57.31992
37.57111	7.140009	39.03451	5.989609	39.44321
53.12285	19.79745	59.27865	18.77695	43.27765
80.70245	43.69065	74.33205	36.08725	78.34675
83.27067	48.75477	91.57607	52.35907	74.53187
63.67518	27.76598	65.87788	24.88668	58.36608
67.65187	31.15627	71.44537	31.04767	53.57957
77.84039	43.35019	84.66169	44.12949	72.57769
61.67844	28.33174	65.33074	33.03434	60.20234
51.80685	17.62985	41.98465	5.521452	26.83765
39.85372	1.60522	21.82782	-20.0174	26.58922
51.74208	17.89348	31.50668	-8.44252	26.50818
53.50898	16.84098	36.94548	-3.16342	31.92938
40.98884	9.209542	23.15334	-13.7239	14.78154
69.52792	38.90882	48.95512	11.82672	51.41022
35.15431	2.278811	32.32861	1.726011	29.10641
36.33733	3.362529	37.32053	3.759029	25.54023
45.2409	0.342798	56.2601	7.985598	47.5151
43.52491	5.578106	51.03271	12.96241	46.43291
35.46892	-6.68198	40.23642	-4.54188	34.27792
26.37691	-7.96799	33.08941	-4.25199	27.18191
63.25197	23.11377	68.38627	28.65047	65.85407
31.37807	-1.60823	34.94797	1.91957	32.79507
51.38404	20.92214	53.32894	18.02614	31.74464
59.74517	14.40207	63.04777	18.67637	38.13487
62.36503	32.49173	62.17313	27.80303	36.98143
72.54548	26.96688	76.26868	34.06648	48.23838
52.4189	21.2273	51.4505	15.9804	26.3404
84.97233	49.14953	86.45913	50.35513	57.82833
47.34301	19.40111	45.72921	14.57641	46.46461

41.57354	8.869139	26.78494	-4.76386	14.32324
63.37581	14.01041	33.00041	-8.14999	25.51841
60.88763	23.05543	26.07953	-18.4398	19.33423
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53.59527	19.48407	25.76187	-13.4854	20.07547
87.10629	44.31969	50.56969	8.602889	41.77279
42.64997	11.46977	37.99957	7.784274	36.97857
24.36177	-3.19903	27.33347	-11.5722	5.296165
45.60614	8.071243	37.11894	-6.71016	18.90394
51.72425	19.81505	43.88755	5.701551	21.62755
41.1918	5.596601	39.7533	-5.3604	20.1083
40.07308	8.393377	35.68338	-5.44092	14.12808
68.69351	36.29801	60.20961	18.18031	39.75941
20.16331	-7.70389	21.69171	-6.41239	23.17991
8.80499	-17.2946	10.75099	-20.4462	1.49489
21.05561	-14.795	21.07891	-22.3238	20.33791
22.33719	-13.0725	21.46679	-17.1411	12.00659
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18.46591	-12.5197	19.22501	-16.4147	7.362213
41.02314	7.696435	44.11054	3.920535	29.22434
15.4119	-14.4538	12.1458	-13.7194	15.222
39.90636	13.54016	47.01236	4.177864	24.49186
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36.01935	1.241953	41.74105	-11.3317	12.49735
12.18639	-16.2595	23.58629	-29.3161	-7.24991
66.74345	38.80005	77.22345	18.32445	45.30495
27.61888	-0.78202	27.99978	-1.80882	27.78248
25.72941	-8.86409	25.75681	-4.18149	7.505806
64.08283	12.16763	57.55583	14.36763	35.65013
25.97413	-21.8365	16.59813	-16.0135	7.159133

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21.46739	-20.6781	17.25539	-14.5553	-0.85921
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43.21609	13.58909	45.09989	10.65309	36.92019
27.9761	-2.729	21.5786	-8.9663	4.640898
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25.8093	-8.7388	7.782697	-25.5638	-7.3362
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34.86295	1.903555	26.94325	-5.78415	5.094255
64.88463	30.67803	50.72593	16.15223	27.74793
24.10155	-4.94685	20.98925	-8.98145	19.45015
41.49201	13.20021	42.27211	13.93691	29.87241
54.29207	15.54997	50.84367	10.46667	37.58427
38.81886	1.915061	31.55756	-4.33894	20.25236
41.84035	7.085054	41.90825	4.529854	29.50935
43.06924	9.336436	41.31974	6.061836	28.44604
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37.28029	9.162692	36.99419	9.435092	35.69049
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25.15876	-8.11524	1.55816	-33.6842	14.51596
6.222358	-27.3269	-9.77174	-49.0149	0.220858
18.75695	-11.2597	-0.89415	-34.5486	10.50465
22.69731	-10.4341	-3.37639	-38.3589	14.56981
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15.75941	-9.63509	14.03971	-12.6203	16.90681
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43.71487	17.93747	44.60587	4.10817	29.91677
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53.52875	11.40115	51.57815	24.53405	36.15745
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74.44943	-22.8006	58.27073	-34.2219	59.91183
106.1495	8.457117	92.50592	-3.68248	96.18662

67.20705	-47.8493	72.32845	-47.4097	71.13595
9.254454	-87.2572	1.613254	-98.2075	1.586854
243.6978	147.6143	248.3108	115.5598	237.5542
334.5956	227.6356	321.1576	215.8031	318.8329
156.6	35.38707	159.0698	29.66687	149.4101
206.0403	100.4743	193.1643	88.1516	190.094
165.6125	66.68481	156.6643	52.83911	155.0491
231.6498	119.6048	232.0905	116.5288	216.6934
-67.5553	-161.681	-68.0381	-166.79	-64.1854
359.621	237.641	355.5343	226.6972	362.9752
384.6815	284.9393	387.495	275.7167	381.7176
202.9	81.70031	199.4303	77.29551	206.5846
323.0503	225.7239	329.6643	224.5906	325.0095
166.9437	70.13325	177.85	72.07855	179.4847
192.7416	79.05233	190.8703	79.62403	208.396
88.33872	-16.2887	75.05202	-29.2469	49.49212
187.4839	48.62632	190.3821	45.57382	178.7095
74.83043	-47.4587	69.55163	-56.5041	43.84753
-86.4667	-217.355	-89.0971	-228.356	-99.0698
-64.445	-175.811	-52.113	-176.072	-68.3667
33.18433	-87.3723	16.51053	-101.738	-7.44157
-89.8285	-203.506	-88.5306	-201.873	-64.6022
366.0738	261.0784	342.3455	248.583	331.6857
-23.3025	-147.994	-18.5237	-140.217	-8.25512
-153.589	-254.056	-147.032	-248.89	-143.844
11.37579	-112.627	2.307889	-119.104	-1.92601
37.84359	-68.791	26.36329	-72.759	20.92929
272.6092	172.1668	267.1814	171.24	255.2312
158.4324	41.71134	172.2871	57.29884	176.0738
77.01579	-11.6295	74.01719	-14.858	77.92369
257.8629	134.109	250.0138	131.8863	262.6258

128.5803	35.17602	125.9348	35.61202	135.4182
151.5409	32.41416	151.5795	34.61556	160.9699
53.60389	-38.0526	53.30169	-34.2808	64.43179
298.2901	206.4248	292.8613	201.9971	298.5645
121.066	11.43849	126.2563	12.50849	126.7529
54.84616	-48.7825	47.14256	-50.0171	49.20306
270.7301	135.2291	267.7159	101.8565	272.2223
168.4455	55.10897	168.985	69.14217	174.5216
205.4527	68.7218	201.8902	60.6612	208.0357
97.18299	-16.6778	94.57609	-4.05751	99.82019
195.5695	85.74727	187.1692	77.09877	193.1623
73.80991	-40.7545	81.94761	-42.477	74.62221
162.4474	62.09917	163.3727	65.47467	153.0367
153.8325	21.29982	142.8984	10.72902	129.0327
43.50955	-59.4778	38.33275	-67.6775	37.87915
166.1933	34.30066	160.2856	31.80506	147.9499
69.95695	-31.2657	70.33855	-21.9114	67.64125
274.8036	175.2958	271.3173	165.0566	262.0253
136.0428	5.846216	137.2077	10.60832	126.1199
54.6998	-56.0875	43.9657	-58.7526	30.9437
193.072	34.88062	169.4109	36.85572	172.3464
130.8943	17.82098	118.1819	7.67888	126.9133
191.6998	41.25515	166.9481	32.49685	165.3443
97.87276	-15.1101	84.04926	-23.5982	87.11446
193.4421	76.00654	170.9548	64.08954	176.2321
91.25665	-40.9126	91.30065	-37.1324	85.16875
3.06907	-101.105	19.87367	-78.2015	15.30467
-157.724	-290.281	-123.718	-254.925	-131.547
-18.5954	-130.324	6.229268	-92.4235	14.19707
-10.2675	-146.02	9.368502	-114.553	2.236602
-0.25989	-107.683	22.93911	-76.2863	32.08091

-115.896	-224.305	-92.501	-191.598	-84.8291
-70.7538	-190.921	-54.8494	-175.282	-53.9314
-48.3005	-145.158	-35.228	-132.986	-42.4477
-39.7749	-164.574	-13.5737	-139.516	3.108853
-63.9852	-155.054	-22.9183	-137.314	-39.3641
-45.9327	-174.233	-29.3102	-155.308	-23.1779
-132.998	-226.796	-107.147	-208.785	-118.477
-121.032	-212.831	-91.7944	-189.742	-95.1294
-4.82646	-124.612	-16.2001	-136.201	-3.81366
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122.2554	-43.9394	123.4068	-8.77677	119.045
267.1734	115.7324	220.8286	119.9429	197.5034
204.6742	64.9101	213.4213	84.6835	204.0107
203.3887	84.23828	189.9488	89.38868	170.2195
243.1097	140.2757	244.4925	144.638	235.3324
91.66306	-38.4714	91.18076	-29.146	83.04926
22.32327	-77.8209	37.76077	-55.5368	24.49957
204.3623	77.30232	148.9405	32.22662	202.6035
208.0852	95.99489	281.262	160.9563	209.0306
135.4864	7.429183	121.8897	-2.34422	140.1255
108.2944	5.385465	152.0457	45.45336	117.0755
16.01932	-90.4533	27.10922	-73.7365	34.62482
117.0711	-1.01776	124.0522	-3.63526	105.1743
192.4065	97.46339	188.461	84.35499	186.2066
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-191.626	-315.248	-178.772	-315.51	-166.727
-11.2008	-106.223	-9.10655	-111.313	-3.59235
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138.615	25.87653	127.0095	18.74343	129.2649

-52.2151	-200.542	-31.636	-185.033	-30.9221
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63.74147	-83.6379	78.93377	-75.5798	74.72677
23.93131	-84.6998	27.10021	-97.7262	26.86761
127.4747	21.38778	140.3175	11.41218	126.9855
159.4901	18.59803	153.5578	12.39123	160.3329
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155.9396	135.3254	155.5627	139.5568	154.9186
73.06952	53.34192	72.37082	53.53092	75.58562
191.5578	174.4831	179.2158	167.4614	188.6118
172.3567	161.6871	162.3955	148.9513	169.7556
312.2293	295.1433	301.7757	287.9881	304.1204
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-272.712	-284.023	-263.087	-273.983	-253.29
205.6577	188.0113	197.5157	174.0528	203.294
92.14201	80.34321	84.25381	69.87051	92.12741
308.0626	291.6002	298.3641	280.3421	298.9049
145.284	126.9236	133.1902	124.0669	135.9134
420.33	403.5395	407.8779	392.3383	411.6528
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108.263	96.0879	114.1261	104.2771	130.5645
35.33035	23.73265	32.93185	14.56955	16.26685
64.96248	54.79458	69.64218	49.71108	56.29938
9.382786	2.312986	0.918686	-11.2622	-7.52811

50.57286	40.13256	50.74386	37.32276	46.40316
11.54739	1.906792	8.176292	-7.78121	0.243692
136.8653	129.178	140.3682	133.3932	136.2153
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-166.571	-189.933	-163.224	-176.606	-168.624
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130.4752	122.9787	137.8161	120.3635	127.1615
64.70762	52.80692	54.07742	44.09762	51.68782
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63.01829	54.42669	63.35459	56.58719	61.93929
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55.22965	36.05735	89.51315	41.11985	50.66105
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134.8318	121.0059	117.8887	110.0193	108.9463
91.88345	72.10765	79.33365	56.50775	69.76235
121.7608	97.17968	106.7278	89.26198	88.78808
13.31387	-3.49113	2.47187	-14.8709	5.72387
42.3248	21.0634	30.6062	14.8975	21.4705
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158.2323	141.9736	167.7283	157.5674	158.6715
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87.77113	80.66793	90.16923	84.79823	95.02793
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23.91063	17.63723	19.00073	11.51093	21.71053
-34.1249	-52.1765	-38.3087	-55.6284	-39.0094
153.772	125.8086	142.7405	123.3682	123.2004
117.2051	83.15019	117.7686	81.18119	95.70559
150.4886	125.858	141.1841	119.4167	128.474
53.02934	20.89054	53.64014	22.88784	50.46404
329.1307	301.183	313.641	288.3305	285.4501
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24.13426	10.56826	22.56876	12.28636	10.59606
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140.6483	130.2709	136.1264	128.4505	131.2545
-307.135	-315.953	-290.218	-298.919	-274.411
-130.931	-154.386	-113.987	-158.403	-107.121
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48.20047	35.70137	48.68257	37.19577	43.96347
-72.8159	-82.1027	-66.5162	-82.1351	-64.9013
88.21785	67.24515	87.65285	69.52585	82.89345
65.50587	49.26487	54.98887	40.78337	51.28727
61.69096	44.48356	51.46436	33.24446	47.70666
46.10631	34.27011	39.00801	26.17951	40.30731
212.9129	196.366	199.5379	184.2852	190.1585
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53.44817	45.01837	62.03177	38.86187	52.50687
98.5791	84.4301	119.0283	94.7942	127.6865
7.705148	-8.48435	12.23415	-8.10665	19.73245
177.2668	163.9324	187.3615	162.8891	186.4195
128.2166	117.2642	136.559	121.3931	138.8199
243.0102	229.9632	256.5749	235.7157	263.2954
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109.3317	95.4957	111.5151	99.9837	103.591
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-63.9316	-87.7892	-59.4868	-77.7052	-67.2496
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-153.169	-182.7	-146.925	-164.567	-160.562
63.71486	54.41426	63.53926	54.25716	59.47666
24.97054	21.76454	34.17424	24.33784	38.32314
142.4824	122.7324	149.5097	124.1032	135.6309
163.2858	151.8359	164.3237	148.4734	167.339
101.4951	90.04612	106.7213	89.37112	99.52982
151.4798	140.9486	157.3795	144.2623	162.9718
241.1958	229.5475	244.4552	225.0085	238.7107

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106.8533	99.46484	104.2457	98.36874	114.6958
49.48662	40.20072	58.18872	41.18172	76.55792
92.32464	78.45494	94.02544	76.08994	104.5751
106.4779	92.39799	104.3822	92.44789	114.3406
130.9167	121.1756	125.5916	112.6359	136.5895
127.2697	115.5605	126.9616	112.0956	140.4843
21.82847	15.17047	24.96207	16.21707	26.88807
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49.84461	26.54461	5.888607	-30.4454	-2.94489
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176.9212	157.0855	133.6947	106.826	126.4889
167.6831	147.9345	124.1	100.7881	107.9579
243.8294	222.9203	194.0931	164.4503	180.8795
3.894247	-5.89375	5.457447	-1.55965	-2.66365
3.791041	-14.382	-0.94166	-11.949	-13.0436
25.76171	-2.81279	34.96401	12.90611	22.89661

35.10628	-11.794	34.63658	12.39258	9.40448
98.99081	81.83251	105.1471	87.83191	85.05911
81.61809	49.79779	80.76529	59.67989	53.04629
161.6162	138.4208	164.1226	143.944	139.2499
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228.6666	209.6102	224.4455	212.692	216.8875
97.8757	69.9859	80.6583	64.9444	81.4542
93.34089	63.16289	87.21159	66.00579	79.71809
177.7981	149.0488	169.0989	152.7349	162.5839
182.6912	154.8556	173.6198	156.2701	169.6957
235.7869	207.6861	224.0994	207.6221	222.3763
97.55095	90.30195	93.38545	82.70255	87.42475
10.08297	-19.336	1.631875	-6.59333	-7.76813
66.57514	36.15544	56.31094	42.08954	45.10414
100.4536	17.32989	74.62399	54.42469	45.52359
164.4607	128.6703	149.4051	136.9294	132.9818
114.7537	39.19131	89.80411	72.94871	70.96481
184.8853	130.5948	163.8055	147.2652	138.0765
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26.6919	14.258	24.7489	7.583299	14.0579
116.166	69.48335	107.207	77.63895	106.3691
156.8295	121.368	133.5997	90.84204	103.5238
116.9247	91.03965	110.0403	90.04165	107.4137
122.8472	97.1004	109.0683	80.6065	89.4311

74.33412	47.93832	61.95352	45.60482	56.56942
54.91591	44.85981	53.00961	42.30961	47.03341
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111.4531	76.85465	94.08635	38.40765	56.06285
101.7446	31.29195	108.8002	78.54735	58.69285
151.7424	128.109	144.5327	116.0051	117.6853
101.4139	60.39343	107.7981	87.26273	74.69223
220.8451	85.9375	218.6764	184.6898	180.1981
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-60.766	-69.8806	-58.2506	-73.0776	-76.4078
34.11127	16.74877	62.28707	36.07027	29.03537
33.55408	24.81148	38.05018	2.227684	-8.88122
-68.491	-84.7987	-39.5857	-61.5459	-51.7827
-15.2886	-28.3883	-2.28776	-23.7954	-24.6812
33.92084	17.62684	67.13464	39.26014	52.68834
-71.1201	-77.6184	-85.4218	-92.6743	-91.1967
43.60872	34.91022	41.65742	23.45562	46.52622
85.36936	74.67426	82.74876	47.65016	80.84596
68.44945	51.66565	65.36945	48.49585	80.45225
-31.4989	-42.0922	-35.3741	-63.3564	-30.3656
7.453243	-9.57126	7.440543	-11.2217	20.00084
51.67074	40.80694	46.83524	20.23174	53.51004
43.11969	37.73129	49.22319	39.09329	51.06889
-114.698	-122.049	-106.153	-120.284	-106.624

-156.648	-216.404	-148.654	-187.965	-148.311
-81.3012	-107.253	-89.9867	-107.069	-85.9611
-252.239	-278.836	-254.253	-265.103	-244.783
-153.852	-168.618	-140.865	-153.751	-137.486
-257.306	-281.658	-255.986	-275.788	-250.187
68.60471	74.14761	75.29071	68.67921	83.53331
-19.8758	-33.1672	-20.3132	-29.7815	9.180998
36.31072	21.63982	38.56272	28.51432	55.93132
-88.1314	-107.686	-71.5439	-83.9514	-49.4905
-38.8254	-52.4544	-30.7825	-40.8596	-5.85975
-8.15763	-22.8944	-3.52773	-14.5115	23.80557
50.4298	35.4672	50.4362	40.7953	68.0302
4.876198	-1.5101	7.515198	1.729398	15.9148
35.02213	-1.49447	28.36293	18.73113	30.28753
67.12684	41.33924	71.76084	23.35384	61.76184
-49.896	-80.7065	-40.943	-73.9184	-29.0649
30.94129	11.64099	32.76759	11.35409	30.17649
52.71543	28.17613	53.78973	35.46223	68.62253
191.9476	166.726	192.348	173.1652	186.3312
-192.797	-199.719	-190.232	-198.985	-185.452
-57.9953	-73.6203	-65.0978	-80.0469	-69.4029
50.33558	14.50458	57.94198	33.48468	71.15948
50.90731	17.30131	47.43131	26.99001	39.53421
-23.8616	-49.3036	-20.6392	-36.7457	-16.8509
-4.88046	-35.8915	-1.47196	-26.2938	-26.1583
-31.9139	-58.0924	-21.4989	-43.845	-13.109
-44.388	-49.7334	-47.942	-56.2868	-52.1996
-4.84804	-13.674	4.383756	-8.07444	6.807256
43.5906	20.7595	112.7688	81.4204	121.6382
56.45727	27.54387	61.50557	30.27977	36.66377
131.9888	111.8266	165.2658	146.3362	169.7224

44.64782	27.81402	62.63102	40.40292	55.00802
258.5727	234.916	297.594	271.3423	296.2803
-90.5302	-97.2348	-96.0506	-103.776	-96.3672
-59.1371	-70.2037	-83.9177	-75.5681	-85.4265
-30.8355	-44.2464	-18.9644	-68.8899	-18.0347
35.00771	18.04381	27.11261	4.922311	29.88891
-36.0726	-49.781	-49.1653	-74.5495	-53.7233
-9.72863	-25.5854	-32.4227	-48.0823	-34.8796
-5.62252	-20.2951	-17.0485	-48.6755	-20.0258
30.30014	22.81044	19.88854	11.15184	9.978839
80.26659	70.45089	93.34049	79.76639	88.80679
-45.924	-61.8234	-49.0094	-64.2567	-6.09219
3.840576	-7.01832	30.89668	0.284076	-1.57842
13.0224	2.397505	23.6178	3.458305	36.0958
-12.3622	-24.8562	13.26597	-8.96213	-8.06263
-77.7881	-91.5835	-72.2327	-81.1775	-43.584
65.22552	55.80402	70.71592	64.13452	74.18092
-92.1142	-103.287	-83.3315	-100.353	-87.7486
-24.2504	-35.0739	-16.9317	-34.6212	-37.7213
-31.8046	-51.5066	-15.4713	-33.1198	1.38949
-120.947	-132.666	-115.017	-129.294	-123.285
-22.8222	-35.7518	-8.50405	-23.5697	-6.11125
-86.1654	-102.278	-89.2723	-104.548	-109.88
-21.8447	-34.805	-8.54788	-19.7003	9.882821
26.3174	14.6631	30.1594	14.5284	29.4811
-41.2553	-71.2247	-44.8657	-110.618	-64.0877
64.57622	32.79492	57.75552	42.72982	46.56242
-14.5205	-30.745	-16.9803	-45.2839	-21.9497
0.159515	-21.3554	3.310315	-12.6612	-12.8994
60.17441	47.38221	51.50181	19.10731	42.51261
26.94032	20.17382	41.58742	31.60962	51.50742

-71.2412	-77.015	-69.9247	-81.0597	-53.9938
-0.74769	-13.4735	-7.72399	-29.1997	4.351005
-103.284	-116.395	-105.313	-128.444	-98.6116
-60.5811	-70.8618	-60.4953	-77.4971	-55.8876
26.5159	14.6379	27.8047	10.959	29.6329
5.110459	-6.75144	-0.32074	-21.1564	2.127759
-92.3596	-100.091	-93.2862	-99.5171	-88.4016
-7.27219	-19.2405	-8.20189	-19.0186	-4.31639
-48.0875	-68.5207	-43.0796	-77.2613	-39.2525
4.88071	-14.1152	-7.64809	-25.5958	4.02351
-23.3108	-40.5648	-27.6189	-41.1671	-19.761
21.74875	6.54715	13.56925	-4.29085	20.71975
-104.285	-123.938	-108.811	-126.952	-98.4831
-13.5581	-22.6032	-14.9688	-22.7485	-15.2585

5.5 MATLAB Functions

Function	**Syntax**
STFT	S = Spectrogram(x)
PSD	[Pxx,x]=Periodogram(x,Window,x)
ERP	mean(x)
NEURAL NETWORK	nnstart
FEEDFORWARD TOOL	feeddorwardnet
Multiple HIDDEN LAYER NEURON	nntool

Figure 5.2: MATLAB Tool Functions [46][47]

5.6 Classification:

After extracting the desired features, classifier was trained. Several methods for classification have been proposed. Some of the most well-known algorithms such as Naïve Bayes, Feedforward Artificial Neural Network, and Multilayer 2- Hidden Layer Neural Network classifier have been used.

5.6.1 Naïve Bayes

The Naïve Bayes algorithm is based on conditional probabilities. It uses Bayes' theorem, a formula that calculates a probability by counting the frequency of values and combinations of values in the historical data. It finds the probability of an event occurring given the probability of another event that has already occurred [27].

5.6.1.1 Algorithm of Naïve Bayes

In general english equation is

Posterior = (prior * likelihood)/evidence

For events r and s, bayes rule is:

$$p(r,s) = p(r \cap s) = p(r|s)p(s) = p(s|r)p(r)$$

$$p(\bar{r}|s)p(s) = p(s|\bar{r})p(\bar{r})$$

$$p(r|s) = \frac{p(s|r)p(r)}{p(s)} = \frac{p(s|r)\,p(r)}{\Sigma_{i=r,\bar{r}}\, p(s|x)p(x)}$$

5.6.2 Artificial Neural Network

A neural network consists of an interconnected group of artificial neurons, and it processes information using a connectionist approach to computation. In most cases a neural network is an adaptive system changing its structure during a learning phase. Neural networks are used for modeling complex relationships between inputs and outputs or to find patterns in data. An artificial neural network is a computational simulation of a biological neural network. These models mimic the real life behavior of neurons and the electrical messages they produce between inpu, processing by the brain and the final output from the brain [48].

Inputs→ NN→ Outputs

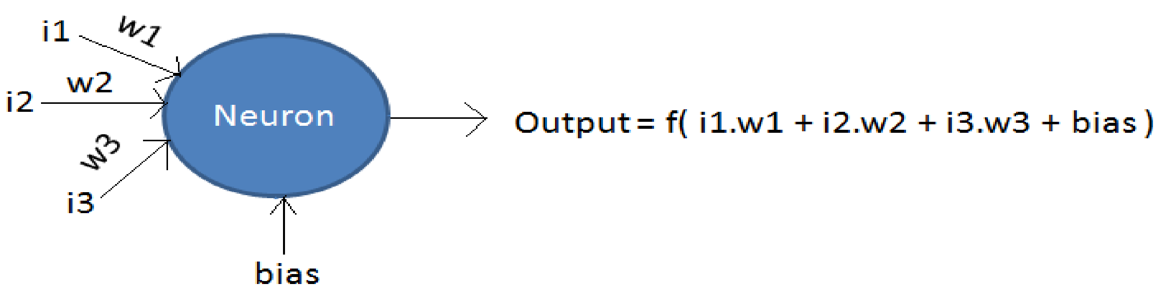

Figure 5.3: Structure of Neural Network

This network has an input layer (on the left) with three neurons, one hidden layer (in the middle) with three neurons and an output layer (on the right) with three neurons. There is one neuron in the input layer for each predictor variable. In the case of categorical variables, N-1 neurons are used to represent the N categories of the variable [8] to load the data with the help of MATLAB Tool (nnstart).

Validation and test data sets are each set to 15% of the original data. With these settings, the input vectors and target vectors will be randomly divided into three sets as follows-

- 70% are used for training.
- 15% are used to validate that the network is generalizing and to stop training before over-fitting.
- The last 15% are used as a completely independent test of network generalization.

5.6.3 Feedforward:

The classifier was also implemented using feedforwardnet inbuilt function in Matlab R2011a version. Feedforward neural network is a biological inspired classification algorithm. It is the first and simplest type of artificial neural network (ANN). In this network, information moves in only one direction, forward, from the input node through the hidden node and to the output nodes. Since data flows only on forward direction with no feedback they are called feedforward neural network[49].

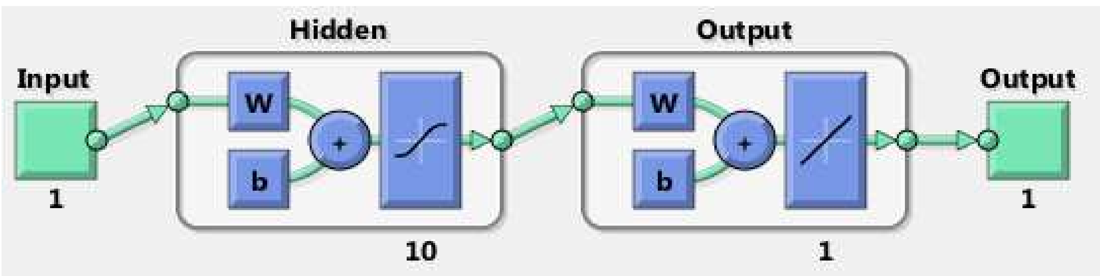

Figure 5.4: Feedforward Neural Network

5.6.4 Multilayer Neural Network:

Multilayer neural network is a feedforward neural network trained with the standard back-propagation algorithm. Generally only one hidden layer neural network is used for classification but we used 2-hidden layer neural network. So we started with 5 neurons in first hidden layer and 7 neurons in second hidden layer for classification. In our thesis to determine the accuracy in emotional EEG data built in MATLAB Tool nntool of MATLAB version R2011 was taken under consideration [50].

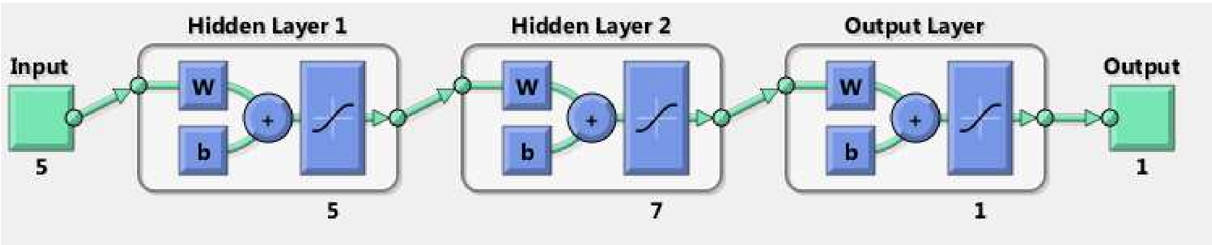

Figure 5.5: Multilayer 2- Hidden Layer Neural Network

CHAPTER 6: RESULTS

For classification through Naïve Bayes, first ERP extracted features were used as attributes for classification. We took the entire data of 3 participants P3, P4, and P5, together and on classification, obtained the accuracy of **56%.** Then classified entire data of STFT of all the 3 participants and obtained the accuracy of **51%.** After this PSD data was used in the same manner and got the accuracy of **56%.** Finally, combined the entire data of STFT and PSD of all 3 participants and then obtained better accuracy of about **64%.**

Features	Accuracy
ERP	56%
STFT	51%
PSD	56%
STFT + PSD	64%

Table 6.1 Accuracy obtained using Naïve Bayes Classifier.

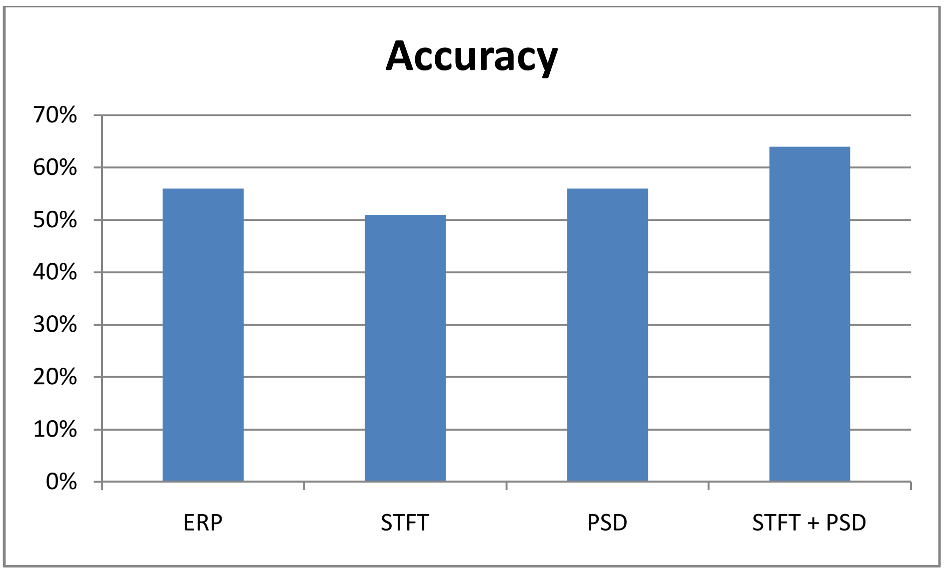

Figure 6.1 Graph Depicting Accuracy for Selected Features.

Since the accuracy obtained using the Naïve Bayes classifier was pretty low, it was decided to use ANN based classifier. For this, again fed entire data of all 3 participants of ERP to ANN classifier (nnstart) and obtained the accuracy of **57%** which is similar to the one obtained using Naïve Bayes classifier. To improve the accuracy of ERP features different combinations of data were prepared and fed as an input to the GUI, obtained using nnstart function.

In first combination, the ERP attributes extracted from a particular participant per session for the selected electrode were used as input.

Table 6.2: Classification Rate for ANN Classifier is shown in the following table.

PARTICIPANT SESSION ELECTRODE	TRAINING	VALIDATION	TEST	ALL
P3S1Cz	85.70%	100%	100%	88.90%
P3S1F1	78.60%	100%	100%	85%
P3S1F2	57.10%	66.70%	100%	65%
P3S1FC1	64.30%	100%	66.70%	70%
P3S1FC2	64.30%	100%	100%	75%
P3S1Fz	100%	100%	33.30%	90%
P3S1Pz	50%	100%	66.70%	60%
P3S2Cz	63.30%	100%	66.70%	70%
P3S2F1	71.40%	66.70%	66.70%	70%
P3S2F2	92.90%	100%	100%	95%
P3S2FC1	85.70%	66.70%	100%	85%
P3S2FC2	57.10%	66.70%	66.70%	60%
P3S2Fz	35.70%	100%	66.70%	50%
P3S2Pz	85.70%	100%	66.70%	85%
P3S3Cz	85.70%	100%	66.70%	85%
P3S3F1	42.90%	66.70%	66.70%	50%
P3S3F2	71.40%	100%	66.70%	75%

P3S3FC1	50%	100%	66.70%	60%
P3S3FC2	35.70%	100%	100%	55%
P3S3Fz	71.40%	66.70%	100%	75%
P3S3Pz	78.60%	66.70%	100%	80%
P4S1Cz	78.60%	100%	66.70%	80%
P4S1F1	85.70%	100%	66.70%	85%
P4S1F2	71.40%	100%	100%	80%
P4S1FC1	64.30%	100%	66.70%	70%
P4S1FC2	78.60%	100%	66.70%	80%
P4S1Fz	50%	100%	66.70%	60%
P4S1Pz	78.60%	100%	66.70%	80%
P4S2Cz	71.40%	100%	66.70%	75%
P4S2F1	78.60%	100%	66.70%	80%
P4S2F2	78.60%	100%	66.70%	80%
P4S2FC1	71.40%	100%	66.70%	75%
P4S2FC2	85.70%	100%	66.70%	85%
P4S2Fz	64.30%	66.70%	66.70%	65%
P4S2Pz	64.30%	66.70%	66.70%	65%
P4S3Cz	35.70%	66.70%	100%	50%
P4S3F1	64.30%	66.70%	66.70%	65%
P4S3F2	35.70%	100%	66.70%	50%
P4S3FC1	57.10%	66.70%	66.70%	60%
P4S3FC2	35.70%	66.70%	100%	50%
P4S3Fz	28.60%	100%	100%	50%
P4S3Pz	42.90%	66.70%	100%	55%
P5S1Cz	57.10%	100%	33.30%	60%
P5S1F1	50%	66.70%	100%	60%
P5S1F2	64.30%	66.70%	66.70%	65%
P5S1FC1	57.10%	100%	100%	70%

P5S1FC2	78.60%	100%	33.30%	75%
P5S1Fz	28.60%	100%	100%	50%
P5S1Pz	35.70%	100%	66.70%	50%
P5S2Cz	35.70%	66.70%	100%	50%
P5S2F1	64.30%	100%	66.70%	70%
P5S2F2	71.40%	100%	66.70%	75%
P5S2FC1	35.70%	100%	100%	55%
P5S2FC2	57.10%	66.70%	66.70%	60%
P5S2Fz	57.10%	100%	66.70%	65%
P5S2Pz	71.40%	66.70%	66.70%	70%
P5S3Cz	85.70%	100%	100%	90%
P5S3F1	35.70%	66.70%	100%	50%
P5S3F2	57.10%	100%	66.70%	65%
P5S3FC1	50%	100%	66.70%	60%
P5S3FC2	78.60%	66.70%	66.70%	75%
P5S3Fz	64.30%	100%	100%	75%
P5S3Pz	78.60%	100%	66.70%	80%

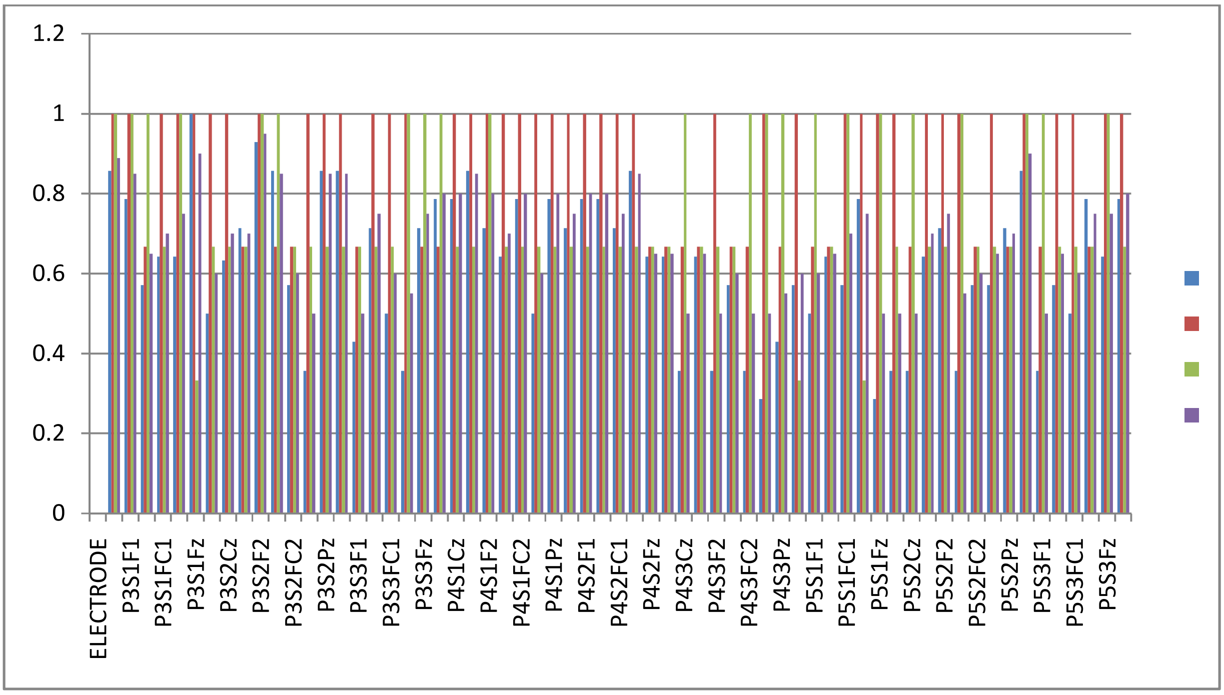

Figure 6.2 Accuracy Graph of Classification Rate for ANN Classifier

Table 6.3: The Averaged Accuracy Results over the Electrodes are shown in the following table.

Participant/ Electrode	P3			P4			P5			Average of each electrode
	S1	S2	S3	S1	S2	S3	S1	S2	S3	
Cz	77.8			77.8			77.76			77.78
F1	77.8			77.8			88.9			77.8
F2	88.9			88.9			66.7			77.8
FC1	77.8			77.8			88.9			77.8
FC2	88.9			88.9			55.53			74.08
Fz	66.6			66.6			88.9			77.78
Pz	77.8			77.8			66.7			74.1
AVERAGE of each participant	79.37			74.68			76.19			

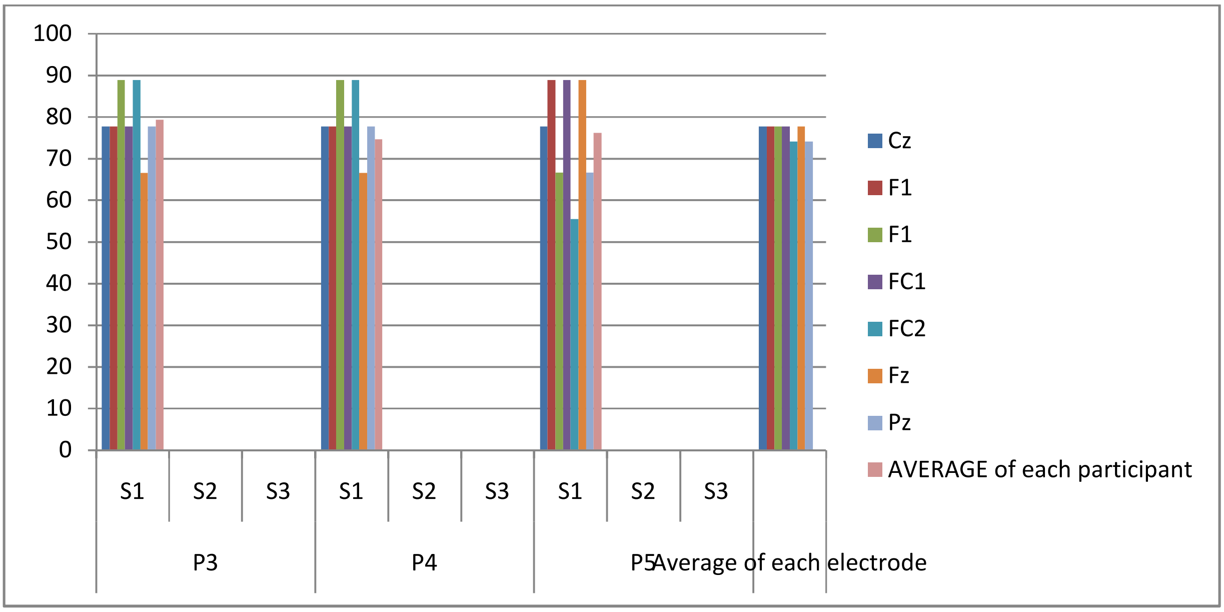

Figure 6.3 Graph of Averaged Accuracy Result over the Electrodes

Now in second combination, took data of each participant with one electrode and repeated the same method for all electrodes. On classifying obtained the following results.

Table 6.4: Accuracy for Each Participant for Each Electrode

Participant and Electrode	Training	Validation	Test	Overall
P3cz	66.7%	66.7%	55.6%	65%
P3f1	66.7%	66.7%	66.7%	66.7%
P3f2	54.8%	100%	44.4%	60%
P3fc1	47.6%	77.8%	66.7%	55.0%
P3fc2	54.8%	66.7%	66.7%	58.3%
P3fz	54.8%	77.8%	55.6%	58.3%
P3pz	54.8%	66.7%	55.6%	56.7%
P4cz	61.9%	66.7%	55.6%	61.7%
P4f1	57.1%	55.6%	77.8%	60%
P4f2	54.8%	55.6%	55.6%	55%
P4fc1	50%	77.8%	55.6%	55%

P4fc2	54.8%	55.6%	55.6%	55%
P4fz	40.5%	55.6%	88.9%	50%
P4pz	54.8%	55.6%	55.6%	55%
P5cz	54.8%	77.8%	66.7%	60%
P5f1	50%	55.6%	55.6%	51.7%
P5f2	42.9%	66.7%	77.8%	51.7%
P5fc1	66.7%	66.7%	44.4%	63.3%
P5fc2	42.9%	55.6%	77.8%	50%
P5fz	50%	66.7%	66.7%	55%
P5pz	64.3%	66.7%	44.4%	61.7%

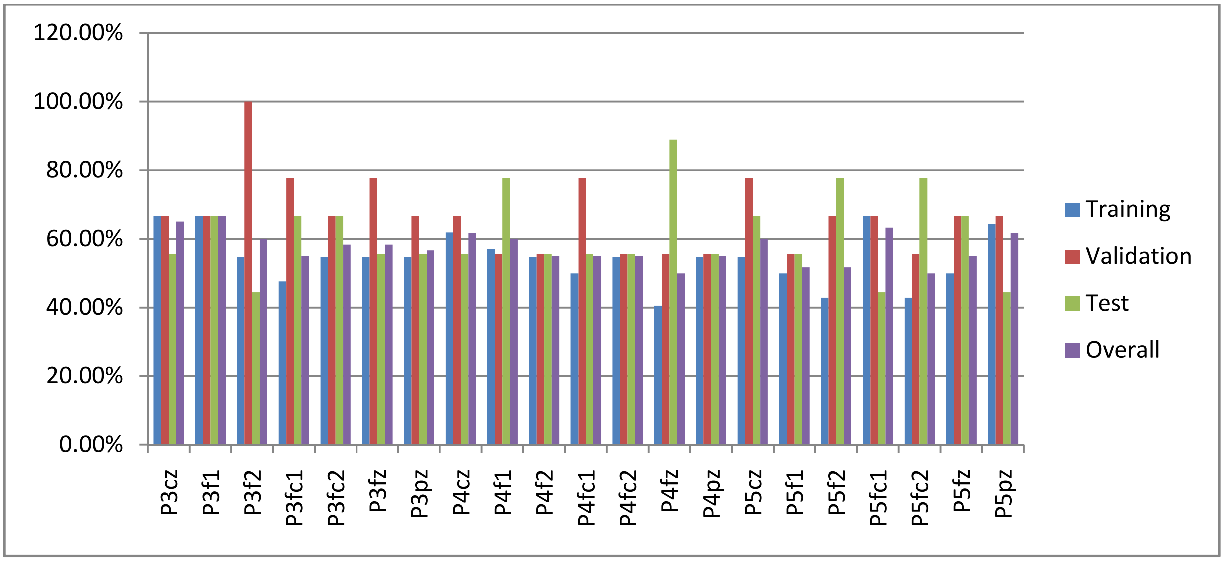

Figure 6.4 Graph of accuracy of Accuracy for Each Participant for Each Electrode

Table 6.5: Averaged Accuracy of Each Participant with One Electrode

Electrode/ Participant	Cz	F1	F2	FC1	FC2	Fz	Pz
P3	55.6	66.7	44.4	66.7	66.7	55.6	55.6
P4	55.6	77.8	55.6	55.6	55.6	88.9	55.6

P5	66.7	55.6	77.8	44.4	77.8	66.7	44.4
AVERAGE	59.3	66.7	59.26	55.56	66.7	70.4	51.86

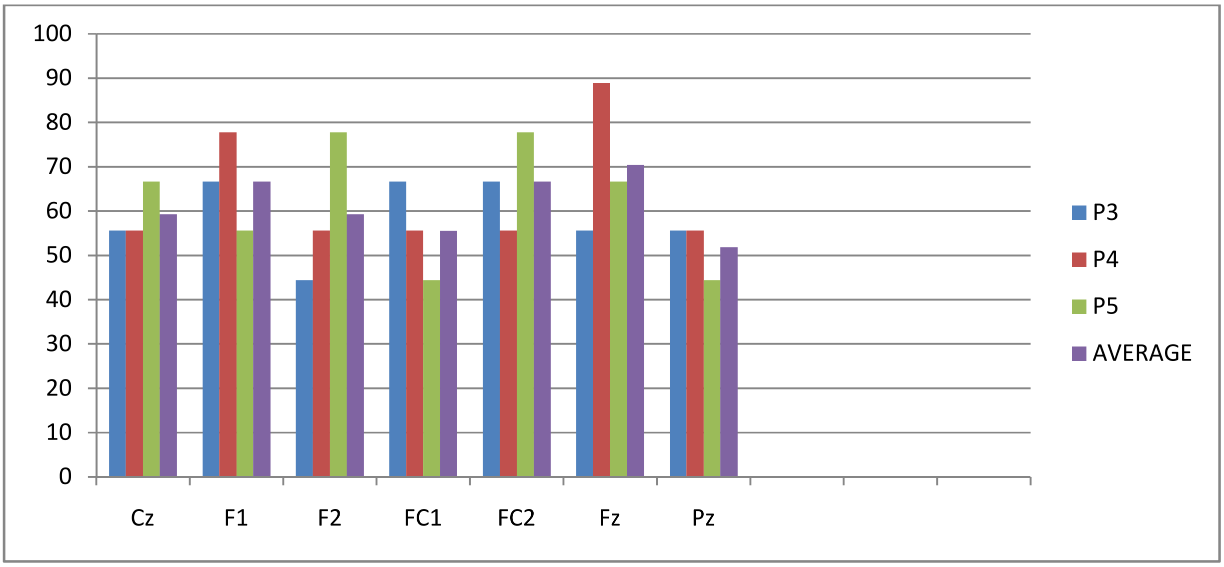

Figure 6.5 Graph of average Averaged Accuracy of Each Participant with One Electrode

Then in third combination, consider one electrode with all 3 participants and repeat same thing for other electrodes. From this got following results.

Table 6.6: Accuracy of all Participants with Each Electrode

ELECTRODE	TRAINING	VALIDATION	TEST	OVERALL
Cz	51.60%	59.30%	51.90%	52.80%
F1	47.60%	70.40%	63%	53.30%
F2	51.60%	51.90%	48.10%	51.10%
FC1	50.80%	55.60%	59.30%	52.80%
FC2	57.10%	51.90%	55.60%	56.10%

Fz	50.80%	59.30%	51.90%	52.20%
Pz	48.40%	55.60%	51.90%	50%

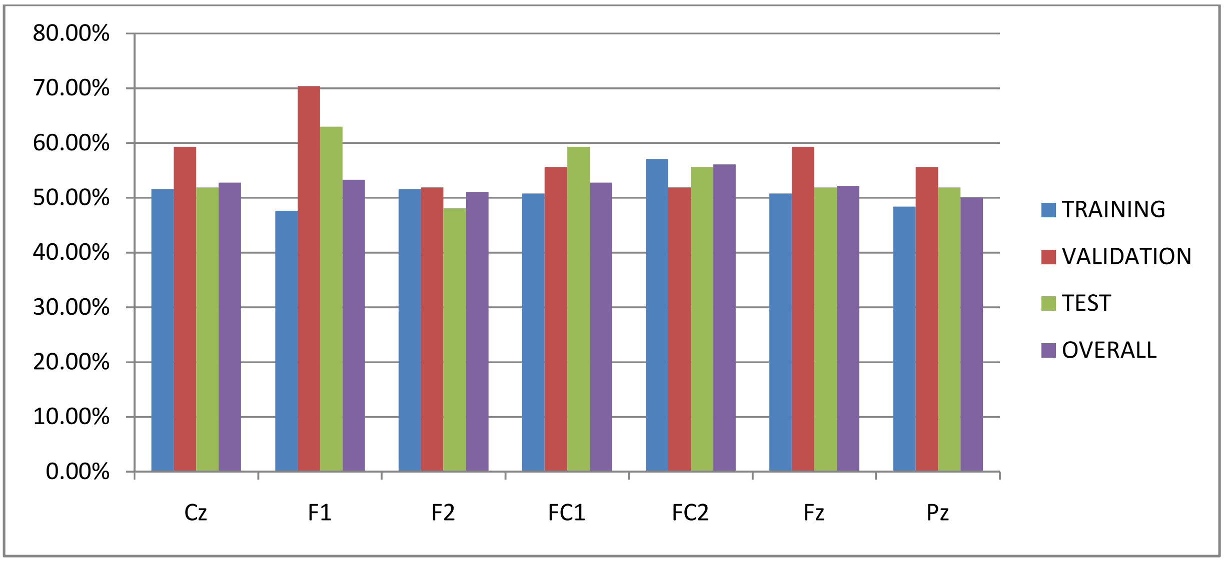

Figure 6.6 Graph of Accuracy of all Participants with Each Electrode

In final combination, took single ERP feature (P100, N100, P200, N200, P300) of all 3 participants with all 7 electrodes of all 3 sessions and then on classification and obtain below table.

Table 6.7 Accuracy of One ERP Feature for all Participants

FEATURES	TRAINING	VALIDATION	TEST	OVERALL
P100	50.20%	56.10%	50.80%	51.20%
N100	51.50%	55%	50.80%	51.90%
P200	50.50%	51.90%	55.60%	51.40%
N200	48%	57.70%	54%	50.30%

P300	51%	57.10%	51.30%	52%

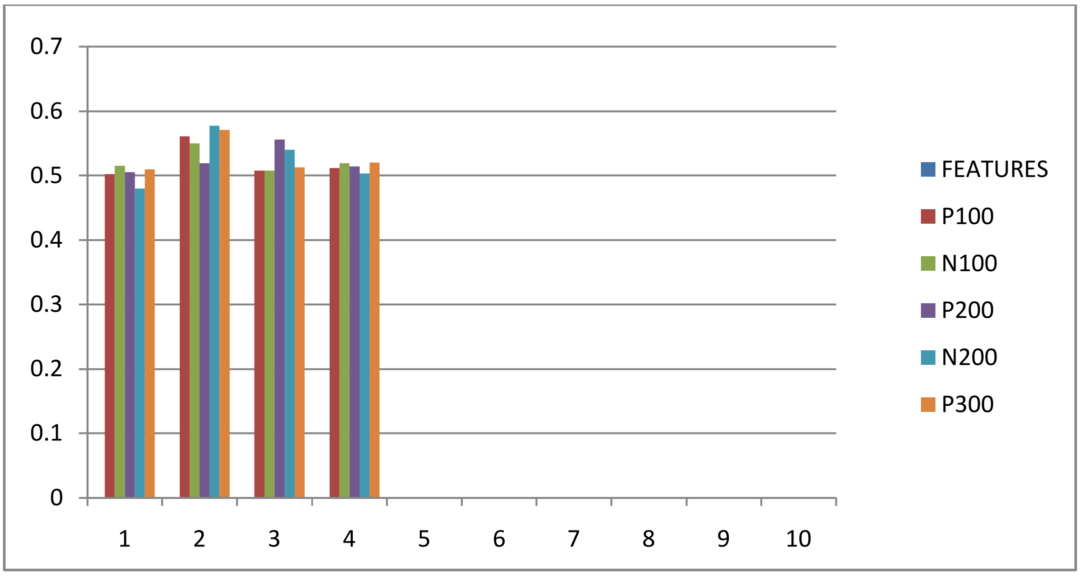

Figure 6.7 Accuracy Graph of One ERP Feature for all Participants

After ANN, feedforward neural network was trained. For this, feedforwardnet matlab tool was used for classification. In this 2 combinations were made to classify the features.

In first combination, fed entire data of each participant at a time to feedforwardnet tool and in second combination entire data of all 3 participants were considered. On classifying obtained following result.

Table 6.8: Accuracy of Feedforward ANN Classifier

Participant	**Error**	**Accuracy**
Participant-3	29.78%	70.21%
Participant-4	34.04%	65.95%
Participant-5	27.66%	72.34%

Participant 3,4 & 5	23.40%	76.59%

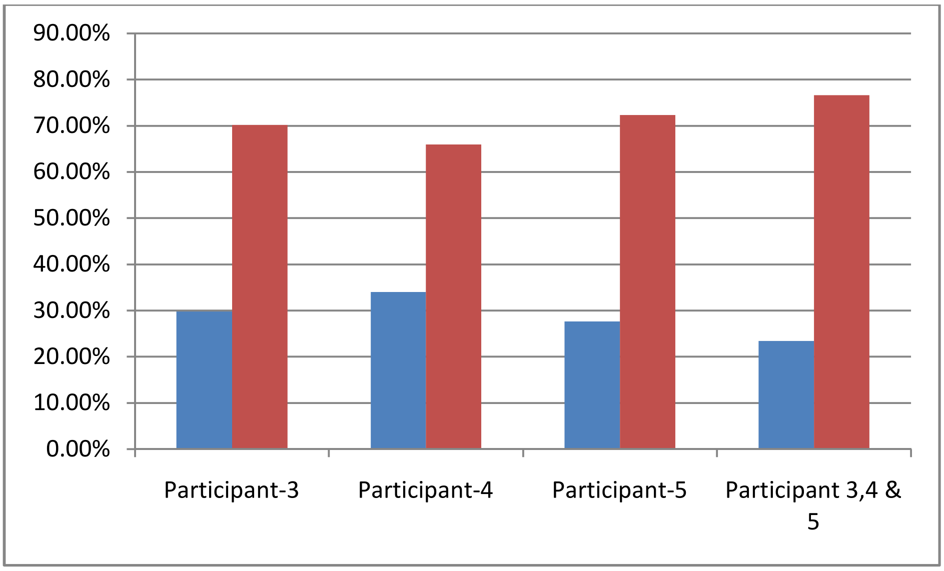

Figure 6.8 Accuracy Graph of Feedforward ANN Classifier

After feedforward neural network, multilayer 2-hidden neural network classifier was tried. For this classification nntool matlab tool was used. With the help of this, the data was analyzed in two combinations. First fed the data on single participant and then fed the combined data of all three participants together. Taking ERP features of EEG signals to classify the emotions in two classes Low Valence (negative) and High Valence (positive). The results obtained for these two combinations came out to be **100%**.

Table 6.9: Accuracy of Multilayer 2-Hidden Layer Neural Network

Features	Accuracy
ERP of Participant 3	100%
ERP of Participant 4	100%

ERP of Participant 5	100%
ERP of Participants 3,4, and 5	100%

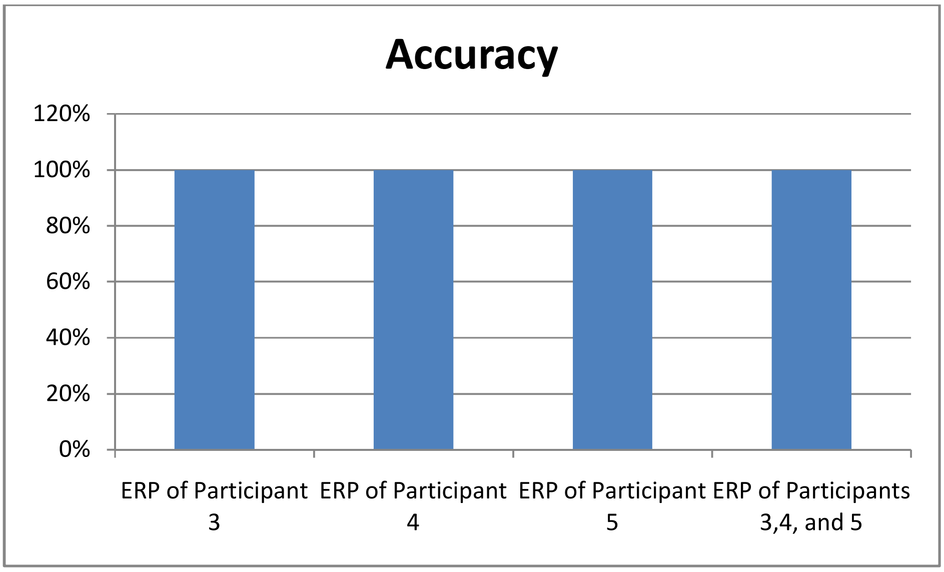

Figure 6.9 Accuracy Graph of Multilayer 2-Hidden Layer Neural Network

CHAPTER 7: CONCLUSION AND FUTURE SCOPE

7.1 Conclusion

In this study, classification of emotions using EEG signals was examined. The results obtained using the Naive Bayes classifier and single layer ANN for the different attributes were very low as compared to the two hidden layer classifier. The classification results obtained from the central electrodes were high as compared to the side electrodes. It can also be concluded that the classification results depend very much on the type of selected attributes, their combinations and the type of classifier used. The individual analyses of participants show that the emotions are a subjective affair. Since the results obtained for classification of emotion along valence axis using Multilayer Neural Network (2 hidden layers) are 100%, it can be considered as a step forward in the direction of brain computer implementation.

7.2 Future Work

For validation of very high results it is required to consider data gathered from more number of participants, further quantification of emotion into more number of classes can be considered as very high accuracy rates have been achieved.

There are several avenues for future research:

1. The analysis has been done on the offline data. This method can be extended for online application of realistic EEG waves.
2. The data reduction techniques and the pre- processing techniques if employed can too improve the classification results.
3. The Multi layer neural network (MLNN) classification needs to be validated and then can be recommended for innumerable civil and military applications.
4. The better statistical classifiers should be evaluated and their performances should be compared.

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