Valence Detection Using EEG Signals

A Dissertation

Submitted in partial fulfilment of the requirements for the award of degree of

Master of Engineering

in

Electronic Instrumentation and Control

Submitted By

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July 2014

DECLARATION

I hereby certify that the work being presented is the thesis work entitled **"Valence Detection Using EEG Signals"** in fulfilment 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. Mooninder Singh, Assistant Professor, Electrical and Instrumentation Engineering Department, Thapar University, Patiala, Punjab.

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ACKNOWLEDGEMENT

I would like to express my sincere thanks to many people who have contributed to the fulfillment of my dissertation. First of all, I am especially thankful to my dissertation guide, **Mr. Mooninder Singh**, Assistant Professor and extremely grateful to **Dr. Mandeep Singh,** Associate Professor, Department of Electrical and Instrumentation Engineering, Thapar University, Patiala for their valuable guidance, scholarly inputs and consistent encouragement I received throughout the dissertation work. It was good experience to work under them.

I am thankful to **Dr. Ravinder Aggarwal**, Head of Department, Electrical and Instrumentation Engineering, Thapar University Patiala for his encouragement and support. I am thankful to all the faculty members and staff members of the Department of Electrical And Instrumentation Engineering, Thapar University for their support during my academic years.

I want to thank God for always being with me. I would like to thank my parents and family for their unwavering support, without them I certainly would not have been where I am today, it would not have been possible for me to quest for postgraduate studies and objective for grater affairs in my vacation. I am proud to dedicate this thesis and all the good things in my life to them. Without them I could do nothing. I owe my dissertation to them.

This vote of thanks will be incomplete if I fail to thank Sakshi, Ruchita, Ekta, Abhishek, Piyush, and last but not the least Renu and my family members who stood beside me, understood my academic goals and helped me to achieve it. My heartiest thanks to all the persons who made me what I am today words fails to express my feelings for them.

Thapar University, Patiala　　　　Ankita Sandel

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ORGANIZATION OF THESIS

The thesis inaugurates by introducing emotions, BCI (Brain Computer Interface) module, depiction of EEG signals 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. Description of data acquisition **Chapter 3.Chapter 4** defines the feature extraction part. **Chapter 5** delves into the results tabular form, bar graph form. Finally

Chapter 6 concludes the thesis and outline directions for future work.

ABSTRACT

Emotions exert an incredibly powerful force on human behaviour. Strong emotions can cause one to take actions which one might not normally perform or avoid situations that one generally enjoys. Emotion can be seen in person's face in voice or in gesture such as reaction to stimuli. By emotions human can communicate, express his view, and share his feelings. Most of the people feel surprise, fear, happiness, sadness, disgust and anger many times, these are called basic emotions. Emotions though a psychological phenomenon, can be easily quantified in a three dimensional plane along valence, arousal and dominance axis.EEG signals play a significant role in knowing feelings or emotions of a person. The EEG signals can be acquired using various EEG acquiring devices with electrodes placed using different standards. This work describes the technique used for acquiring EEG signals from 3 participants with electrodes placed as per 10-20 system by using the images provided by International Affective Picture System (IAPS). The sampling frequency is chosen to be 500 Hz. About 80 images with suitable mean Valence and mean arousal values have been used. Some of the images are repeated to elicit the desired emotion in a subject. Various techniques to process upon the raw EEG signals for extracting the features for emotion recognition has as well been explained in this work. It also presents a review on the data acquisition techniques used for acquiring EEG signals for emotion recognition. In an endeavour to classify emotions into two classes namely Low Valence High Arousal (Negative Valence) and High Valence High Arousal (Positive Valence). Event Related Potential features are determined from the processed EEG signals.

The event related potential features selected for emotion classification are P100, N100, P200, N200, P300 and N300 collected from three electrodes namely Cz, f3 and p4. The Support Vector Machine classifier has been used to classify the emotions into two classes along the valence axis. An accuracy of 95% is achieved on p4 electrode, 93.75% accuracy on f3 electrode and 92.5% accuracy is achieved on Cz electrode when a polynomial Order of 14 is used for the classifier.

In Order to reduce the dataset obtained for classification, average Event Related Potential (ERP) features are also taken into account. The average ERP features in this case are

collected from 3 subjects but at five electrodes namely Cz, fp1, fp2, p3 and p4. Not only we could reduce the data set but also classified the emotions into two classes by using the SVM classifier with a low polynomial Order and that with improved accuracy. An accuracy of 100% has been achieved for both Cz electrode and a combination of p3-p4electrodes while 91.67% accuracy has been achieved on combination of fp1-fp2 using 5^{th} Order SVM. Using averaged ERP, the accuracy of emotion classification along valence axis improves and Order of SVM decrease as compared to unaveraged ERP.

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LIST OF ABBREVIATIONS

EEG Electroencephalogram

ERP Event Related Potential

fNIRS functional Near – Infrared Spectroscopy

IAPS International Affective Picture System

KNN K-Nearest Neighbour

MD Mahalanobis Distance

PET Positron Emission Tomography

SAM Self - Assessment Manikin

SVM Support Vector Machine

CHAPTER 1
EMOTIONS

1.1 Introduction

In psychology, emotion is often defined as a complex state of feeling that results in physical and psychological changes that influences thought and behaviour. Why do we have emotions? What causes us to have these feelings? Researchers, philosophers and psychologists have proposed a number of different theories to explain the how and why behind the human emotions. Emotion is a high level cognitive process and physiological state related to a complex of feelings, thoughts, and behaviour. It probably contains a better input from the brain in which limbic system charges the main task for generating emotional experience [1]. Emotionality is associated with a range of psychological phenomena including temperament, personality, mood and motivation [2]. Emotion is an important aspect in the interaction and communication between people. Even though emotions are intuitively known to everybody, it is hard to define emotion. In spite of the difficulty of precisely defining it, emotion is omnipresent and an important factor in human life. The mood of a human heavily influences his way of communicating, acting and productivity. Imagine two car drivers, one being happy and the other being very mad. They will be driving totally different [3]. Emotion also plays a crucial role in all day communication. Facial expression recognition and speech signal analysis is also used for assessing emotions [4] [5]. One can say a word like 'OK" in a happy way, but also with disappointment or sarcasm [3]. Ekman used the idea that all emotions can be composed of some basic emotions like white colour composed of primary colours. He found six basic emotions [6]. It is physiological process which is being triggered by a perception of a situation, and objects and is associated with the personality, mood or disposition [7]. Parrot et al. proposed tree structure of emotions [8]. Jack et al. (2014) analyzed the 42 muscles of the face which helps in shaping emotions on the face [9].

EEG is used to quantify emotions in the human. Some basic emotions are sad, happy, anger, surprised which can be seen in daily life.Fig.1.1 shows the basic emotions which are experienced in daily life such as happy, sad, angry, excited, frustrated, calm, astonished, shocked, funny and naughty.

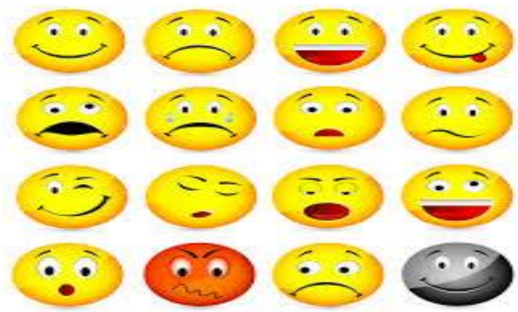

Fig.1.1 Square of Basic Emotions [10]

1.2 Basic Emotions

Ekman et al. found six different expressions related to face such as angry, sad, disgust, happy, surprise and fearful by showing a set of stimulus to subjects [6]. Plutchik's also related emotions such as fear, disgust, sadness, joy, acceptance surprise and curiosity [11].

1.3 Quantification of emotions

Russell, J.A. (1980) proposed that the feelings like fear, angry, joy, happiness, depressed, displeasure are not independent but are interconnected. The emotional states were represented on the circumference of a circle in a two dimensional space namely Valence and Arousal. In this approach arousal was given number one on the circle and emotion describing words or phrases were placed that the similar meaning words were closer while the opposites lied diagonally. Russell took valence along the X-axis. Though in Peter Lang's model valence replaced valence along Y-axis [12] [13].The circumplex model of affect proposed in his study is shown below in Fig.1.2

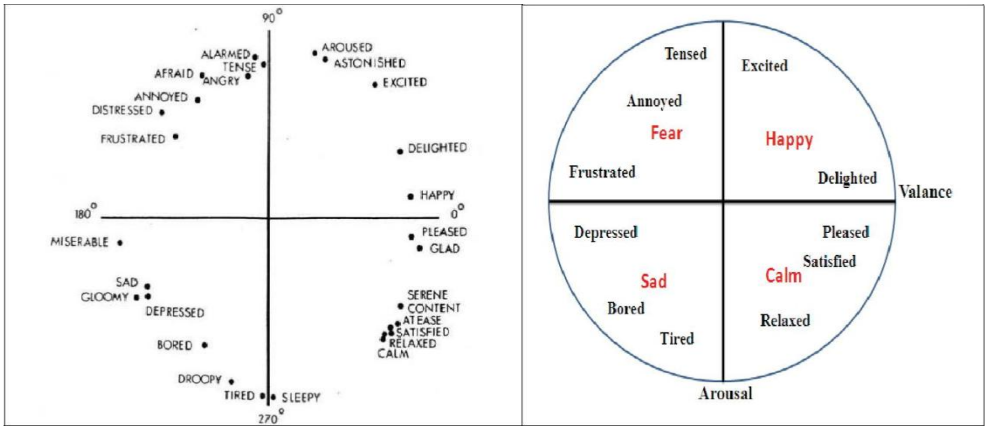

Fig.1.2 Circumplex Model

1.3.1 Emotions in two dimensional plane

1. Valence
2. Arousal

Valence and arousal can be defined by using Self-Assessment Manikin Method. SAM ratings lies from 1 to 9.Valence can be represented as positive or negative state of emotions. The highest value of valence means a person is positively happy and has positive state of emotions and lowest value of valence means a person is negatively sad and has negative state of emotion. Similarly, arousal is also defined on SAM scale from 1 to 9.The highest value of arousal means a person is positively aroused and has positive state of emotions and lowest value of arousal means a person is negatively aroused and has negative state of emotion.

1. Valence: It is specially used in discussing emotions. This term is used to describe specific emotion. Valence axis is divided along X axis in two categories that is pleasant and unpleasant. Pleasant is along positive X axis while unpleasant is along negative X-axis. For example, if the emotion is anger or fear means negative, it means negative valence. If the emotion is happy or joy then it is called positive valence. These negative or positive valence emotions are evoked with negative or positive events, objects or situations. Ambivalence creates a difference between positive and negative valence. Ambivalence means a situation in which both positive and negative valence exists and can't judge what the situation depicts.

2. Arousal: It is an energized state of mind in which a brain motivates a person to take actions or a physiological state of mind in which the body prepares for the action. The arousal is divided along Y-axis and is divided into two categories excited and unexcited. For example, if the person get excited by showing some event or image it shows that a person is positively or highly aroused and if for the same image or event the person feels calm or is in unexcited state than it shows negatively or low aroused.

1.3.2 Classes of Emotions

There are four classes in which emotions can be quantified along Valence (V) and Arousal (A) axis. Valence axis is divided into two classes namely Low Valence (LV) and High Valence (HV) keeping the arousal state constant. Now these two emotional states can be divided into four classes namely High Valence High Arousal (HVHA), High Valence Low Arousal (HVLA), Low Valence Low Arousal (LVLA) and Low Valence High Arousal (LVHA) states depending upon the arousal and valence state of emotions. The four quadrants thus obtained with valence and arousal placed along x and y axis are shown in Fig.1.3.

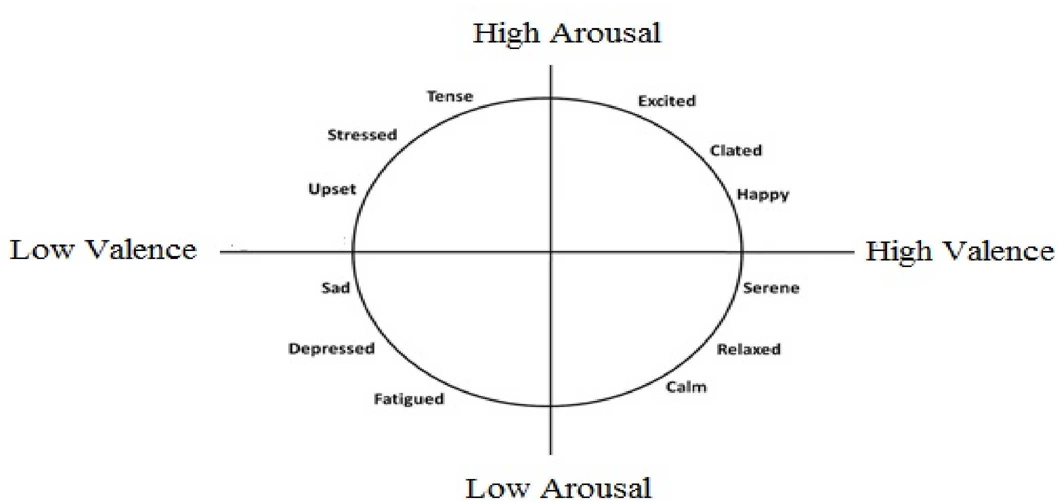

Fig.1.3 Arousal and Valence Axis

1.4 Human Brain

Brain is the main part of the body which controls all the activities of the brain. It is the central control of the nervous system and is highly complex. The largest part of the brain is the cerebrum which contains the cerebral cortex.

It is the most complex and magnificent organ in the human body. Brain gives us awareness of ourselves and of our atmosphere. It controls secretions of our glands, muscle movements, and even breathing and internal temperature. The cerebral cortex is the outmost layered structure of neural tissue of the brain [14].

1.4.1 Brain Lobe:

The cerebral cortex is nearly equal with left and right hemisphere that is estimated mirror images of each other. Each hemisphere is divided into four lobes. It has four lobes.

1. Frontal Lobe

2. Parietal lobe

3. Occipital Lobe

4. Temporal Lobe

1. Frontal Lobe: The frontal lobe of the brain is the most anterior, which means they are positioned right behind the forehead and at the top front of the head. Frontal lobe is separated by a space among tissues called central sulcus by parietal lobe. It contains sensitive neurons which is present on the cerebral cortex. It is the major lobe of all the lobes. Cerebral hemisphere is the part in front of which frontal lobe is located.

Frontal lobe is used to make decisions such as what to eat or drink in the meal, as well as for thinking or studying for a test. It is necessary to be able to speak fluently without fault and meaningfully [15].

2. Parietal lobe: The parietal lobe is located overhead of the occipital lobe and behind the central sulcus and frontal lobe and the central sulcus. Separation between parietal lobe from the frontal lobes is done by central sulcus and temporal lobe is separated by lateral sulcus.

The parietal lobe carries out very specific functions. It has a lot of responsibilities and be able to process sensory information within seconds. It is that part of the brain where information such as taste, touch and temperature are integrated or processed [16].

Humans would not be able to feel the sensations of touch if the parietal lobe is damaged.

3. Occipital Lobe: It is the smallest of four paired lobes. It is located in the back most portion of the skull. These lobes are part of the forebrain.

The occipital lobe is important being able to correctly understand what your eyes are seeing. These lobes have to be fast to process the information that our eyes are sending. Occipital lobe makes sense of visual information so that one can able to understand it

If the occipital lobe is impaired or injured a person would not be able to process the visual signals.

4. Temporal Lobe: The temporal lobe is located beneath the lateral fissure on both cerebral hemispheres. The temporal lobes are involved in the retention of visual memories, processing sensory input, storing new memories, emotion and deriving meaning.

It also revolves around hearing and selective listening. Sensory information such as sound and speech is received from the temporal lobe. If temporal lobe is damaged, a person would be unable to listen and hear. Different types of sound are being transferred from the sensory receptors of the ears [17]

All the brain lobes are shown in Fig.1.4

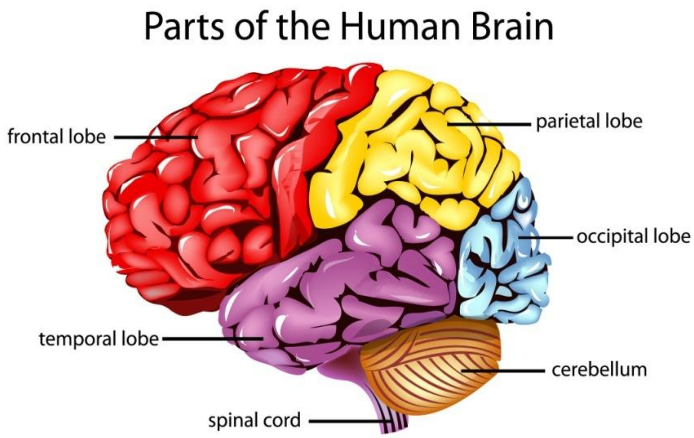

Fig.1.4 Human Brain [18]

1.4.2 Brain Waves

There are four types of brain waves which emits when brain do some functions such as sleeping, thoughtful etc. Brain is an electrochemical organ which produces electrical activity in the form of brain waves.

1. Alpha Wave
2. Beta Wave
3. Delta Wave
4. Theta wave

Alpha Wave: These waves are the slowest of all the waves but have higher amplitude. Frequency range of alpha wave is between 9 to 14 Hz. Wave represents non arousal state. A person who is doing some work and suddenly he takes break to relax that means a person is in alpha state. A person who takes a break from the conference and walk in a garden is also is in alpha state.

Beta Wave: These waves are the fastest waves which respond or act in human brain. It has low amplitude. A person who is engage in his work will definitely emit beta waves. One can say that brain will reflect high beta waves in the person who is a debater or a teacher who is teaching. Normal beta waves can be reflected by a brain if a person is engaged in a normal conversation. A range of the beta wave is between 15 to 40 Hz.

Delta Wave: These type of brain waves have greatest amplitude and slowest frequency. This type of brain wave deals with the deep sleep. Range of delta wave is between 0.1 to 3 Hz. If a person goes to bed and starts reading a book for few minutes, his brain will emit beta waves but suddenly while reading he fall asleep, it means brain waves changes from beta to alpha then to theta and finally delta. At the same time if a person wants to awake, the brain waves changes from delta to theta then to alpha and finally beta. Delta waves never tend to 0 because if it goes to 0 then a brain will come in dead condition.

Theta Wave: These waves are of greatest amplitude and slower frequency. Range is between 5 to 8 Hz. A person who does day dreaming is often in theta state or a person who is driving a car and can't remember the last few miles is in theta state. A person whose brain emits theta waves is prone to flow of ideas [19].

All the brain waves are shown in Fig.1.5

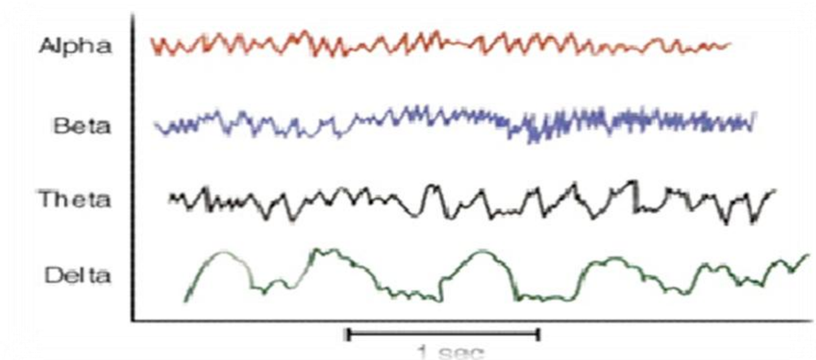

Fig.1.5 Brain Waves [20]

1.5 EEG

It is a technique which is used to record electrical activity of brain. This electrical activity is account of firing of millions of neurons within the brain and the final electrical signals are picked from multiple electrodes placed on the scalp. The main application of the EEG is in diagnosing epilepsy. An epileptic seizure is a transient symptom of excessive neural activity in the brain [21].

EEG can be used to detect emotions. Emotions cannot be classified directly from the signals, but base line removal, analysis of signals such as signal conditioning, feature extraction is helpful in analyzing emotions. Emotions can be detected from other techniques also such as Functional Magnetic Resonance Imaging, Positron Emission Tomography, and Positron Emission Tomography but the best way is through EEG as it has simple and portable hardware, high temporal resolution, and direct measurement of electrical activity [22].

Brain is the central nervous system of the human. Brain is composed of neurons and so brain produces electrical activity in the form of waves. These waves can be captured with the help of electroencephalogram. It is a technique which is used to capture brain signals from the human. EEG can be used to detect emotions. Recording of EEG can be done with the help of electrodes placed on the scalp of human. A conductive gel is used which is filled in the holes of the electrodes so that a contact can be made between the scalp and the electrodes. These electrodes capture the electrical activity in the brain and capture the signals in the recording device.

There have been several works done by researchers for finding the correlation between the emotions and EEG signals [23].

The tools for the investigation of human emotions depend on the recording and statistical analysis of physiological signals from peripheral signals sand central nervous system (EEG).Several works have been carried out using peripheral signals in combination with the EEG signals [24 25]. But very few researchers have considered the EEG signal alone to assess emotions [26].

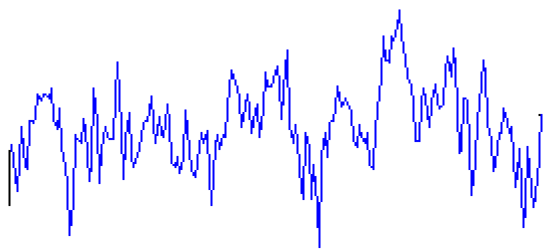

Fig 1.6 EEG Signal [27]

1.6 Brain Computer Interface

The reason a Brain Computer Interface works because of the method our brains works. Brain is filled with **neurons,** individual nerve cells connected to each other by dendrites and axons. Every time someone think, remember something or feel, our neurons work. Differences in electric potential is carried out with the help of ions which are on the membrane of neuron generates brain signals.

Myelin is something which helps in insulation of the path from which signals pass but due to which some signals escape. These signals can be detected by the scientist which use these signals to direct some device [28].

BCI with the help of ERP signals allow us to communicate with the computer. It is a best approach now a days in the field of entertainment, health, neuro marketing etc. [29]

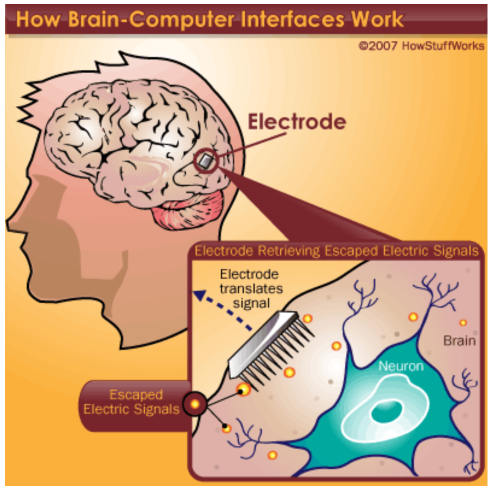

Fig.1.7 Brain Computer Interface[28]

1.7 Electrodes

Electrodes play an important role in capturing the EEG signals. These electrodes make contact with the scalp in order to capture signals emitted from the brain. Electrodes are designated according to the alphabets in which they are positioned on the scalp. The brain is divided into four lobes. They are parietal lobe, temporal lobe, frontal lobe and occipital lobe. The alphabet F is designated for Frontal lobe, O is designated as Occipital lobe, P is designated as Parietal lobe and T is designated as Temporal lobe.

Electrodes on the left side of the brain denote the odd number of electrodes and similarly electrodes on right side of the brain is denoted by even numbers of the electrodes. All the electrodes are placed according to 10-20 international system of electrodes. The electrodes are made of Silver/Silver Chloride (Ag/AgCl). The electrodes can be placed directly on the scalp or can be embedded on the cap which can be placed on the scalp of the human. The methods of electrode placement are 10-10 system and 10-5 system. But mostly 10-20 system of electrode placement is used while capturing data [30].

1.7.1 10-20 System

It is an internationally recognized method for the placement of electrodes for the EEG signals to capture EEG data. Many of the researchers used 10 -20 system to capture data. Each electrode placed on the scalp is defined using alphabets. The frontal lobe is designated as F, parietal lobe as P, Temporal lobe as T and Occipital lobe is designated as O. The 10-20 system of placement of electrodes is shown below in Fig.1.8

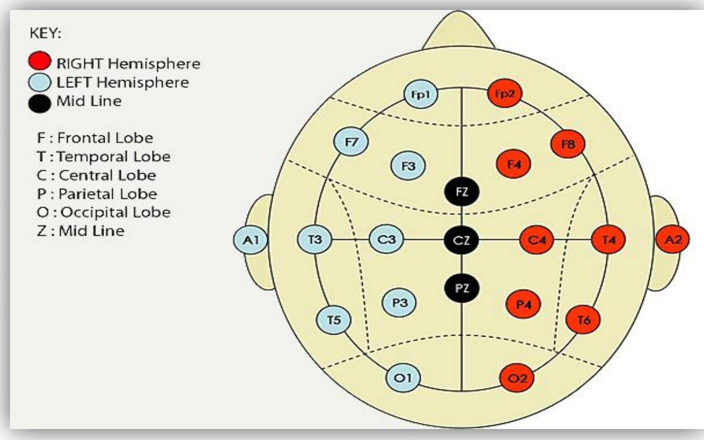

Fig.1.8 10-20 Electrode Placement [31]

Vertical imaginary line is drawn from nasion to the inion and a horizontal line from left ear lobe to right ear lobe. From 10% above the nasion and inion, along vertical line a circle is drawn around the head, other electrodes are positioned maintaining a 20% inter electrode as is indicated by the 20. 20% up from the circle from the nasion is Fz, and another 20% further along is the top of head labeled Cz. Pz is positioned on the vertical line in a similar manner. C3, T3, C4 and T4 are positioned in the same way along the horizontal mark. The electrodes on the imaginary circle are also at a 20% distance from each other, while keeping T3 and T4 on the horizontal line. The remaining electrodes are placed equidistant between the vertical line and the circle, filling the horizontal lines of the frontal and parietal electrodes [32].

1.7.2 10-10 System

There was immense need of extending 10-20 electrode system to higher density electrode settings, just for the sake of advancement of multi - channel hardware system. Chatrian et al. (1985) gives the extension of 10-20 system as 10-10 system of electrodes with higher channel density of 81[33]. 10-10 system of placement of electrodes is shown below in Fig.1.9.

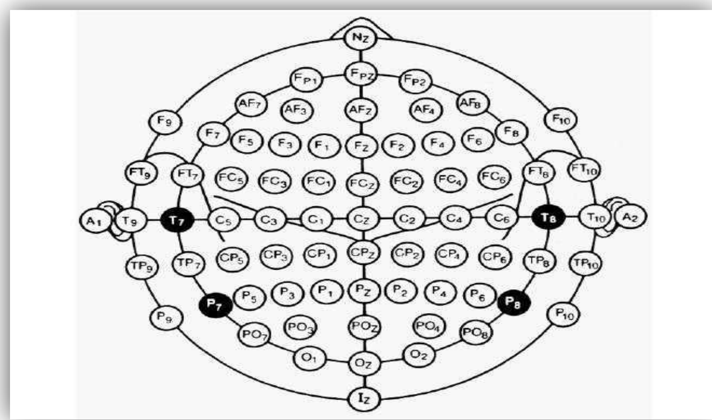

Fig.1.9 10-10 Electrode Placement [34]

1.7.3 10-5 System

Suarez et al. (2000) describe 128 channel system of choice is common for high end users who sought even higher density electrodes [35]. In fact 256 channel system are commercially available. This Oostenveld and Praamstra (2001) logically extended the 10-10 system to 10-5 system with 300 electrode location [36]. 10-5 system of placement of electrodes is shown below in Fig.1.10.

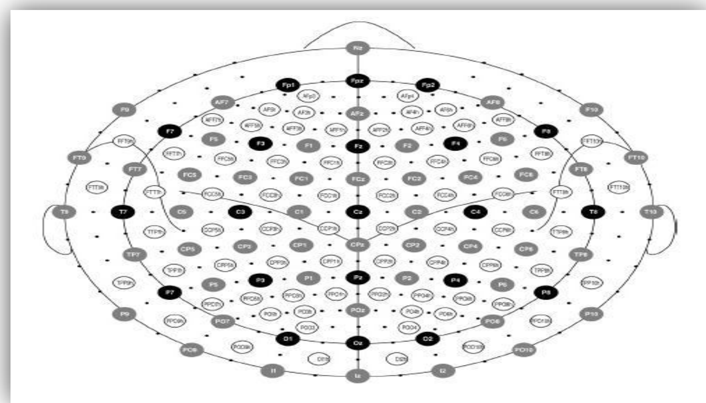

Fig.1.10 10-5 Electrode Placement [37]

1.8 Data Acquisition

1. **Acquisition of Signal:** Various methods are used to capture EEG signal. Methods are such as positron emission tomography, magnetic resonance imaging. But these methods have time resolution between seconds and minutes .But electroencephalography is a

technique which responds in milliseconds and by far the best method to know the electrical activity in the brain. EEG measures brain activity directly but other methods measures changes in blood flow. Now after acquisition of signal, emotions cannot be measured directly; preprocessing is done for measuring signals.

2. Preprocessing: At the time of acquisition of EEG signals, many unwanted signals or artifacts come along with it, that unwanted signal or noise or artifacts only weakens the signal, so for better results these signals should be removed so preprocessing of the signal is necessary. Removal of unwanted signal or noise or artifacts can also remove useful information. Preprocessing method is used to reconstruct original signal. These original signals give accurate and good results.

3. Noise: Noise is that part of the signal which comes along with signal while capturing the EEG signals. Most of the noise is generated from electromagnetic field produced by the surrounding devices. It is necessary to remove noise to get original signal for better results.

4. **Filtering of Noise:** Noise can be filtered by using filters. Mainly the information in the EEG signal is contained within the frequency of 30 Hz, so all the noise with higher frequency can be removed with the help of low pass filter. Band pass filter is also helpful in removing noise as it divides the signal in various frequency bands and low pass filter can be easily applied.

5. Artifacts: Along with the noise, artifacts are also present in the signal. These artifacts are heavily influenced by the body movements during capturing of EEG signals. Some of muscular movements also leave their marks in the signal and interfere in producing the output with the original signal. Artifacts are more difficult to remove in comparison to noise because they are not all the time present in the signal.

6. Filtering of Artifacts: Filtering of the signals which contains artifacts is very significant as it is not present all the time in the signal and can disturb the signal any time while analyzing. High pass filter is used to eliminate the artifacts under 1 or 2 Hz. Artifacts occur at low frequency and this technique shows that there is very little brain movement on low frequency. Some information can be easily removed as this method is not precise. Many methods are also present which is used to remove artifacts from the signal but this method is better one [38].

CHAPTER 2

LITERATURE SURVEY

2.1 Emotion Detection in the Loop from Brain Signals and Facial Images

Arman Savran et al. (2006) took a project to develop technique for multimodal emotion detection. Three modalities were taken, first in the capturing of brain signals using fNIRS, second modality is the face video and third modality is the EEG signals captured from the EEG signals. The internal look of emotion generation processes is provided by EEG and fNIRS while the external look is provided by video sequence [39].

2.2 Towards Emotional Aware Computing: An Integrated Approach Using Multichannel Neurophysiological Recordings and Affective visual Stimuli

Christos A. Frantzidis et al. (2010) proposed procedure for the classification of neurophysiological data into four emotional states. These emotional states were collected during passive viewing of emotional pictures selected from IAPS. It adopts the independency of two emotive dimensions. These are named as arousal and valence. For the judgment of emotional states between EEG signals evoked by pleasant and unpleasant stimuli, two step classification method was used, which also vary in their arousal/intensity levels. The arousal judgment was involved by first classification level. After performing arousal judgment, the valence judgment was applied. For the discrimination of emotions, there were two factors used named as the Mahalanobis Distance based classifier and Support Vector Machine. For the MD, gained classification rates were 79.5% and for SVM the gained rates were 81.3%.The first step towards number of applications including the sphere of human computer interaction was the robust classification of objective emotional measures. This procedure used the bidirectional cognitive model to get the provoked neurophysiological emotional reactions. These responses were classified by means of data mining methods [40].

2.3 Feature Extraction from EEG for Emotion Classification

Mandeep Singh et al. (2013) took the enterface data provided by Savran et al. (2006) [41] [42] [43] for 3 participants and performed classification along valence axis by using the naïve bayes classifier on the extracted ERP features. The overall accuracy achieved for ERP feature was 56% and by changing the feature to STFT, accuracy obtained was 51%. Similarly with the PSD feature, accuracy was 56% and after combining all the three features accuracy obtained was 64% which was comparatively high among all [44], while the overall accuracy achieved for 3 participants by using Artificial Neural Network was 76.59% [45].

2.4 Mahalanobis Distance-Based Classifier Are Able to Recognize EEG patterns by Using Few EEG Electrodes

Fabio Babiloni et al. (2001) took 8 subjects and collected EEG signals on 4 electrodes, C3, P3, C4, P4.All the electrodes were placed according to 10-20 international system of electrodes. Reduced set of recording electrodes were used by quadratic classifier based on MD classifier to detect EEG patterns so that emotions can be detected. Covariance and diagonal matrix were used by the classifier to detect imagination of movement. The accuracy obtained was 98% .By this accuracy it was made easy for Brain Computer Interface to use Mahalanobis distance classifier in which important factor was reduced set of recording electrodes [46].

2.5 A Real Time Model Based Support Vector Machine for Emotion Recognition through EEG

Viet Hoang Anh et al. (2012) used Russell's circumplex model in which two approaches were used. Higuchi Fractal Dimension algorithm and Support Vector Machine was also used as a classifier. One approach was the machine learning in which EEG signals of all the subjects under consideration were taken and second approach was the machine learning in which EEG of individual subjects were taken. EEG signals of different subjects has different characteristics and so first approach of machine learning was not applied but second approach of machine learning was used and five states of emotions were recognized with average accuracy of 70.5%.The conclusion at the end was that the model should be improved since emotions and accuracy both were very small for real applications [29].

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

Guillaume Chanel et al. (2005) talked about emotion recognition using facial and verbal emotion with the help of EEG PET devices considering valence arousal dimensions.5 participants and 39 stimuli were taken and 4 emotions were categorized by splitting the data into training, testing and validation **[**47**].**

2.7 Feature Extraction Techniques of EEG Signal for BCI Application

Abdul Hameed Fatehi et al. (2011) studied the extraction of EEG signals.16 channels were used to gather EEG data with the help of mental and motor tasks. Features such as Time Analysis, Frequency Analysis, Time frequency analysis and space were extracted. Filtration was done with low pass filter kept at 40 Hz and high pass filter with a frequency of 0.5 Hz. Artificial Neural Network was used to classify and the accuracy was 99%.Other classifiers used were FFT for time analysis, STFT for time frequency analysis [48].

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

Bradley M.M et al. (2005) discussed the images as stimuli from the IAPS which is known as the International Affective Picture System. It helps in evoking the emotion. Arousal, pleasure and dominance ratings are possible through these IAPS images. The IAPS was currently used in experimental investigations of emotion by enabling the comparison of results of different studies in grouping to control the feelings across psychosomatic and neuroscience research workshops [49].

2.9 A Database for Emotion Analysis using Physiological Signal

Sander Koelstra et al. (2012) worked on multimodal data.32 participants were taken for analysis and they were asked to watch the 40 min music video and simultaneously EEG recording was going on. The video was rated according to valence arousal scale, likes/dislikes, dominance. Frontal face video was also recorded for 22 participants out of 32 [50].

2.10 Other literature on emotion recognition using physiological signals

K.Ishino et al. found estimation of joy, anger, sorrow and relaxation for emotion estimation and found accuracy of 62.9% for relaxation, 67.7 % accuracy for anger, 59% for sorrow and 54.4 % for joy [51].

Lin et al. found accuracy of 82.37% for joy, anger, sadness and pleasure by suing a multiclass SVM classifier [52].

Lin et al. used fractal dimension algorithm for the classification of emotions. It has been concluded that it provides better accuracy and performance in case of EEG classification. Model made by him could recognize six basic emotions such as fear, satisfied, sad, pleasant, happy and frustrated. [53].

Takahashi used a setup of three dry electrodes on a headband to classify five emotions based on multiple bio-potential signals (EEG, pulse, and skin conductance): joy, anger, sadness, fear, and relaxation. The success rate when classifying solely on the EEG using support vector machines was 41.7% [54].

Delorme, Arnaud et.al (2003) used “EEGLAB”(an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis) describes the development of an open source toolbox that works on the MATLAB platform in which EEG data from a channel can be imported for processing and analyzing operations. It includes the functions to perform pre-processing operations like baseline removal, change of sampling rate, Artifacts removal and filtering as well as operations like independent component analysis (ICA) and statistical analysis [55].

CHAPTER 3
METHODOLOGY

EEG data is acquired from three subjects for the classification of emotions. All the subjects are male, right handed and physically fit and have no health issues.

3.1 Hardware used for acquisition of EEG

BIOPAC system is used as hardware for capturing brain signals for emotion classification. The MP System is a computer-based data acquisition system that is used to perform many of the same functions such as chart recorder, other data viewing device. The MP data acquisition unit (MP150 or MP100) is the heart of the MP System. The MP unit takes incoming signals and converts them into digital signals that can be processed with the computer. Data collection generally involves taking incoming signals (usually analog) and sending them to the computer, where they are displayed on the screen and stored in the computer's memory. These signals can then be stored for future examination, much as a word processor stores a document or a statistics saves a data file. Graphical and numerical representations of the data can also be produced for use with other programs. The MP System can be used on a PC with Windows® or a Macintosh®. The software has the same "look and feel" on both Windows and Mac® computer operating systems [56]. The system comprises of EEG amplifiers, EEG gel used in electrode, earlobes attached to the subject. EEG cap has 20 electrodes that could be used in bipolar or unipolar and placed on the cap using 10-20 international system. EEG gel is used in the electrodes so that contact could be made between the electrodes and the scalp.

3.2 Method

The subject is allowed to wear EEG cap over the head and is made to sit facing the stimulus presenter. EEG gel is filled on those electrodes whose data is to be captured. The subject is asked to sit properly while capturing data. He is not allowed to move, yawn, to blink his eyes, or to make any other movements during the time of acquisition of EEG data. The EEG gel is filled into the electrodes with the help of a syringe. The level of the impedance is maintained below 10 KΩ .The equipment used for acquisition of EEG signal is as shown in Fig.3.1

Fig.3.1 Equipments for EEG Recording [57]

For classification of emotions the data is analyzed from three electrodes namely Cz, p4 and f3.Cz is the central electrode, p4 is the parietal electrode and f3 is the frontal electrode. Stimulus to the subjects for evoking emotions is provided by using images from the IAPS system provided by NIHM Centre of University of Florida [49]. The images are of different types such as snake, nature, children, mutilations, graves etc. Total of 80 images are used to capture emotions. For evoking an emotion along the valence axis, an image corresponding to low valence class is shown to the subject for a period of 1second followed by a white cross with a black background for a period of 1.5 seconds to normalize the subject. The next image belonging to another class namely high valence follows the cross image for a period of 1 second. A total of 80 images are shown in this manner to each subject and his EEG is acquired for recognition of emotion into two classes. The software used to capture EEG signals is Acknowledge 4.2 software [58]. Duration of the stimulus which is shown to the subject is less than 5 minutes. The images are of low valence low arousal, low valence high arousal [59] [60] [61]. One of the EEG signals acquired from a subject is shown below in Fig.3.2

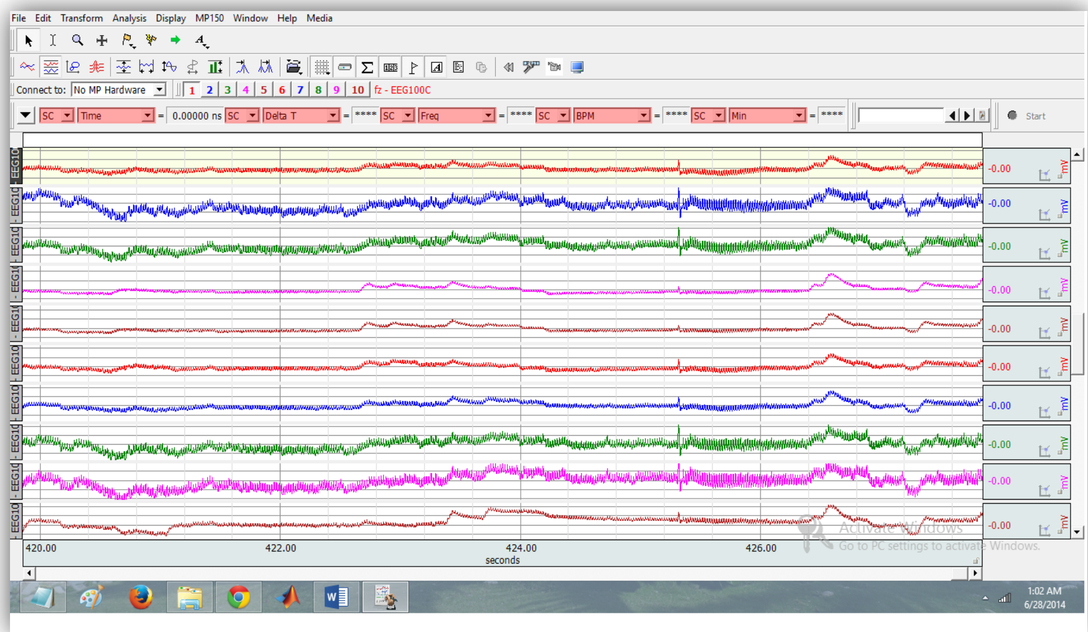

Fig.3.2 Unfiltered EEG Signal

3.3 Signal Conditioning

After the acquisition of EEG signals, signal conditioning is very important part which should be performed in order to get better results. The EEG signals may contain some interference such as noise and artifacts and this interference should be removed to get better results as shown in figure 3.2. Acqknowledge software is very helpful while applying filter operations. Filtered operations present in acqknowledge software are digital IIR filters, adaptive filters, comb band stop filter. The acquired EEG signals are filtered using a low pass filter with a bandwidth of 40 Hz to remove noise and artifacts. A high pass filter with a cut off frequency of 0.5Hz is used to obtain a signal in the desired frequency range of 0.5 – 40 Hz. The comb band stop filter is used to eliminate the power noise at a frequency of 50 Hz and its harmonics. [59]. The processed EEG signal can now be used to extract Features for emotion recognition. The filtered EEG signal is shown in Fig.3.3.

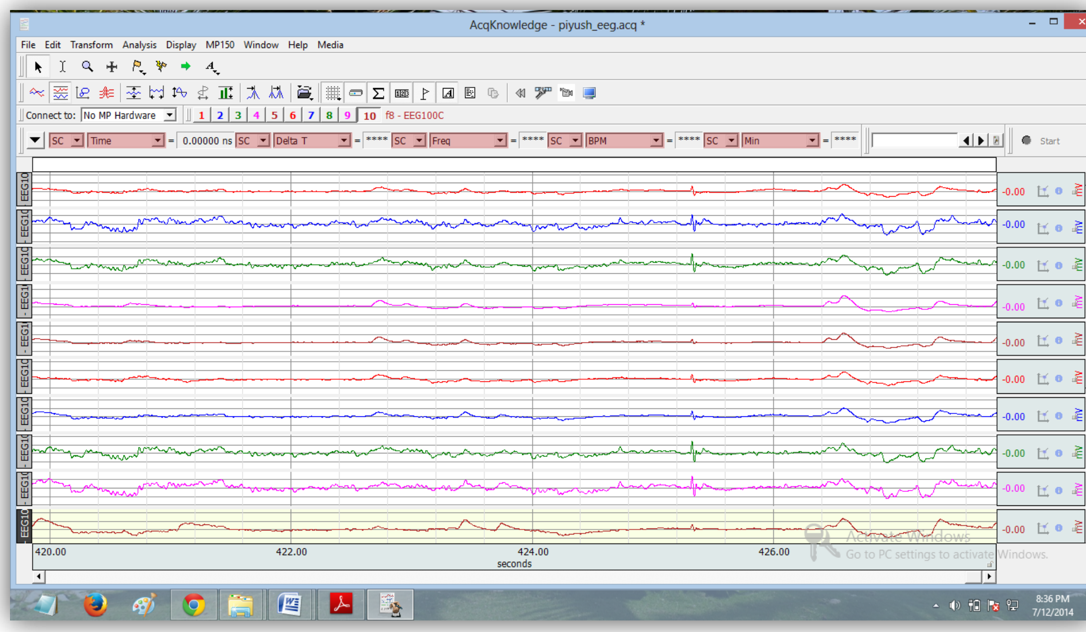

Fig.3.3 Filtered EEG Signal

3.4 International Affective Picture System (IAPS)

It is a system of NIHM Centre of University of Florida which is widely used in classification of emotions as it provides external stimuli to the subject through pictures. The pictures provided by the IAPS are quantified along three axes namely arousal, valence and dominance. The pictures can be of snake, scenery, mutilation, erotic images or child and all of these are used to evoke emotions in human being. IAPS has an advantage of using images as stimuli because using this can lead to the minimization of eye and muscle movements due to which interference can be easily reduced in the EEG signal [49].

CHAPTER 4

FEATURE EXTRACTION

4.1 Event Related Potential

The features that are extracted from EEG signals are P100, N100, P200, N200, and P300 and N300. P100 which is also called the P1 is the first positive peak observed between 80 and 120ms after the onset of stimuli, so P100 is considered as the maximum ERP of the subject in the time limit of 80 to 120ms. N100 is just the reverse of P100. Here the minimum of ERP that is N100 value is chosen as an attribute for classification. The N100 value is also determined between the time limit of 80 and 120ms. P200 is a second positive peak observed about 200ms, varying from 180 to 220ms. N200 is a negative-going wave that also peaks from 180-220ms P300 is a positive peak observed at 300 ms, varying between 280 and 320ms. The features extracted for P100 and N100 is between the time limit of 80-120 ms and for P200-N200 the time limit is 180-220ms and similarly for P300-N300 value the time limit range is 280-320ms [61]. For all the subjects, ERP features have been extracted using Acq4.2 software. The ERP values are shown below in Fig.4.3

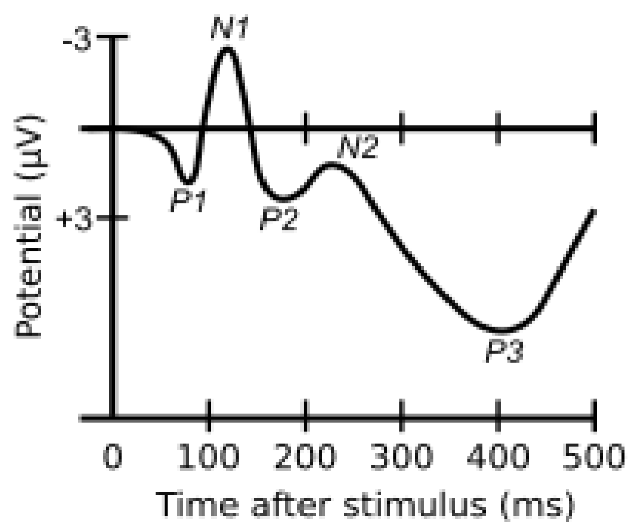

Fig. 4.1 Event Related Potential [62]

Table 4.1 Extracted features of gathered data

p100	n100	p200	n200	p300	n300
-0.01152	-0.01621	0.00776	-0.00057	-0.00135	-0.00669
-0.01037	-0.02208	-0.0135	-0.01991	-0.00175	-0.01349
0.00289	-0.00285	0.00485	-0.003	0.00879	-0.00738
-0.00771	-0.01538	-0.00675	-0.01534	0.00216	-0.0059
0.02624	0.00012	0.00775	-0.00363	0.02699	9.48E-05
-0.00186	-0.01753	0.02721	-0.00092	0.01627	0.00817
0.00347	-0.01775	0.00392	-0.00722	0.01744	0.00131
0.00198	-0.01472	-0.00431	-0.02401	0.00286	-0.00472
0.00366	-0.02529	0.00986	-0.00356	0.00336	-0.01274
-0.00549	-0.01609	0.01582	-0.01701	-0.00447	-0.00807
-0.01802	-0.02509	-0.0204	-0.02898	-0.01045	-0.01478
-0.01017	-0.02993	-0.00056	-0.01806	0.00818	-0.00671
0.00744	-0.00066	0.01712	-0.00899	0.00369	-0.00434
1.57E-05	-0.00771	-0.00619	-0.01282	0.01857	0.00412
0.01796	0.00394	0.00152	-0.00251	0.00927	-0.0015
0.00348	-0.00148	-0.00161	-0.00979	-0.00387	-0.01309
0.00122	-0.01032	0.01573	-0.00916	0.00917	-0.00234
0.01674	0.00581	0.0159	0.00023	0.01506	0.00541
-0.00081	-0.00876	0.02954	-0.0054	0.02773	0.00313
0.03821	0.01753	0.02256	0.01598	0.02427	0.01221
-0.00568	-0.01998	-0.0031	-0.01458	9.28E-05	-0.00561
-0.00195	-0.02171	-0.00448	-0.01475	-0.00378	-0.02525
0.00745	-0.01167	0.00448	-0.0074	0.01485	0.00359
0.01016	-0.00343	0.01685	0.00565	0.01954	-0.00018
-0.00013	-0.00747	0.02214	-0.01445	0.00051	-0.01559
0.01154	-0.01303	0.01381	-0.00179	0.00225	-0.00511
0.00398	-0.00796	-0.00294	-0.00806	-0.00354	-0.01322
0.00102	-0.00706	0.0099	-0.01337	0.00754	-0.00078
0.0015	-0.01159	0.00312	-0.01475	0.00585	0.00087
0.01787	-0.01201	0.00346	-0.00612	0.01353	-0.00441
0.01183	0.00022	0.01732	0.00672	0.02813	0.0119
-0.00274	-0.01443	-0.00065	-0.01454	0.00355	-0.00828
0.01943	-2.97E-05	0.00854	0.00023	0.00304	-0.00348
0.00109	-0.01646	-0.00013	-0.01653	0.00039	-0.0155
0.02731	0.00738	0.01479	0.00141	0.01246	0.00364
0.01372	0.0002	0.02568	-0.0049	0.02864	0.00971
0.04351	0.03304	0.04365	0.02247	0.02972	0.02282
-0.00595	-0.00933	-0.00493	-0.01355	-0.00033	-0.01307
0.00436	-0.00449	-0.00257	-0.01348	-0.0025	-0.01059
-0.00359	-0.01892	-0.01096	-0.01844	0.00438	-0.00668

0.00386	-0.00502	0.01408	-0.00011	0.00747	0.00387
0.01366	-0.00167	0.02847	0.014	0.02357	0.01853
0.02077	-0.00484	0.00436	-0.00107	0.00243	-0.00445
-0.01315	-0.02312	-0.01332	-0.02192	-0.00321	-0.01016
0.00231	-0.01021	0.00537	-0.01422	0.00031	-0.01182
0.01351	-0.00184	-0.00268	-0.01198	0.00226	-0.0028
-0.0017	-0.01606	0.02151	-0.01867	0.01329	-0.00587
-0.00491	-0.01139	-0.00467	-0.00964	-0.00039	-0.01987
0.0169	0.00602	0.01597	0.00975	0.02953	0.01279
0.00663	-0.01385	-0.00114	-0.00817	0.01129	-0.00532
0.00439	-0.02215	0.00953	-0.01313	0.0237	0.01033
0.01184	0.00407	0.02056	0.0092	0.0287	0.00669
0.01321	-0.01451	-0.00112	-0.02445	0.00194	-0.01473
0.00238	-0.01118	-0.00516	-0.02012	-0.00344	-0.01665
-0.01585	-0.03004	-0.00878	-0.01728	0.01249	-0.00487
-0.00189	-0.01247	-0.00566	-0.01577	0.00467	-0.01981
-0.00783	-0.02583	-0.01273	-0.01928	-0.01209	-0.02621
0.02077	-0.00476	0.0004	-0.00964	0.01214	-0.00157
0.0107	-0.00649	0.00901	-0.0027	0.04308	-0.01532
-0.01164	-0.02223	-0.00795	-0.03402	-0.00679	-0.01407
0.01178	0.00161	0.01717	0.00132	0.02481	0.01355
-0.01555	-0.02112	-0.02155	-0.02728	0.00064	-0.01283
0.00232	-0.01292	-0.00783	-0.02115	6.45E-05	-0.01832
0.00187	-0.01363	0.00046	-0.01698	-0.00376	-0.0168
0.02314	0.01583	0.0138	0.00221	0.00381	-0.00527
0.01691	0.01414	0.01489	0.01216	0.04173	0.0293
0.00304	-0.01205	0.00641	-0.01695	0.00626	-0.00836
-0.00715	-0.02573	-0.00036	-0.01273	0.00183	-0.01304
0.01732	0.00584	0.0178	0.00641	0.01705	0.00373
0.03559	-0.00958	0.00194	-0.01602	0.00578	1.22E-05
0.0029	-0.009	0.00378	-0.01854	-0.001	-0.01172
-0.01439	-0.05112	-0.00952	-0.05391	-0.00087	-0.044
0.00461	-0.00258	0.01073	-0.00307	-0.00071	-0.00553
0.00121	-0.01657	0.00171	-0.00419	0.0049	-0.00079
0.01724	0.00318	-0.00255	-0.01222	-0.00221	-0.0087
0.00482	-0.0028	-0.00418	-0.03974	-0.01426	-0.03495
-0.00813	-0.01895	-0.00542	-0.02958	5.21E-05	-0.0181
0.01855	0.00611	-0.00705	-0.01897	0.01343	0.00093
0.01437	0.00273	0.00663	0.00087	0.02009	0.01556
0.01643	0.00194	0.0157	-0.0022	0.02198	0.00392

-0.01646	-0.02229	-0.00168	-0.01136	-0.00958	-0.01214
-0.01843	-0.02724	-0.02158	-0.02926	-0.01086	-0.01942
0.00469	-0.00042	0.00397	-0.00647	0.0043	-0.00795
-0.01073	-0.01859	-0.01038	-0.01878	0.00105	-0.01002
0.0154	-0.00143	0.00554	-0.0084	0.02513	-0.00366
0.00303	-0.01513	0.01279	0.00618	0.01402	0.00922
0.00609	-0.01215	0.0032	-0.00657	0.00875	0.00254
0.01405	-0.00963	-0.00832	-0.01776	0.0016	-0.0054
-0.00565	-0.01973	-0.00118	-0.01273	0.00113	-0.0145
-0.02374	-0.02973	-0.0053	-0.03067	-0.00557	-0.01646
-0.01577	-0.02333	-0.01983	-0.02588	-0.01411	-0.01948
-0.00382	-0.02406	-0.01009	-0.01759	0.00307	-0.00813
0.00671	0.00384	0.00801	-0.00561	0.0091	0.00241
0.00182	-0.00169	0.00039	-0.00899	0.01371	0.00553
0.00759	0.00247	0.00288	-0.00292	0.00538	-0.00131
0.00371	-0.00124	-0.00236	-0.01245	0.00534	-0.00356
-0.0088	-0.01762	0.00041	-0.01453	0.0034	-0.00427
0.01544	-0.00453	0.01178	0.0035	0.01605	0.00294
-0.0008	-0.00643	0.00639	-0.00422	0.00977	0.00403
0.03282	0.01957	0.02414	0.00729	0.02348	0.01232
-0.00918	-0.02096	-0.00966	-0.01825	0.00135	-0.01466
-0.00452	-0.02372	-0.0031	-0.01043	-0.0068	-0.02357
0.00164	-0.0049	0.00214	-0.00519	0.01396	-0.00032
0.0082	-0.00549	0.01674	0.00369	0.02052	0.00484
-0.00461	-0.01499	0.01218	-0.01509	-0.0005	-0.01227
0.01127	-0.00724	0.01603	-0.00215	0.00951	0.00074
0.00019	-0.00571	0.00699	-0.01291	0.00484	-0.01285
0.00334	-0.00326	0.0039	-0.01945	0.00264	-0.00686
0.00012	-0.00604	-0.00125	-0.01526	0.00391	-0.00473
0.01016	0.0013	0.02571	0.01208	0.02912	0.01224
0.01174	0.0035	0.01781	0.00929	0.0278	0.01748
-0.00242	-0.0084	0.00157	-0.01384	0.00553	-0.00581
0.00656	-0.00958	-0.00497	-0.01134	-0.00289	-0.01094
-0.00859	-0.01603	-0.00907	-0.01511	-0.00427	-0.01235
0.0114	0.00288	0.0079	0.00397	0.00038	-0.00615
0.00572	-0.00321	0.01829	-0.00198	0.0205	0.00751
0.04064	0.03825	0.03835	0.02729	0.0285	0.02287
-0.00222	-0.00621	-0.00684	-0.01405	0.00072	-0.00482
0.00068	-0.00672	-0.0099	-0.02395	0.00111	-0.00349
-0.00577	-0.01689	-0.01448	-0.01794	-0.00249	-0.00807

0.00524	-0.00264	0.00971	-0.00216	0.01418	0.00504
0.00674	0.00013	0.01785	0.00734	0.02153	0.01581
0.00718	-0.00777	-0.00299	-0.01002	0.00633	-0.00041
-0.02185	-0.02795	-0.02136	-0.02823	-0.01143	-0.01503
-0.0084	-0.01222	-0.00957	-0.01756	-0.00917	-0.02055
0.0061	-0.00581	-0.00409	-0.00723	0.00079	-0.00401
-0.0063	-0.01942	-0.00976	-0.01799	-0.00292	-0.01105
-0.01064	-0.01936	-0.01562	-0.01917	-0.00821	-0.01637
0.01493	0.00545	0.01609	0.005	0.02478	0.01872
-0.00207	-0.01209	-0.00858	-0.01583	0.00419	-0.00759
-0.01065	-0.0243	-0.00924	-0.01523	0.0164	0.00799
0.01166	0.00596	0.01547	0.01001	0.02528	0.01886
-0.017	-0.02497	-0.00608	-0.0231	0.00029	-0.01304
-0.00641	-0.00995	-0.00813	-0.01691	-0.00864	-0.0187
-0.01069	-0.02123	-0.00518	-0.01856	0.00862	-0.00294
-0.00709	-0.01143	-0.01161	-0.01968	-0.00376	-0.00962
-0.02477	-0.03236	-0.02249	-0.02945	-0.01903	-0.03463
0.0037	-0.00527	-0.00534	-0.01363	-0.00279	-0.01484
0.0098	-0.00187	0.00078	-0.00563	0.01565	-0.01122
-0.0157	-0.02216	-0.01274	-0.0232	-0.00822	-0.01121
0.01866	0.01012	0.02048	0.01118	0.03114	0.02204
-0.01065	-0.02555	-0.01598	-0.02103	0.00869	-0.01122
-0.00182	-0.01049	-0.01115	-0.02044	-0.0103	-0.0217
-0.00754	-0.01404	-0.00114	-0.0177	-0.01674	-0.02616
0.02483	0.01597	0.02105	0.00743	0.01498	0.00701
0.02172	0.01097	0.01667	0.01076	0.0484	0.0393
-0.0108	-0.01893	-0.00338	-0.01291	-0.00481	-0.01718
-0.00475	-0.01739	-0.00094	-0.01106	-0.00375	-0.01047
0.01	-0.00228	0.01378	-0.00396	-0.00026	-0.00531
-0.00236	-0.01231	-0.01153	-0.02011	-0.00407	-0.00823
-0.00132	-0.01007	0.00082	-0.01973	0.00212	-0.00687
-0.05062	-0.05594	-0.04222	-0.04818	-0.02447	-0.04373
0.0011	-0.00516	0.01142	-0.00193	0.00476	0.00043
0.00129	-0.01434	0.00543	-0.00115	0.00594	0.00259
0.00664	-0.00472	-0.00939	-0.01205	-0.00692	-0.01722
-0.0038	-0.0123	-0.01339	-0.04242	-0.01825	-0.02939
-0.00798	-0.01368	-0.00944	-0.01995	-5.28E-05	-0.01675
0.04403	0.0289	-0.00846	-0.01435	0.01382	0.00238
0.0065	-0.00494	0.0071	-0.0065	0.01625	0.011
0.01073	0.00474	0.01138	0.00234	0.01713	0.00678

-0.01372	-0.02526	0.00523	-0.00534	-0.00148	-0.01179
-0.01364	-0.02264	-0.01002	-0.02681	-0.0035	-0.00826
-0.00445	-0.01241	0.00019	-0.00933	0.00248	-0.01732
-0.00889	-0.02063	-0.00816	-0.01897	-0.00053	-0.00891
0.02363	-0.01109	0.00786	-0.00341	0.01418	-0.00017
-0.01008	-0.01877	0.01229	-0.00498	0.01867	0.00824
-0.00534	-0.02458	0.00087	-0.01537	0.01773	-0.00568
0.00654	-0.02361	0.00131	-0.03343	0.00929	-0.01204
-0.01023	-0.03825	0.00995	-0.0025	-0.00839	-0.01771
0.00745	-0.01611	0.02449	-0.01608	-0.00456	-0.00987
-0.02206	-0.03049	-0.02195	-0.02712	-0.00609	-0.02175
-0.01476	-0.03245	0.00835	-0.01284	0.00937	0.00323
-0.00493	-0.01863	0.00805	-0.02557	-0.00671	-0.01087
-0.00461	-0.00993	0.0021	-0.01412	0.03422	0.00123
0.00865	-0.00082	0.00372	-0.00458	0.01086	0.00223
-0.00342	-0.01794	0.00244	-0.01653	-0.00504	-0.02674
0.00495	-0.0127	0.02697	-0.00577	0.00944	-0.00307
0.00565	-0.01054	0.003	-0.00816	0.01204	-0.00524
0.0034	-0.00948	0.01464	0.00609	0.01166	0.00618
0.04365	0.00745	0.02924	0.00475	0.02052	-0.00156
-0.0139	-0.03203	-0.00301	-0.01769	-0.0011	-0.01626
-0.00865	-0.02619	-0.00246	-0.0205	-0.00434	-0.02008
0.0076	-0.03833	0.01131	-0.04406	0.00797	-0.0067
0.00337	-0.01009	0.01461	0.00384	0.01536	-0.00252
0.00583	-0.00891	0.01245	-0.02239	-0.00124	-0.01489
-0.00497	-0.01388	0.00408	-0.00464	-0.0005	-0.01803
0.01188	-0.04251	-0.00236	-0.04086	-0.01302	-0.02399
-0.00281	-0.02426	0.00728	-0.01678	0.005	-0.00597
0.00171	-0.01886	-0.00295	-0.01404	0.00655	-0.0015
-0.00708	-0.01345	0.00158	-0.00435	0.0092	-0.01261
-0.00553	-0.01616	0.00355	-0.007	0.01337	-9.64E-05
-0.00227	-0.03244	0.00525	-0.02194	-0.00717	-0.01615
0.01353	-0.00809	0.01102	-0.00164	-0.00186	-0.01047
-0.00161	-0.02267	-0.00466	-0.01775	-0.00469	-0.01583
0.02727	-0.00578	0.01439	-0.01202	0.01725	-0.00105
0.01913	-0.00953	0.02166	-0.00251	0.03769	0.01105
0.01968	0.00968	0.04263	-0.00417	0.02173	0.00834
-0.01321	-0.02593	-0.01266	-0.01949	-0.01069	-0.02651
-0.00057	-0.01545	-0.00316	-0.01191	-0.00782	-0.01666
-0.00404	-0.0245	-0.01046	-0.02248	0.00162	-0.01156

0.0005	-0.00845	0.00899	0.00364	0.00509	5.57E-05
-0.0056	-0.01651	0.01021	0.00038	0.01348	-0.00134
0.02114	-0.01351	0.01231	-0.01924	-0.00164	-0.00789
-0.0157	-0.02217	-0.02167	-0.0261	-0.00721	-0.01158
0.00153	-0.03444	-0.00166	-0.03904	-0.00326	-0.00945
-0.003	-0.01767	-0.01665	-0.02502	-0.00262	-0.0118
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-0.00434	-0.00851	0.00042	-0.00809	-0.00044	-0.02739
0.0039	-0.00698	0.02043	-0.01085	0.01228	0.0006
-0.00317	-0.02273	0.00139	-0.00428	0.01093	-0.00386
0.01388	-0.04205	0.02087	-0.0082	0.02435	-0.00048
0.0034	-0.00735	0.01879	-0.00042	0.01942	-0.00111
0.00278	-0.01129	0.0117	-0.01338	0.00741	-0.0157
-0.00618	-0.01441	-0.00745	-0.01886	-0.01179	-0.02326
-0.02606	-0.03795	-0.014	-0.02299	0.00678	-0.01148
0.00316	-0.01874	-0.00247	-0.01601	0.00076	-0.02312
-0.02256	-0.03217	-0.02041	-0.02549	-0.01906	-0.03041
0.00693	-0.01002	0.00257	-0.00799	0.02175	0.00469
0.00447	-0.01427	0.0038	-0.01147	0.02769	-0.01056
-0.02498	-0.04289	-0.00928	-0.04479	-0.00852	-0.02255
0.00424	-0.03303	0.00675	-0.0304	0.01304	0.00369
-0.0166	-0.03583	-0.0127	-0.04409	-0.01279	-0.01969
0.00068	-0.02488	-0.01521	-0.02823	0.00727	-0.01328
-0.00182	-0.04827	0.00106	-0.02048	-0.00588	-0.0219
0.00857	-0.00518	-0.00074	-0.01323	-0.00983	-0.01929
0.01687	0.00787	0.02088	0.01143	0.03141	0.01533
0.00016	-0.01579	0.00767	-0.01943	0.01311	-0.01222
-0.01195	-0.04332	-0.01257	-0.02465	-0.00716	-0.02016
0.00756	-0.01101	0.00636	-0.00621	0.01039	-0.00134
0.02442	-0.02382	0.01093	-0.02146	0.00551	0.00203
-0.00209	-0.03019	0.0058	-0.02882	-0.01	-0.02844
-0.02988	-0.0371	-0.01926	-0.02802	-0.0153	-0.02608
0.00016	-0.01026	0.00661	-0.0082	0.00029	-0.00264
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0.03735	0.00403	0.00288	-0.01524	0.00601	-0.00526
0.00298	-0.00614	0.00221	-0.03093	-0.01225	-0.04182
-0.01261	-0.02939	0.00083	-0.03466	0.00215	-0.03124
0.00242	-0.00469	-0.0076	-0.02326	0.01374	0.00547
0.01711	0.00153	0.01803	0.00959	0.02636	0.01747
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-0.00049	-0.0095	-0.0021	-0.01165	0.00688	-0.00782
-0.03028	-0.03847	-0.03639	-0.04457	-0.04121	-0.05209
-0.02075	-0.03134	0.00494	-0.02088	-0.01339	-0.02233
-0.01309	-0.03352	-0.03311	-0.04122	-0.03349	-0.03902
-0.02241	-0.033	-0.0203	-0.03471	-0.02445	-0.02989
-0.01718	-0.02554	-0.01418	-0.02102	-0.0097	-0.01753
-0.00833	-0.03312	-0.0183	-0.02766	-0.02963	-0.03722
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-0.01769	-0.02342	-0.00664	-0.00977	-0.00276	-0.00506
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-0.0304	-0.03855	-0.03425	-0.04437	-0.03345	-0.04262
-0.01274	-0.02018	0.00261	-0.00213	0.00291	-0.00662
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-0.02988	-0.03934	-0.03229	-0.03648	-0.03474	-0.04254
-0.0153	-0.02309	-0.00817	-0.0143	-0.00187	-0.01331
-0.03218	-0.03664	-0.02992	-0.03802	-0.03444	-0.04164

-0.00851	-0.01499	0.00224	-0.00598	0.00144	-0.00551
-0.03436	-0.04148	-0.0366	-0.05347	-0.03717	-0.04667
-0.01156	-0.0181	-0.00488	-0.01088	0.00277	-0.01171
-0.0319	-0.04336	-0.04714	-0.05256	-0.04537	-0.05792
-0.0084	-0.01598	-5.82E-07	-0.0035	0.00609	-0.00135
-0.04095	-0.04614	-0.04654	-0.05211	-0.04861	-0.05216
0.0002	-0.01289	0.01479	0.00487	0.01515	0.00595
-0.02506	-0.03515	-0.02964	-0.03595	-0.02875	-0.03078
-0.03218	-0.04268	-0.03477	-0.04084	-0.03944	-0.04387
-0.00114	-0.0241	0.00918	-0.00761	0.00407	-0.00066
-0.01292	-0.03546	-0.02653	-0.03378	-0.01678	-0.0292
-0.03786	-0.04563	-0.04393	-0.05046	-0.05189	-0.05686
-0.00281	-0.02049	0.00811	-0.00723	0.00578	-0.00545
-0.01204	-0.03202	-0.01155	-0.0253	-0.01777	-0.02726
-0.04379	-0.0481	-0.03475	-0.0505	-0.0454	-0.05045
-0.01743	-0.02716	-0.0174	-0.01915	-0.01093	-0.02256
-0.00532	-0.01616	0.00712	-0.00399	0.0033	-0.00877
-0.0232	-0.03061	-0.02036	-0.02489	-0.02544	-0.02773
-0.03452	-0.05072	-0.04215	-0.04575	-0.03782	-0.04244
-0.00405	-0.02382	-0.00062	-0.0183	-0.0048	-0.0166
-0.00476	-0.0171	-0.00042	-0.00496	0.00257	-0.00662
-0.03029	-0.03885	-0.02889	-0.03609	-0.02909	-0.036
-0.02682	-0.03587	-0.03631	-0.04329	-0.03593	-0.05059
-0.02611	-0.04321	-0.03874	-0.04462	-0.03443	-0.04342
-0.01919	-0.0249	-0.01487	-0.02036	-0.00865	-0.01523
-0.00828	-0.01535	0.00311	-0.00619	0.0108	-0.00421
-0.02454	-0.03133	-0.02751	-0.0356	-0.02993	-0.03767
-0.03332	-0.04005	-0.03089	-0.03599	-0.03338	-0.0444
-0.00924	-0.0182	-0.00608	-0.01553	0.00107	-0.00433
-0.01877	-0.03078	-0.0189	-0.03384	-0.02281	-0.03278
-0.02396	-0.03176	-0.01461	-0.0282	-0.02193	-0.03017
-0.0255	-0.04013	-0.02542	-0.03212	-0.01872	-0.02663
-0.01805	-0.0337	-0.02462	-0.02921	-0.01781	-0.02882
-0.02456	-0.03238	-0.01406	-0.02645	-0.01701	-0.02262
-0.03315	-0.0474	-0.04205	-0.05092	-0.04702	-0.0538
-0.02648	-0.03036	-0.01351	-0.0205	-0.00864	-0.02373
-0.01841	-0.02872	-0.01795	-0.03059	-0.02097	-0.02774
-0.02728	-0.03318	-0.0243	-0.03198	-0.02895	-0.03573
-0.01741	-0.02657	-0.00545	-0.01648	-0.0056	-0.01792
-0.02242	-0.02898	-0.01293	-0.02102	-0.00997	-0.01445

-0.02047	-0.03024	-0.02823	-0.03696	-0.02922	-0.0335
0.00014	-0.01083	0.00327	-0.00109	0.01193	0.00711
-0.00913	-0.01981	-0.01736	-0.02089	-0.00389	-0.00654
0.02311	0.01105	0.01735	0.00797	0.0244	0.01207
-0.00564	-0.01788	-0.01759	-0.03056	-0.02179	-0.03171
0.00178	-0.01103	0.02761	-0.00437	0.0106	-0.00017
-0.0014	-0.02085	-0.02129	-0.02933	-0.01898	-0.02484
-0.00072	-0.01155	-0.00335	-0.01794	0.00072	-0.01274
0.00195	-0.00799	0.003	-0.00183	0.01066	0.00187
0.00865	-0.01386	-0.00571	-0.01098	-0.00388	-0.01358
-0.01114	-0.02358	-0.02436	-0.03239	-0.02506	-0.03
0.00035	-0.00356	0.0133	0.00459	0.01714	0.01531
-0.00511	-0.01699	-0.00629	-0.02353	-0.00276	-0.01847
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0.01191	0.0085	0.02476	0.01911	0.02732	0.02229
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-0.0096	-0.02205	-0.01431	-0.02816	-0.01239	-0.01887
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0.00095	-0.00647	0.00901	0.00617	0.0169	0.00891
0.00028	-0.00884	0.0106	-0.00584	-0.00074	-0.00558
-0.00881	-0.01809	-0.02452	-0.03396	-0.02756	-0.03273
-0.0174	-0.0253	-0.02562	-0.03476	-0.01833	-0.02711
0.01258	0.00409	0.02341	0.01661	0.02342	0.01687
0.01379	0.00431	0.01424	0.01169	0.02448	0.01572
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0.0096	0.00306	0.00439	-0.00139	0.00854	0.00288
0.0103	0.00672	0.01691	0.01286	0.02781	0.02368
-0.00643	-0.01425	-0.00783	-0.0247	-0.00263	-0.0164
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0.00565	-0.0054	0.00382	-0.00214	0.01309	0.00364
0.00876	-0.00654	-0.00178	-0.0195	-0.01129	-0.02154
0.01201	0.00688	0.01565	0.00965	0.02489	0.00272
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0.01063	0.00178	0.0166	0.00995	0.02663	0.02295
-0.0087	-0.01953	-0.01552	-0.02851	-0.03293	-0.03896
0.0192	0.00913	0.02366	0.01099	0.02272	0.01661
-0.0033	-0.0148	-0.01518	-0.02256	-0.02244	-0.02663
0.00827	-0.00076	0.00904	0.00098	0.02122	0.00618
-0.01508	-0.0229	-0.02218	-0.02741	-0.02112	-0.02923

0.01389	0.00652	0.02564	0.01444	0.02604	0.01945
-0.00686	-0.01608	-0.01577	-0.03203	-0.01536	-0.02742
0.00689	-0.00165	0.0087	0.00263	0.02182	0.00373
-0.01729	-0.03078	-0.03653	-0.04504	-0.02515	-0.04114
0.00874	-0.00028	0.01541	0.00885	0.02492	0.01881
-0.01143	-0.02237	-0.02287	-0.03269	-0.02481	-0.03413
0.02658	0.01627	0.03591	0.02668	0.04599	0.03589
-0.00752	-0.01281	-0.02025	-0.02454	-0.01271	-0.01705
-0.01086	-0.02703	-0.02464	-0.03266	-0.03067	-0.03662
0.01074	-0.0088	0.01873	0.00732	0.02196	0.01808
0.00935	-0.00922	-0.0052	-0.01596	0.0031	-0.00965
-0.01612	-0.02485	-0.02683	-0.03289	-0.03685	-0.04261
0.01632	-0.00038	0.02382	0.00589	0.01835	0.01291
0.00579	-0.01212	0.01425	-0.00511	0.005	-0.00413
-0.02308	-0.03514	-0.02121	-0.03785	-0.02684	-0.03977
0.00129	-0.01049	-0.00552	-0.0094	0.00329	-0.01407
0.0216	0.00738	0.02466	0.0181	0.02203	0.01852
0.0023	-0.00323	0.00571	-0.00373	0.00058	-0.00439
-0.0124	-0.02751	-0.02248	-0.02668	-0.02186	-0.02569
0.01244	-0.0044	0.00547	-0.00138	0.00764	-0.00218
0.01081	0.00416	0.01531	0.01219	0.0272	0.01834
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0.00858	0.00068	0.01498	0.00649	0.01997	0.01056
0.0007	-0.00846	-0.00142	-0.0145	-0.01347	-0.02129
-0.00857	-0.01802	-0.0122	-0.01993	-0.01028	-0.0156
0.00921	0.00168	0.01278	-0.00109	0.01667	0.01304
0.00127	-0.0115	-0.00857	-0.01766	-0.00255	-0.0202
0.00028	-0.00853	-0.00221	-0.00844	0.00212	-0.01214
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-0.01349	-0.03288	-0.03477	-0.04507	-0.02635	-0.03732
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0.00463	-0.00487	0.00094	-0.01342	0.00092	-0.00691
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0.01054	0.00697	0.01008	0.00168	0.01632	0.00846
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0.01226	-0.00771	-0.00551	-0.01493	-0.00921	-0.01746
0.00313	-0.00376	0.01783	0.00356	-0.00642	-0.01231
-0.01799	-0.03045	-0.00138	-0.01037	-0.0012	-0.01467
0.00118	-0.00942	-0.00018	-0.0091	-0.01086	-0.0208
-0.01031	-0.01509	-0.00189	-0.01648	-0.00815	-0.01477
-0.00101	-0.01574	0.00039	-0.00783	0.00375	-0.00933
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0.0032	-0.00829	0.0155	0.01248	-0.01873	-0.02508
0.00995	0.00496	0.02905	0.01434	0.01177	0.00286
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0.01531	0.00975	0.03966	0.03384	0.01976	0.00094
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-0.01021	-0.0146	0.00428	-0.00432	-0.01716	-0.02385
0.01023	0.00606	0.03545	0.01735	0.00399	-0.00257
0.01219	-0.00446	0.02456	0.01446	0.02213	0.0047
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0.00581	-0.00223	0.00888	0.00148	0.00324	-0.00182
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0.04934	0.03392	0.05835	0.03738	0.02158	0.01488
0.01107	0.00413	0.01416	-0.00483	-0.01584	-0.0251
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0.0018	-0.0031	0.02816	0.01823	0.02036	0.01608
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0.00891	-0.00688	0.00713	-0.00419	0.00838	0.00105
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0.00833	-0.01103	0.00281	-0.00662	0.00409	-0.00423
-0.01105	-0.01451	0.01082	-0.00219	-0.00386	-0.01072
-0.02061	-0.02319	-0.00088	-0.00695	-0.00876	-0.02123
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0.00177	-0.00365	0.00844	0.00391	-0.00192	-0.01792
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0.00056	-0.0044	-0.00124	-0.00543	-0.00381	-0.02166
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0.02003	-0.00357	0.03289	0.01449	-0.02647	-0.03262
0.00622	-0.00335	0.01641	0.0051	0.00587	0.00133
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0.00831	-0.007	-0.00177	-0.01103	-0.00904	-0.01419
0.00356	-0.00707	0.0132	-0.00623	-0.00293	-0.01488
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0.01159	-0.0044	0.00961	-5.6E-05	-0.01051	-0.01679
-0.02118	-0.03861	-0.02384	-0.0302	-0.02099	-0.02758
0.00196	-0.00118	0.00542	-0.00224	-0.00286	-0.01222
0.01008	0.00348	0.02046	0.01251	0.01152	-0.00647
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0.00956	0.00421	0.02904	0.0116	0.01276	0.00554
0.00432	-0.0045	0.02535	0.01921	0.00759	0.00037
0.04985	0.00952	-0.01785	-0.04227	-0.02902	-0.04836
-0.01464	-0.02281	-0.00668	-0.01739	-0.01259	-0.02548
0.00204	-0.00983	0.01207	0.00604	-0.00678	-0.01274
-0.01072	-0.01662	-0.00109	-0.00937	-0.00482	-0.00999
-0.01714	-0.02395	-0.00453	-0.01381	-0.022	-0.03377
-0.02192	-0.02856	-0.0178	-0.02257	-0.03534	-0.04325
-0.02443	-0.03999	-0.0024	-0.00975	-0.01602	-0.02628
0.05667	0.04033	0.06044	0.04239	0.02134	0.01468
0.00702	-0.00246	0.01074	-0.00565	-0.0134	-0.02265
-0.03049	-0.03691	-0.00983	-0.01156	0.00298	-0.00691
-0.01616	-0.02389	-0.00901	-0.01747	-0.01136	-0.0211
-0.00448	-0.01175	0.00141	-0.01149	-0.00706	-0.01268
-0.01047	-0.01728	0.00078	-0.00269	-0.00049	-0.01074
0.00573	-0.00335	0.028	0.01253	0.02435	0.01612
-0.02269	-0.03124	-0.0128	-0.03582	-0.01918	-0.02964

-0.01052	-0.01565	0.00562	-0.00199	0.00333	0.00095
-0.03556	-0.03812	-0.00701	-0.02335	-0.02545	-0.03745
-0.02074	-0.02366	-0.00129	-0.00768	0.0072	-0.00418
-0.00506	-0.01408	0.01918	0.00468	0.00332	-0.00284
-0.00503	-0.0161	0.00781	-0.00999	-0.02885	-0.03328
0.01496	-0.0002	0.00886	0.0007	0.00838	0.00191
-0.00117	-0.00747	0.00156	-0.00316	0.02588	0.01249
0.00953	-0.00171	0.01182	0.00748	0.00607	-0.00037
-0.02467	-0.03236	-0.01988	-0.03426	-0.01349	-0.02747
-0.02771	-0.03777	-0.00375	-0.00792	-0.00532	-0.01142
0.00593	-0.00265	0.01094	0.00063	0.00604	0.00199
-0.00317	-0.00848	0.01649	0.0019	0.00924	-0.00968
-0.02969	-0.04522	-0.02483	-0.03273	-0.03269	-0.03989
-0.02389	-0.03279	-0.00998	-0.01451	0.01549	0.00011
0.00382	-0.01087	0.01959	0.01079	0.01487	0.00377
-0.01178	-0.01845	-0.00487	-0.01307	-0.01373	-0.02662
0.001	-0.00341	0.0035	-0.00303	-0.00773	-0.01247
0.00493	-0.01365	0.00574	-0.00106	0.01061	0.00145
-0.00777	-0.01441	0.00159	-0.00617	-0.00857	-0.01285
-0.02542	-0.02845	-0.00808	-0.0161	-0.0099	-0.01519
-0.01815	-0.02796	-0.0157	-0.02289	-0.01625	-0.02265
-0.0188	-0.02711	-0.02423	-0.03444	-0.03422	-0.042
0.01292	0.00199	0.00813	-0.0085	0.01326	0.00559
-0.00158	-0.00752	0.01424	0.00198	0.01197	0.00915
-0.02021	-0.02889	-0.01764	-0.02127	-0.02349	-0.02969
-0.00379	-0.01749	-0.00943	-0.01649	0.00314	-0.00223
-0.03347	-0.03806	-0.01729	-0.03344	-0.02323	-0.02995
-0.00589	-0.01202	0.00755	-0.00097	-0.00044	-0.00373
-0.0272	-0.03254	-0.02067	-0.02337	-0.0277	-0.04365
-0.00508	-0.0229	-0.00652	-0.02132	0.00309	-0.01218
0.00054	-0.00284	0.0243	0.00473	0.0343	0.01457
-0.0081	-0.01353	0.00373	-0.01224	-0.01143	-0.03029
-0.01657	-0.02683	-0.02107	-0.02831	-0.01851	-0.02518
-0.02962	-0.03422	-0.02405	-0.03403	-0.0252	-0.02854
-0.01832	-0.02357	-0.01622	-0.02993	-0.0228	-0.02762
-0.0477	-0.05625	-0.0501	-0.0566	-0.05508	-0.07124
0.00245	-0.00584	0.01656	0.01371	-0.00499	-0.01639
-0.00991	-0.01275	0.00571	0.00201	-0.00187	-0.00555
-0.00746	-0.01146	-0.00657	-0.01381	-0.01436	-0.0268
-0.02607	-0.03147	-0.01198	-0.01641	-0.01535	-0.02825

0.01603	0.01155	0.02419	0.01321	0.02956	0.01576
0.01374	0.00894	0.03218	0.02131	0.04011	0.03426
0.00827	-0.00248	0.01716	0.00053	0.01001	0.00384
0.02095	0.01044	0.00298	-0.0043	0.00687	-0.00682
0.00621	-0.00124	0.02066	0.00433	0.00952	0.00652
-0.00269	-0.00901	0.00568	0.00114	0.01564	0.00339
0.00766	-0.00547	0.00658	-0.00831	0.00279	-0.00651
0.01196	0.00525	0.00918	-0.00273	0.01961	0.0152
0.01749	0.00084	0.02094	0.00389	0.02042	0.01511
0.00169	-0.00678	-0.00961	-0.02308	0.00436	-0.00586
0.00594	-0.00016	0.02287	0.02098	0.0099	0.00144
0.02391	0.0159	0.0333	0.02174	0.03234	0.02629
0.00313	-0.00069	0.01152	0.0014	0.01252	0.00495
0.02501	0.01334	0.00657	0.00284	-0.00188	-0.0104
0.01451	0.00272	0.01254	-0.00138	0.0084	0.00105
0.02033	0.01129	0.03284	0.01918	0.02426	0.003
0.02349	0.01457	0.03237	0.01386	0.00602	-0.00235
-0.01351	-0.02673	-0.00772	-0.01671	-0.01564	-0.01933
0.02188	0.01745	0.0163	0.00773	0.01387	0.00799
0.02654	0.01833	0.04969	0.04658	0.03528	0.01902
-0.00137	-0.0105	0.00264	-0.01269	-0.01129	-0.01471
0.0116	0.00574	0.01137	0.00871	0.01304	0.00101
0.00552	-0.00062	0.00576	-0.0046	-0.00212	-0.01303
0.02967	0.02476	0.04543	0.03385	0.02055	0.01241
0.02841	0.00769	0.02116	0.01501	0.03441	0.02901
0.01751	0.01313	0.01733	0.00726	0.00306	-0.00092
0.0083	-0.00244	-0.00438	-0.01367	-0.01105	-0.02056
0.00495	0.00116	0.01032	0.00601	0.00321	-0.00023
0.02611	0.01896	0.01896	0.01565	0.02138	0.01724
0.00381	-0.0014	0.01973	0.01415	0.01565	0.00891
0.00239	-0.00616	0.00963	0.00572	-0.01093	-0.01489
0.01555	0.0089	0.03489	0.02075	0.01255	0.00331
0.0553	0.04209	0.05925	0.03918	0.03612	0.02685
0.01714	0.0059	0.01926	-2.6E-05	-0.00012	-0.0088
-0.0066	-0.01679	0.00624	0.0032	0.01231	0.00839
-0.00432	-0.01095	0.00553	-0.00548	0.00391	-0.00153
0.00762	0.00228	0.02192	0.0059	0.01207	0.00209
0.01118	0.0029	0.02221	0.01831	0.02059	0.00813
0.01746	0.01122	0.03813	0.02704	0.03723	0.02677
-0.00373	-0.01204	-0.0056	-0.01338	0.00266	-0.00055

0.00395	-0.00096	0.01851	0.0101	0.01325	0.00899
-0.01235	-0.01705	0.01299	-0.00311	-0.01341	-0.02571
0.0038	-0.00704	0.01154	0.0057	0.00861	-0.00016
0.01445	0.01004	0.03576	0.02878	0.02391	0.01523
-0.01765	-0.02483	0.00131	-0.01013	-0.01348	-0.0206
0.01788	0.00139	0.01152	0.00201	0.02193	0.01898
0.00779	0.00511	0.00853	0.00201	0.02918	0.01365
0.01768	0.00532	0.01537	0.00237	-0.00119	-0.00837
-0.00328	-0.03019	-0.01209	-0.01773	-0.00622	-0.01324
0.0063	-0.00359	0.00885	0.0004	0.00299	-0.00591
0.01875	0.00928	0.01763	0.01034	0.0145	0.00508
0.0178	0.0103	0.01924	0.0154	0.01891	-0.00071
0.00457	-0.01326	-0.0056	-0.02209	-0.0044	-0.024
0.01349	0.00927	0.00952	0.00466	0.02641	0.02344
0.00977	-0.00468	0.02358	0.02007	0.02308	0.01897
0.00682	-0.00016	0.01058	-0.01814	-0.01217	-0.01655
0.0062	-0.00184	0.01748	0.00945	0.01268	0.0055
0.02578	0.01552	0.01549	0.01043	0.01965	0.01141
0.00695	0.00439	0.0216	0.0136	0.01228	0.0046
0.00648	-0.00021	0.01145	0.00361	0.0028	-0.01228
-0.00572	-0.01035	-0.00334	-0.01416	0.00592	-0.01248
-0.00918	-0.02309	-0.00499	-0.0141	-0.00415	-0.02144
0.00895	0.00093	0.02017	-0.00127	0.02998	0.0199
0.0109	0.00255	0.02018	0.0076	0.03003	0.02128
0.00565	-0.00075	0.00149	-0.0031	0.0019	-0.00129
0.00328	-0.00468	0.01475	0.00339	0.00997	-0.00495
-0.00594	-0.01233	0.00387	-0.00287	0.02104	0.01291
0.01028	0.00498	0.01727	0.00644	0.0266	0.01921
-0.00884	-0.01526	0.00315	-0.01423	0.00276	-0.00705
0.01467	0.00575	0.01763	0.00811	0.01693	0.00363
0.01413	0.00172	0.01971	0.01649	0.01329	0.00999
0.00383	0.0009	0.01922	0.01187	0.02778	0.02007
-0.00896	-0.0201	-0.00645	-0.01383	-0.0008	-0.00895
-0.00404	-0.01608	-0.00883	-0.01779	-0.01059	-0.01561
-0.00618	-0.02621	-0.0072	-0.01954	-0.01854	-0.02749
-0.01614	-0.02231	0.00085	-0.01904	-0.00997	-0.01544
0.01653	0.00487	0.02149	0.01841	0.01886	-0.00181
0.00705	-0.00111	0.01696	0.01322	0.00574	0.00107
0.01528	0.0051	0.00016	-0.00261	0.00612	-0.01124
-0.000329	-0.00411	0.00408	-0.00151	0.00154	-0.00117

4.2 Classification

A classifier is a system which divides the data into different classes and gives relationship between the extracted features and the emotion related to the subject under observation. To know which emotions are present in the signal, classification of the signal is done. Classification is done with the help of Support Vector Machine into two classes namely low valence high arousal and high valence low arousal [61].

The extracted ERP feature values such as P100, N100, P200, N200, P300 and N300 with their corresponding latencies are fed to the classifier for classification.

4.3 Matlab:A Brief Introduction

MATLAB is a numerical computing environment and fourth generation programming language. It allows matrix manipulations, implementation of algorithms, plotting of functions and creation of user interfaces and can interface with other programs written in different languages such as C /C++, JAVA and FORTAN [64].

SVM Classifier is used for classification of above data. MATLAB functions and commands are used in classifier in order to classify the data

CHAPTER 5

RESULTS & DISCUSSION

5.1 Results

From the Classification technique, we classified the extracted data into two classes that is high valence and low valence using a Support Vector Machine (SVM) classifier. Extracted features from ERP in different combinations are used to analyze the accuracy of data. MATLAB Tool is used for classifier and high polynomial order is taken. The polynomial order is taken from 10 to 16.Though the higher polynomial is taken but it is not necessary that it always shows higher accuracy for each subject. Higher accuracy can be achieved by lower order polynomial also. Accuracy depends on the ERP feature extraction and classifier used. SVM classifier is used in this study. The results for higher order polynomial from 10 to 14 are shown from Fig.5.1 to Fig.5.7

ORDER 10

	SUB 1			SUB 2			SUB 3		
	Cz	F3	P4	Cz	F3	P4	Cz	F3	P4
P100-N100	81.25	80	85	81.25	90	82.5	80	82.5	78.75
P200-N200	73.75	78.75	81.25	81.25	85	85	82.5	80	81.25
P300-N300	83.75	85	86.25	83.75	77.5	78.75	78.75	83.75	86.25

Table 5.1 Accuracy of 3 Participants on 3 Electrodes on Order 10

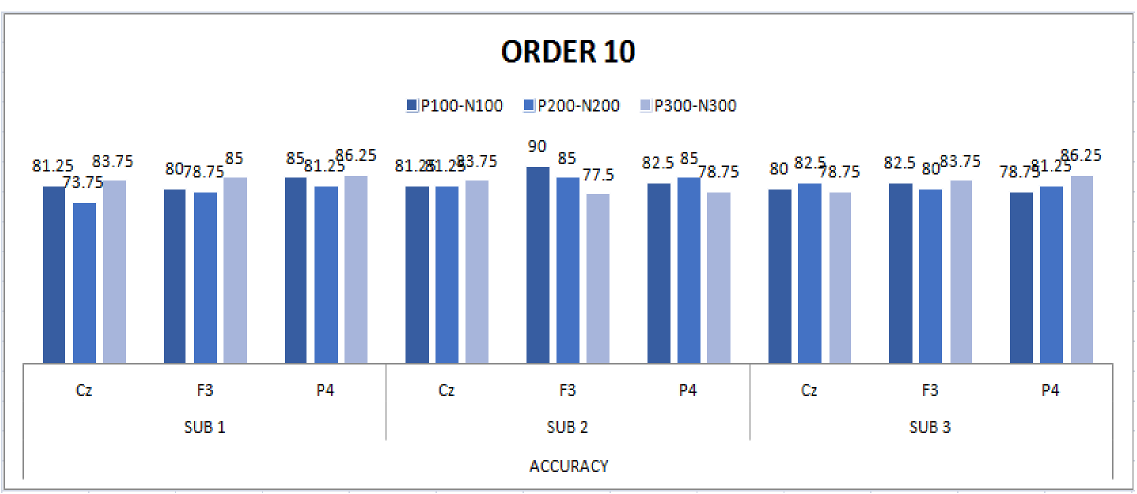

Fig 5.1 Accuracy of 3 participants on 3 electrodes on Order 10

While taking P100-N100 features of ERP as attributes to SVM with a polynomial order of 10 an accuracy of 81.25% is obtained on Cz electrode, 80% accuracy for f3electrode, 85% accuracy for p4 electrode for subject 1,similarly for the same attributes 81.25% accuracy is achieved on Cz electrode, 90% for f3 electrode and 82.5% for p4 electrode for subject 2 and for subject 3, an accuracy of 80% is obtained on Cz electrode followed by 82.5% for f3 and 78.79% for p4 electrode.

However when P200-N200 attributes are used for classification, 73.75% accuracy is obtained on Cz electrode, 78.75 % accuracy on f3 electrode and 81.25% accuracy on p4 electrode for subject 1, while 81.25% accuracy is obtained on Cz electrode, 85% accuracy on f3 electrode and 85% on p4 electrode for subject 2 and for subject 3 82.5% accuracy on Cz electrode, 80% accuracy for f3 electrode, 81.25% accuracy is achieved on p4 electrode.

For P300-N300 attributes the accuracy obtained is 83.75% accuracy on Cz electrode, 85 % accuracy at f3 and 86.25% accuracy for p4 electrode for subject 1, similarly 83.75% accuracy on Cz electrode, 77.5% accuracy for f3 electrode and 78.75% for p4 electrode for subject 2 and for subject 3, 78.75% accuracy on Cz electrode, 83.75% accuracy for f3 electrode and 86. 25% accuracy for p4 electrode is achieved.

ORDER11

	SUB 1			SUB 2			SUB 3		
	Cz	F3	P4	Cz	F3	P4	Cz	F3	P4
P100-N100	83.75	81.25	87.5	83.75	87.5	85	83.75	87.5	85
P200-N200	82.5	83.75	87.5	81.25	88.75	86.25	86.25	88.75	86.25
P300-N300	87.5	85	91.25	71.25	80	83.75	81.25	80	83.75

Table 5.2 Accuracy of 3 Participants on 3 Electrodes on Order 11

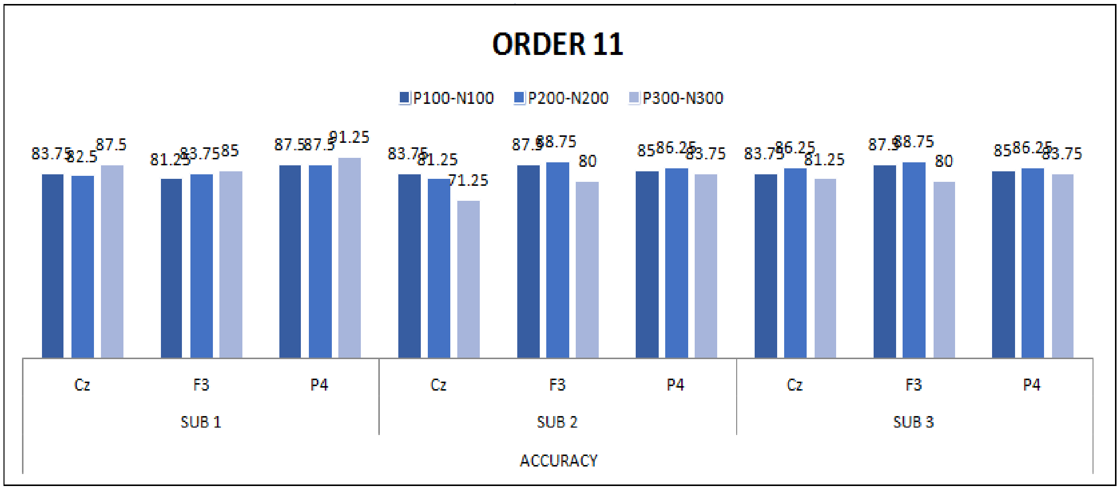

Fig.5.2 Accuracy of 3 participants on 3 electrodes on Order 11

Similarly the charts shown in figures 5, 6, 7, 8, 9 and 10 shows the accuracies obtained for the three subjects on ERP features when different polynomial orders are taken for emotion classification.

ORDER 12

	SUB 1			SUB 2			SUB 3		
	Cz	F3	P4	Cz	F3	P4	Cz	F3	P4
P100-N100	85	81.25	87.5	88.75	90	83.75	85	48.75	48.75
P200-N200	85	83.75	87.5	85	88.75	91.25	87.5	83.75	87.25
P300-N300	87.5	86.5	91.25	87.5	78.75	82.5	82.5	61.25	85

Table 5.3 Accuracy of 3 Participants on 3 Electrodes on Order 12

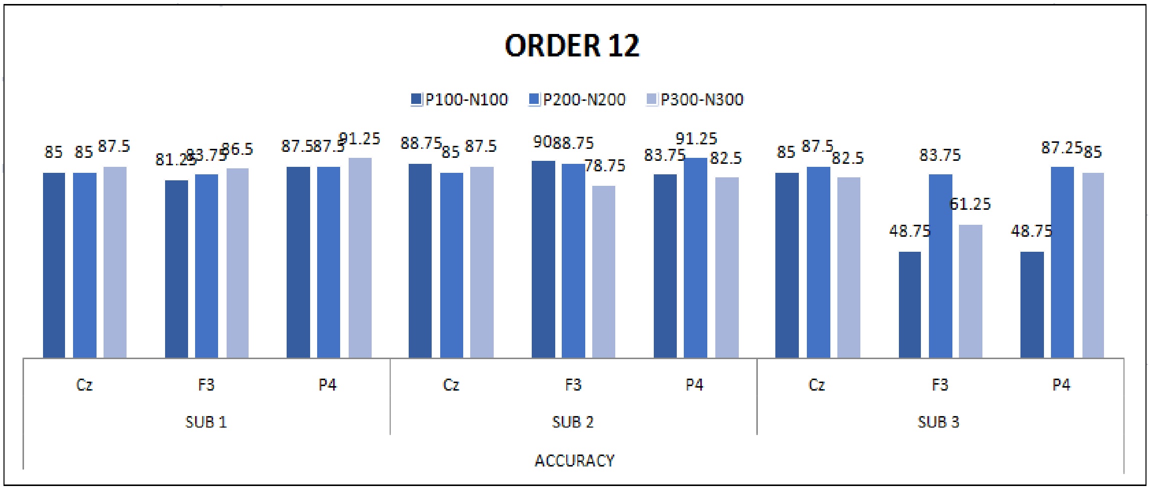

Fig. 5.3 Accuracy of 3 participants on 3 electrodes for Order12

Subject 2 shows consistently higher accuracies of 90% on f3 electrode of all the three electrodes for the selected p100-n100 attribute.

ORDER 13

	SUB 1			SUB 2			SUB 3		
	Cz	F3	P4	Cz	F3	P4	Cz	F3	P4
P100-N100	65	86.25	87.5	90	91.25	86.25	85	91.25	86.25
P200-N200	76.25	87.5	87.5	85	91.25	93.75	90	91.25	93.75
P300-N300	88.75	70	91.25	76.25	85	82.5	86.25	85	82.5

Table 5.4 Accuracy of 3 Participants on 3 Electrodes on Order 13

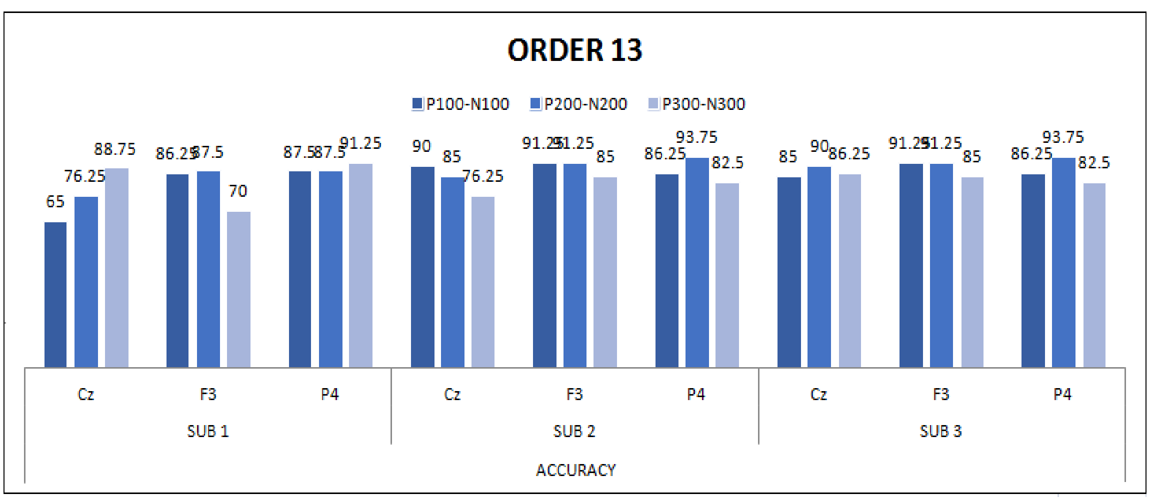

Fig.5.4 Accuracy of 3 participants on 3 electrodes for Order 13

While taking P100-N100 features of ERP as attributes to SVM with a polynomial order of 13, an accuracy of 65% is obtained on Cz electrode comparatively smaller as compared to the polynomial orders 10, 11 and 12. Similarly on classification with P200-N200 attributes, the accuracy shows a lower trend as compared to the subjects 2 and 3 for the same polynomial order.

ORDER 14

	SUB 1			SUB 2			SUB 3		
	Cz	F3	P4	Cz	F3	P4	Cz	F3	P4
P100-N100	67.5	66.25	90	91.25	93.75	87.5	78.75	51.5	52.5
P200-N200	91.25	70	90	82.5	90	95	90	65	92.5
P300-N300	68.75	87.5	95	87.5	87.5	87.5	87.5	43.75	88.75

Table 5.5 Accuracy of 3 Participants on 3 Electrodes on Order 14

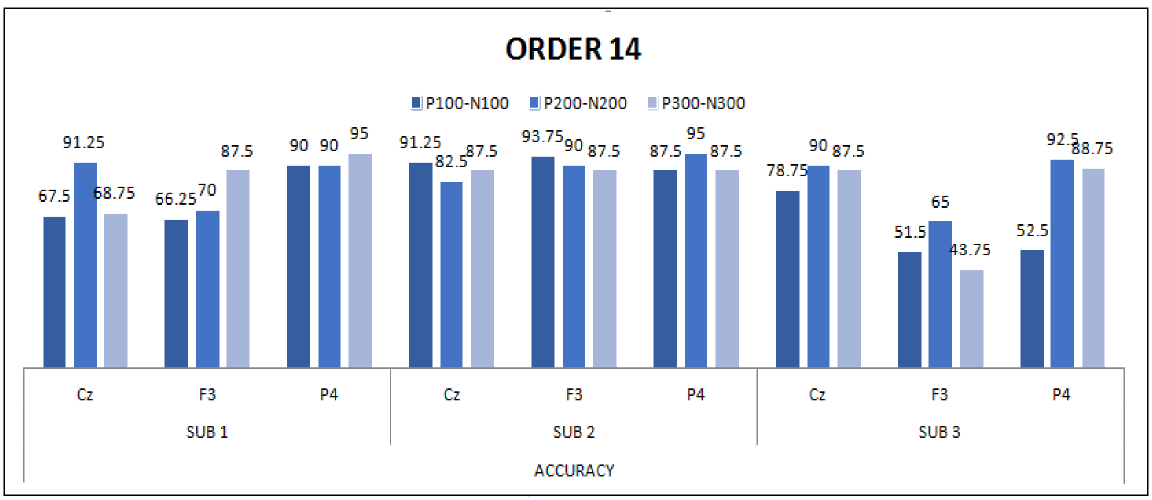

Fig.5.5 Accuracy of 3 participants on 3 electrodes for Order 14

On classification with a polynomial order of 14, lower accuracies are obtained on F3 electrode of subject 3. While using P100- N100 attributes for classification with this polynomial order, lower accuracies are obtained on Cz and F3 electrodes of subject 1 and F3 and P4 electrodes for subject3. Subject 2 shows consistently higher accuracies on the three electrodes for the selected attributes. Higher accuracies are consistently obtained on P4 electrodes of the three subjects on the acquired ERP features.

ORDER 15

	SUB 1			SUB 2			SUB 3		
	Cz	F3	P4	Cz	F3	P4	Cz	F3	P4
P100-N100	70	63.75	71.25	92.5	93.75	88.75	85	93.75	88.75
P200-N200	92.5	85	80	92.5	90	95	91.25	90	95
P300-N300	71.25	72.5	77.5	82.5	90	55	90	90	55

Table 5.6 Accuracy of 3 Participants on 3 Electrodes on Order 15

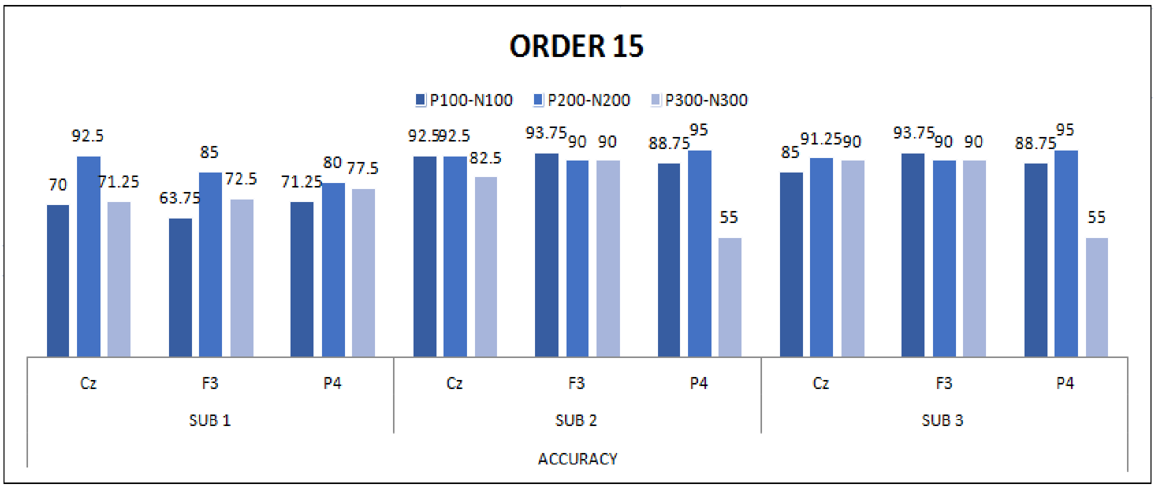

Fig.5.6 Accuracy of 3 participants on 3 electrodes for Order 15

Good results are obtained on almost all the electrodes except for P300-N300 ERP features. The accuracy as high as 95 % is obtained on P4 electrode.

ORDER 16

	SUB 1			SUB 2			SUB 3		
	Cz	F3	P4	Cz	F3	P4	Cz	F3	P4
P100-N100	81.25	80	85	81.25	90	82.5	80	82.5	78.75
P200-N200	73.75	78.75	81.25	81.25	85	85	82.5	80	81.25
P300-N300	83.75	85	86.25	83.75	77.5	78.75	78.75	83.75	86.25

Table 5.7 Accuracy of 3 Participants on 3 Electrodes on Order 16

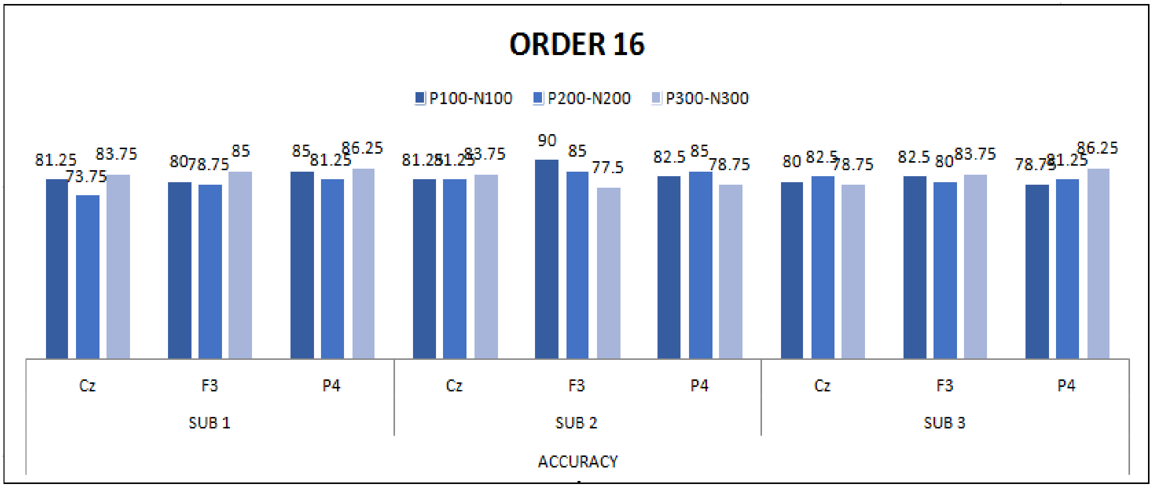

Fig.5.7 Accuracy of 3 participants on 3 electrodes for Order 16

At this polynomial order, the accuracy remains high on all the three electrodes for the three subjects under observation.

To perform the subject wise analysis for classification of emotions, the figures 5.8, 5.9 and 5.10 are shown herein for different polynomial orders.

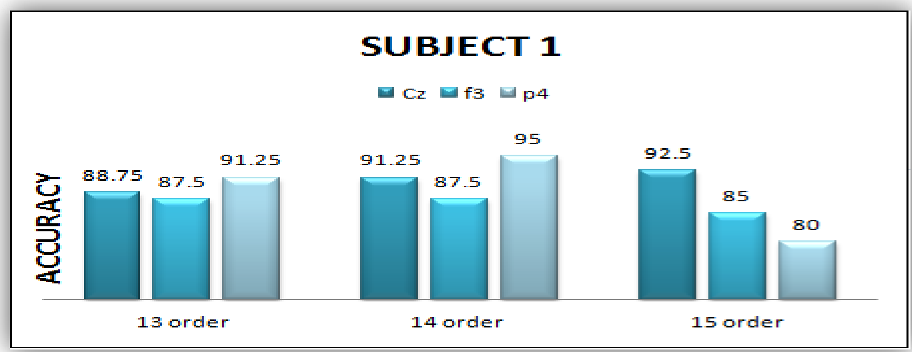

Fig.5.8 Accuracy of Subject 1 for all 3 electrodes

From Fig.5.8 it can be seen that the best results are obtained at polynomial order 14 on all the selected 3 electrodes for subject1.

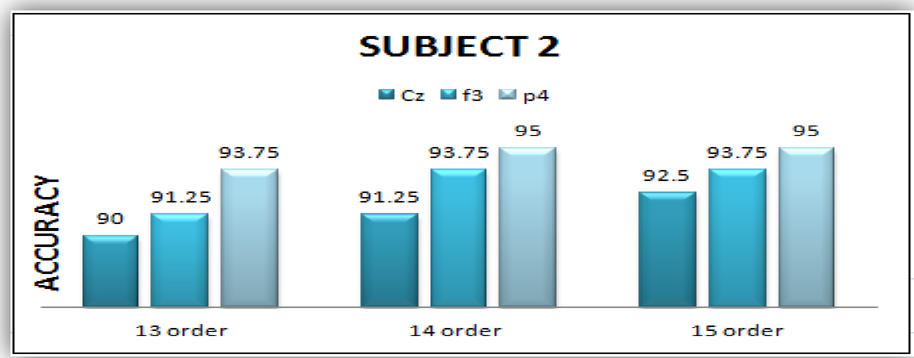

Fig.5.9 Accuracy of Subject 2 for all 3 electrodes

Fig.5.9 also asserts that when using polynomial order 14, better results are obtained for subject 2 with P4 electrode topping the table by displaying higher accuracies. Even good results are obtained at polynomial order 15.

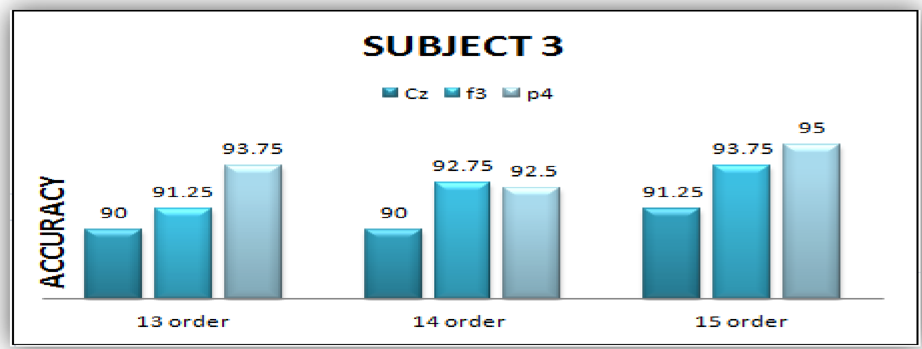

Fig.5.10 Accuracy of Subject 3 for all 3 electrodes

Lower accuracies are obtained for subject 3 on polynomial orders other than polynomial order 15. P4 electrode again tops the chart by displaying higher accuracies at almost all the polynomial orders.

5.2 Averaged ERP

The average ERP is taken of 5 electrodes in combination. Five electrodes are Cz, P3, P4, Fp1 and Fp2 and out of which Cz is the electrode which is being analyzed and p3-p4 and fp1-fp2 are taken in combination and being analyzed depending upon the values of the

ERP feature. Average ERP is being analyzed on the basis of polynomial order .Lower order polynomial is taken.

The Averaged results in are shown from Fig.5.11 to Fig.5.16

ORDER 1

	SUB 1			SUB 2			SUB 3		
	Cz	**Fp1-Fp2**	**P3-P4**	**Cz**	**Fp1-Fp2**	**P3-P4**	**Cz**	**Fp1-Fp2**	**P3-P4**
ERP-LATENCY	75	70.83	62.5	58.33	50	54.17	58.33	66.67	50

Table 5.8 Accuracy of 3 Participants on 5 Electrodes on Order 1

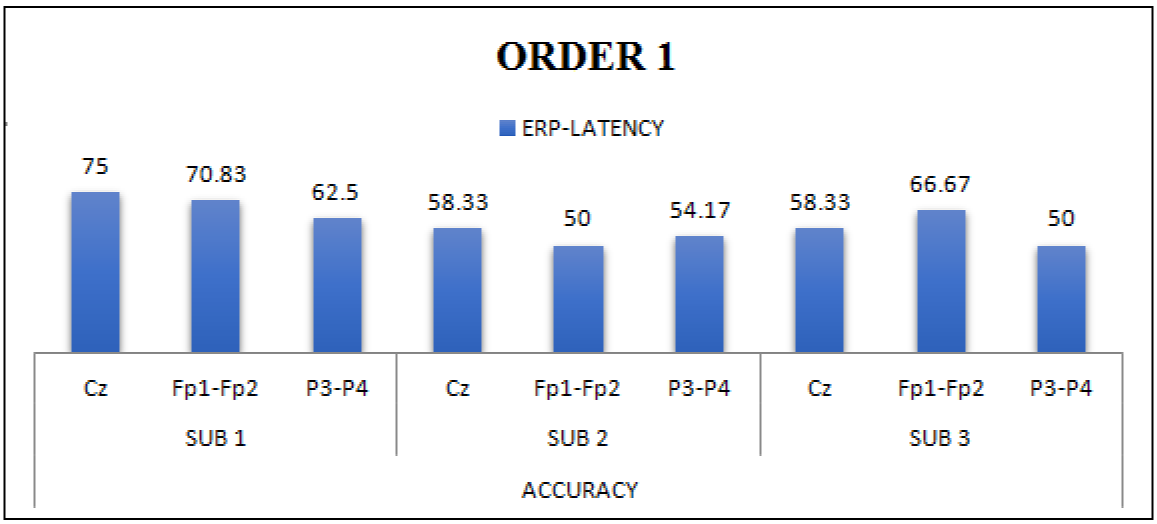

Fig.5.11 Accuracy of 3 electrodes for 3 participants for order 1

Fig.5.11 shows that while taking ERP and their corresponding latencies as attributes to SVM, an accuracy of 75% is obtained on Cz electrode, 70.83% on fp1-fp2 electrodes and 62.5% accuracy is achieved on p3-p4 electrodes for subject 1. For subject 2, 58.33% accuracy is achieved on Cz electrode, 50% on fp1-fp2 electrodes and 58.33% is obtained on p3-p4 electrodes and similarly, 58.33% accuracy is achieved on Cz electrode, 66.67% is achieved on fp1-fp2 electrode and 50% on p3-p4.

ORDER 2

	SUB 1			SUB 2			SUB 3		
	Cz	Fp1-Fp2	P3-P4	Cz	Fp1-Fp2	P3-P4	Cz	Fp1-Fp2	P3-P4
ERP-LATENCY	75	66.67	70.83	66.67	62.5	41.67	75	66.67	50

Table 5.9 Accuracy of 3 Participants on 5 Electrodes on Order 2

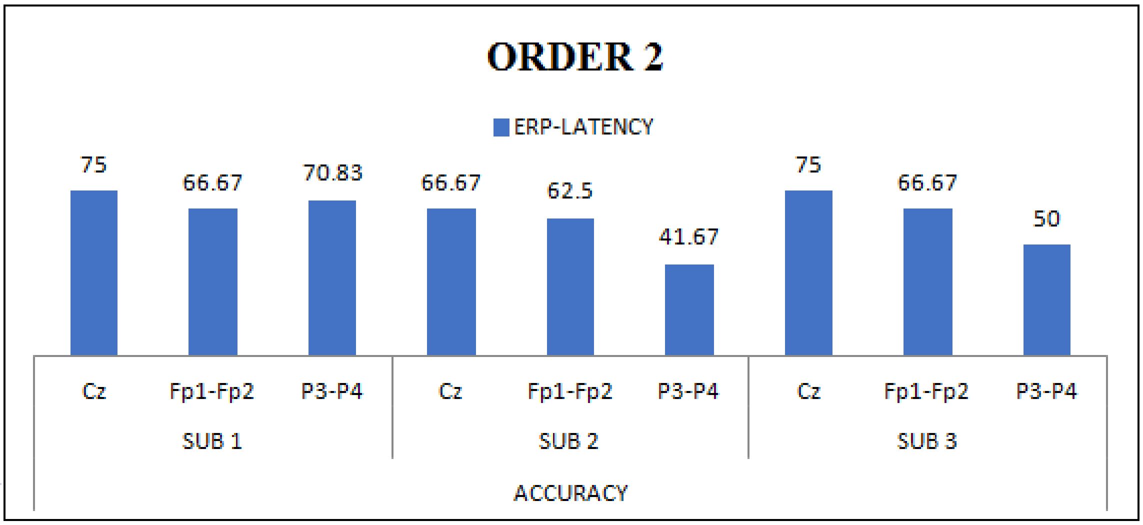

Fig.5.12 Accuracy of 3 electrodes for 3 participants for order 2

Similarly the charts shown in figures 5.12, 5.13, 5.14, 5.15 and 5.16 shows the accuracies obtained for the three subjects on ERP features and their corresponding latencies when different polynomial orders are taken for emotion classification.

ORDER 3

	SUB 1			SUB 2			SUB 3		
	Cz	Fp1-Fp2	P3-P4	Cz	Fp1-Fp2	P3-P4	Cz	Fp1-Fp2	P3-P4
ERP-LATENCY	91.67	70.83	66.67	66.67	62.5	50	91.67	66.67	87.5

Table 5.10 Accuracy of 3 Participants on 5 Electrodes on Order 3

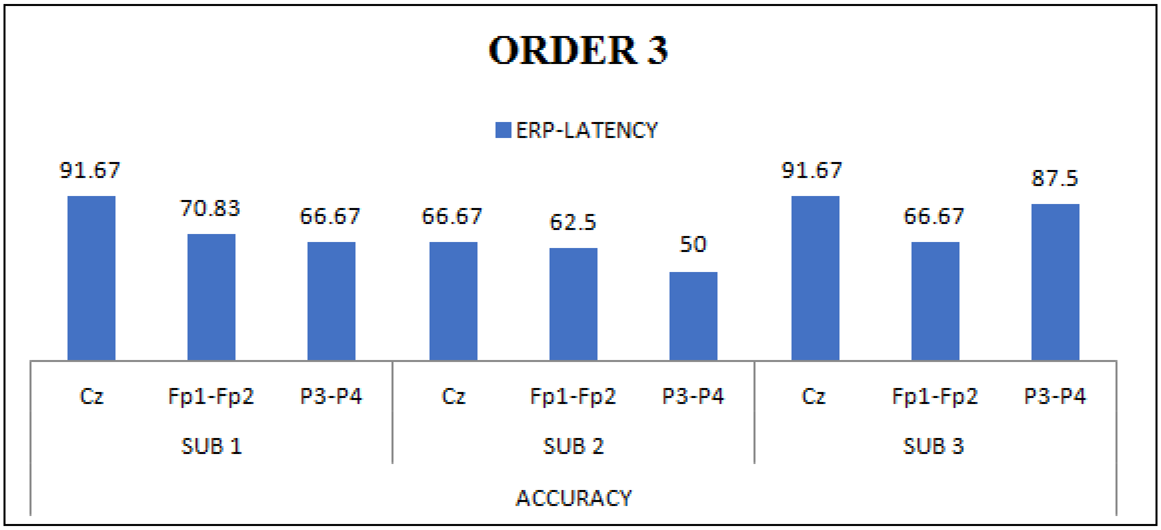

Figure 5.13 Accuracy of 3 electrodes for 3 participants for order 3

Fig.5.13 shows that while taking ERP and their corresponding latencies as attributes to SVM, an accuracy of 91.67% is obtained on Cz electrode, 70.83% on fp1-fp2 electrodes and 66.67% accuracy is achieved on p3-p4 electrodes for subject 1. For subject 2, 66.67% accuracy is achieved on Cz electrode, 62.5% on fp1-fp2 electrodes and 50% is obtained on p3-p4 electrodes and similarly, 91.67% accuracy is achieved on Cz electrode, 66.67% is achieved on fp1-fp2 electrode and 87.5% on p3-p4.

ORDER 4

	SUB 1			SUB 2			SUB 3		
	Cz	**Fp1-Fp2**	**P3-P4**	**Cz**	**Fp1-Fp2**	**P3-P4**	**Cz**	**Fp1-Fp2**	**P3-P4**
ERP-LATENCY	91.67	79.167	70.83	75	62.5	66.67	91.67	79.16	100

Table 5.11 Accuracy of 3 Participants on 5 Electrodes on Order 4

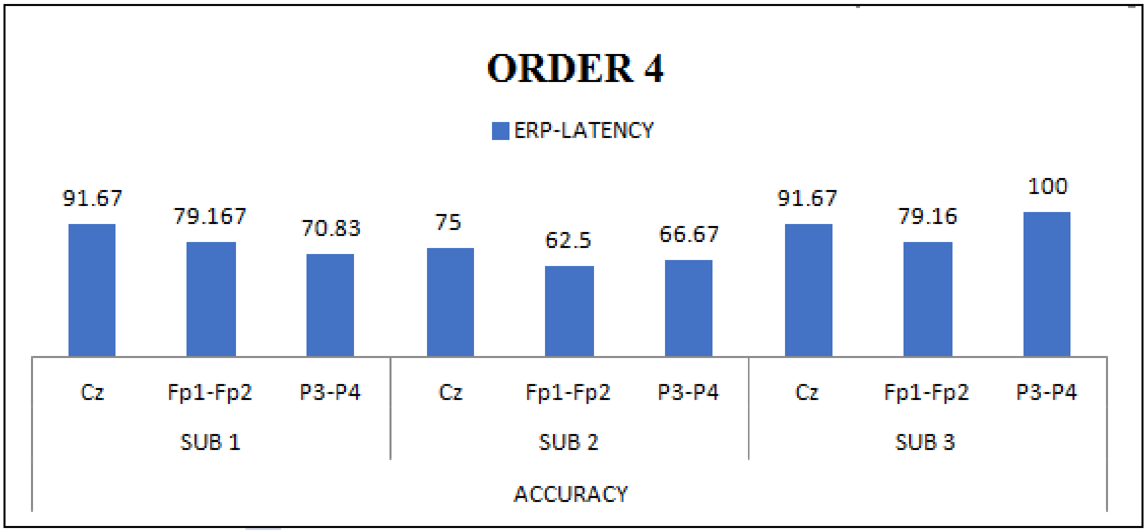

Fig.5.14 Accuracy of 3 electrodes for 3 participants for order 4

On classification with a polynomial order of 4, lower accuracies are obtained on fp1-fp2 electrodes of subject 2 and higher accuracy related to fp1-fp2 electrodes are 79.17% for subject 1 and 3.

ORDER 5

	SUB 1			SUB 2			SUB 3		
	Cz	Fp1-Fp2	P3-P4	Cz	Fp1-Fp2	P3-P4	Cz	Fp1-Fp2	P3-P4
ERP-LATENCY	100	91.67	83.33	91.67	79.17	66.67	91.67	79.17	100

Table 5.12 Accuracy of 3 Participants on 5 Electrodes on Order 5

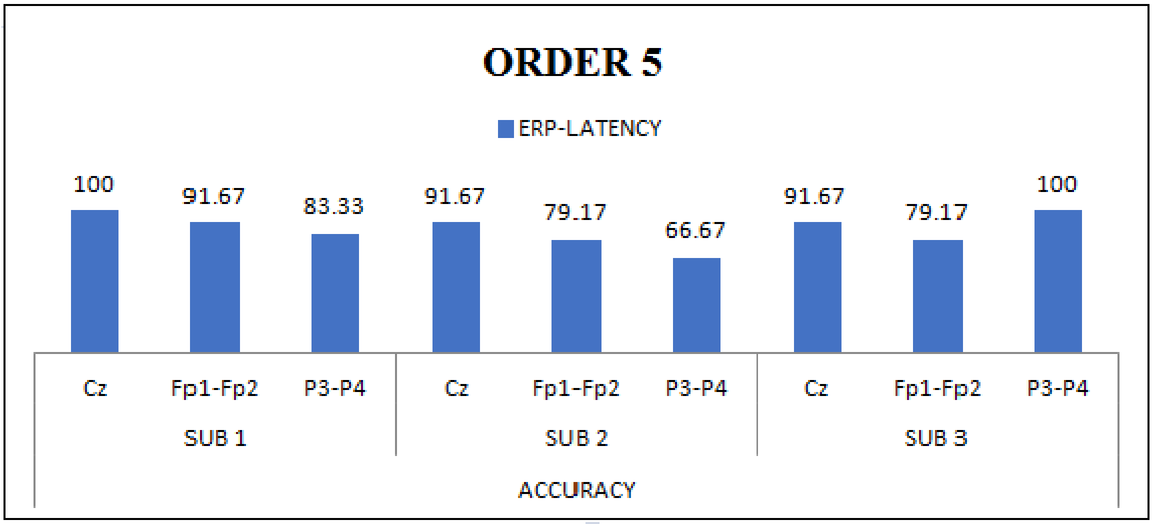

Fig.5.15 Accuracy of 3 electrodes for 3 participants for order 5

Good results are obtained on almost all the electrodes except p3-p4 for subject 3.The accuracy as high as 100% is obtained on Cz electrode.

ORDER 6

	SUB 1			SUB 2			SUB 3		
	Cz	**Fp1-Fp2**	**P3-P4**	**Cz**	**Fp1-Fp2**	**P3-P4**	**Cz**	**Fp1-Fp2**	**P3-P4**
ERP-LATENCY	100	91.67	91.67	91.67	87.5	75	100	87.5	100

Table 5.13 Accuracy of 3 Participants on 5 Electrodes on Order 6

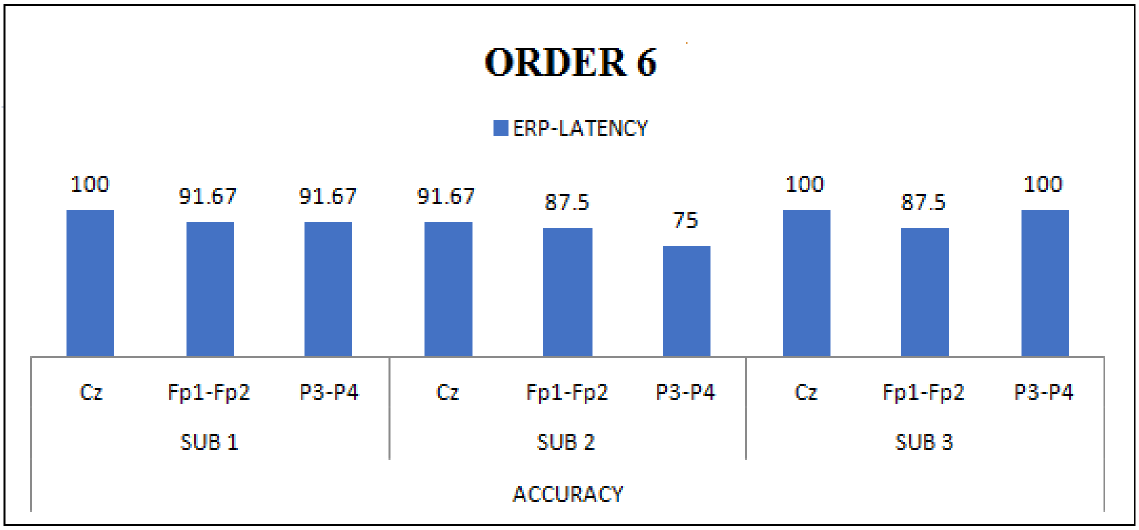

Fig. 5.16 Accuracy of 3 electrodes for 3 participants for order 6

At this polynomial order, the accuracy remained high on all five electrodes for three subjects under observation.

To perform the subject wise analysis for classification of emotions, the figures 5.17, 5.18 and 5.19 are shown herein for different polynomial orders.

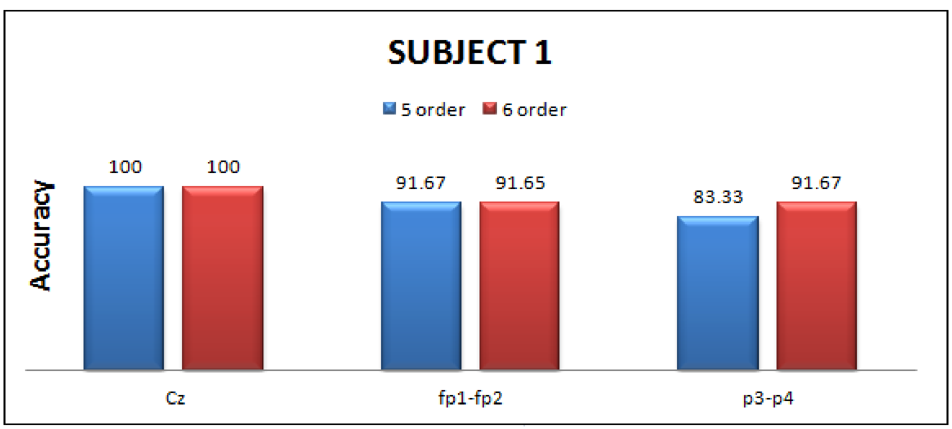

Fig.5.17 Accuracy of participant1 for 3 electrodes

Fig.5.17 shows that best results are obtained on Cz electrode at polynomial order 5 and 6 for subject 1.

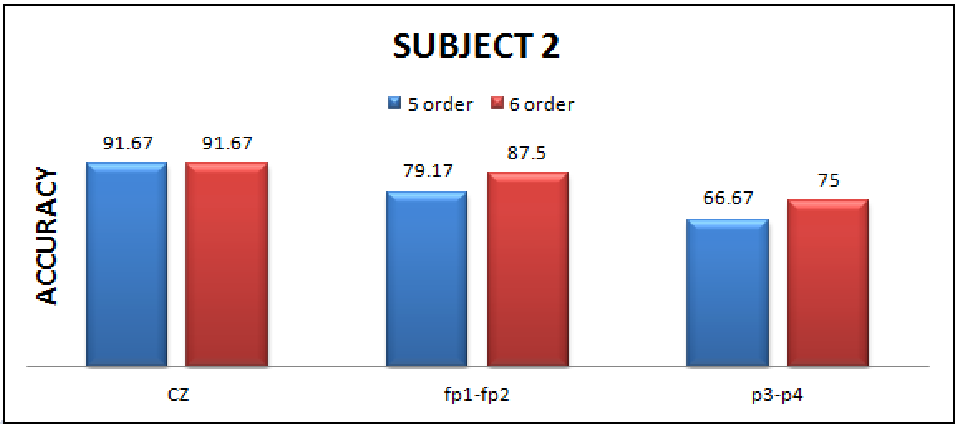

Fig.5.18 Accuracy of participant 2 for 3 electrodes

Lower accuracies are obtained for subject 2 on polynomial order 5.Cz electrode again tops the chart by displaying higher accuracies at almost both the polynomial order that are 5 and 6.

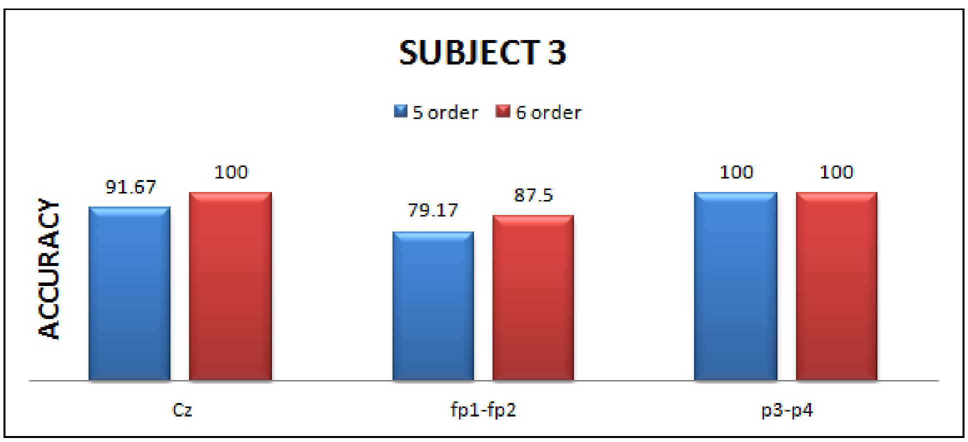

Fig.5.19 Accuracy of subject 3 for 3 electrodes

Fig.5.19 also asserts that when using polynomial order 5 and 6, better results are obtained for subject 3 with p3-p4 electrode toppings the table by displaying higher accuracies

CHAPTER 6

CONCLUSION

6.1 ERP

This paper includes the data acquisition technique which is used to classify emotions. The filter used in EEG signal is comb band stop filter. This filter has been used to eliminate the interference of 50 Hz power source in the acquired EEG signal. Though the filter reduces the noise and its harmonics but as well attenuates the signal in the time range of 300 ms, thereby attenuating ERP P300, this ERP has been attenuated will yield in lower classification accuracy by which using this ERP and its latency values. After the data has been acquired, filtering operation is being carried out. The processed data can be then used for the feature extraction and after that classification can be performed to classify emotions along valence axis.

The highest accuracy obtained on p4 electrode is 95%, 93.75 % on f3 electrode and 92.5% accuracy on Cz electrode. From the considered electrodes for emotion classification, P4 electrode tops the chart for almost all polynomial orders used for classification of emotions. It can also be concluded from the obtained results that accuracy in emotion classification is proportional to the polynomial order of SVM classifier. Lower order gives lower accuracy as is seen for polynomial order lesser than 9. Though after increasing the order accuracy increases for the ERP features. Though, the two classes of emotions could be classified with 95% accuracy, decreasing the polynomial order still remained a challenge. The highest accuracy for all the five electrodes in combination is shown in Fig.6.1

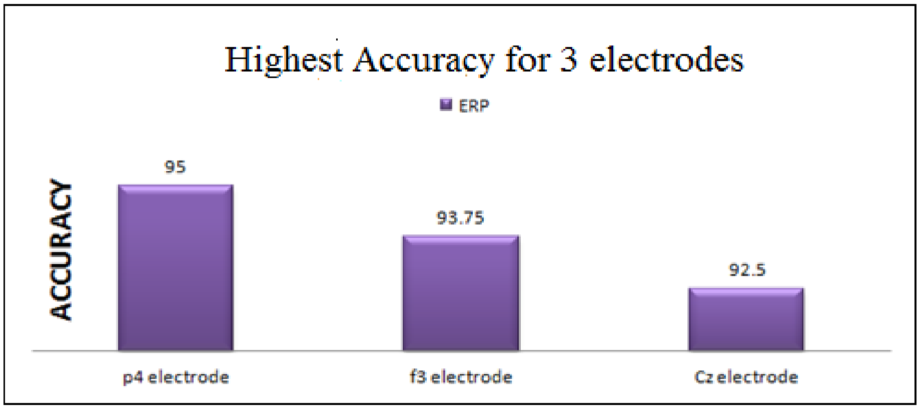

Fig.6.1 Accuracy of all 3 electrodes for ERP

6.2 Averaged ERP

The electrodes Cz, fp1, fp2 p3 and p4 are chosen for average ERP analysis. Data is acquired at the sampling rate of 500Hz. The acquired data for 40 similar EEG signals evoked by showing high and low valence images is averaged to remove random signals in time domain. The data collected is used for extracting ERP features that are P100, N100, P200, N200, P300 and N300 with their corresponding latencies and after that features are classified using SVM. The overall accuracy obtained on Cz is 100% for subject 1 and subject 3, 91.67% accuracy is obtained on fp1-fp2 for subject 1 and 100% accuracy is achieved on p3-p4 electrode for subject 3. It has been concluded that accuracy is proportional to polynomial order. Lower order gives lower accuracy and after increasing the order, accuracy automatically increases. Averaging of the signals helps in achieving better accuracy with much lesser order as compared to that done without averaging of the signals. The highest accuracy for all the five electrodes in combination is shown in Fig.6.2

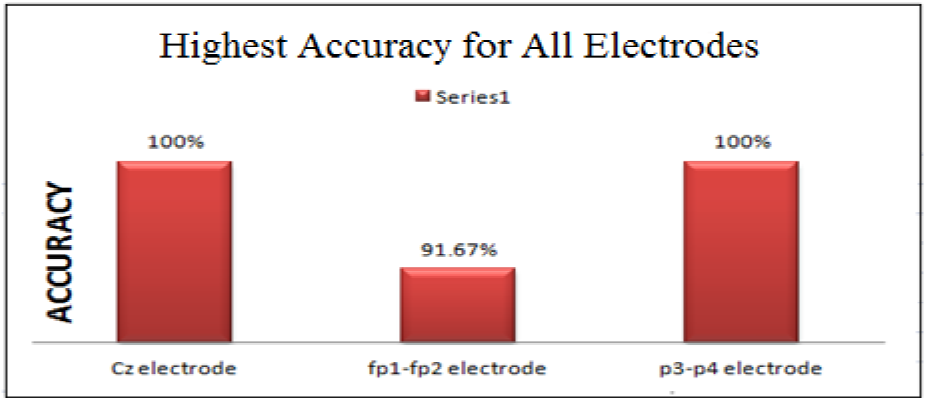

Fig.6.2 Accuracy of all 3 electrodes for Averaged ERP

6.3 Future Work

There are several avenues for future research:

1. Data has been acquired only on 3 electrodes, more number of electrodes can also be taken for further classification.

2. Only ERP feature is taken, more number of features can be extracted in order to get very high accuracy results.

3. As data has been classified in two classes, data classification in 4 classes can also be done to improve results.

CHAPTER 7

Check for Originality

The dissertation report presented here has been checked for its originality using online plagiarism checker "Paper Rater", available at "http://www.paperrater.com/plagiarism_checker". Various theoretical concepts are explained as per the references from different technical books which I studied during my engineering graduation and post graduation studies. Thanks to all those who are already present in my references text.

REFERENCES

[1] T. Dalgleish, "The Emotional Brain," Nature Reviews Neuroscience, vol. 5, pp. 582-589, July 2004.

[2] Theories of emotion, available at "http://psychology.about.com/od/psychologytopics/a/theories-of-emotion.htm"

[3] Robert Horlings, "Emotion recognition using brain activity", Delft University of technology, Man-Machine Interaction Group, 27 March 2008.

[4] H. Bung and S. Furui, "Automatic Recognition and understanding of spoken languages- a first step toward natural human machine communication", Proceedings of IEEE, vol. 88, issue: 8, pp.1142- 1165. Doi 10.1109/5.880077 Aug. 2000.

[5] R. Cowie, E. Douglas, N.Tsapatsoulis, Votsis G., Kollias G., Fellenz W. and Taylor J.G, "Emotion Recognition in human computer interaction", Transactions IEEE Signal Processing, Volume: 18 Issue: 1 pp.32-80 doi 10.1109/79.911197Jan 2001.

[6] P. Ekman, W.V. Friesen, M. O'Sullivan, A. Chan, I. Diacoyanni-Tarlatzis, K. Heider, R. Krause, W.A. LeCompte, T. Pitcairn, and P.E. Ricci-Bitti, "Universals and Cultural Differences in the Judgments of Facial Expressions of Emotion," J. Personality and Social Psychology, vol. 53, no. 4, pp. 712-717, Oct. 1987.

[7] Sander Koelstra, "A database for emotion analysis using physiological signals", IEEE Transactions on Affective Computing, vol. 3, no.1, Jan-Mar 2012.

[8] W.G. Parrott, "Emotions in Social Psychology", Essential Readings Psychology Press, 2001.

[9] R.E. Jack, O.G.B Garrod, and P.G Schyns, "Dynamic Facial Expressions of Emotion Transmit an Evolving Hierarchy of Signals over Time", Current Biology, vol.24, no. 2, pp. 187-192, 2014.

[10] What's your company's emotion score, available at "http://www.beyondphilosophy.com/blog/whats-your-companies-emotion-score".

[11] R. Plutchik, "The Emotions: Facts, Theories and a New Model", Random House, New York, 1962.

[12] M.M. Bradley and P.J. Lang, "Measuring Emotion: The Self-Assessment Manikin and the Semantic Differential," J. Behavior Therapy Experimental Psychiatry, vol. 25, no. 1, pp. 49-59, Mar. 1994.

[13] James A. Russell, "A Circumplex Model of Affect", Journal of Personality and Social Psychology, vol. 39, no.6, pp. 1161-1178, 1980.

[14] Inner body, available at "http://www.innerbody.com/image/nerv02.html".

[15] Frontal lobes, available at "http://www.cyclopaedia.es/wiki/Frontal_lobes".

[16] Parietal lobes, available at "http://www.cyclopaedia.es/wiki/ Parietal_lobes".

[17] The Brain made simple, available at "http://brainmadesimple.com/temporal-lobe.html"

[18] The human brain and its primary divisions, available at "http://www.paulkiritsis.net/_blog/Down_The_Rabbit_Hole/post/The_Human_Brain_and_it _Primary_Divisions/".

[19] What is the function of various brainwaves, available at "http://www.scientificamerican.com/article/what-is-the-function-of-t-1997-12-22/".

[20] Brain Waves Anatomy, available at http://www.medicalook.com/human_anatomy/organs/Brain_waves.html"

[21] Mandeep Singh, Sunpreet Kaur, "Epilepsy Detection using EEG: An Overview", International Journal of Information Technology & Knowledge Management, Val 6, no1, pp.3-5, 2012.

[22] Mandeep Singh, "Introduction to biomedical Instrumentation", PHI Learning, New Delhi, 2010.

[23] K. Takahashi, "Remarks on Emotion Recognition from Bio- Potential Signals", Int. Conf. on Autonomous Robots and Agents, pp. 186-191, 2004.

[24] K.H. Kim, S.W. Band., and S.B. Kim, "Emotion Recognition System using short-term monitoring of physiological signals", Proceedings on Medical & Biological Engineering & Computing, vol. 42, pp. 419-427, 2004.

[25] K. Takahashi, and A. Tsukaguchi, "Remarks on Emotion Recognition from Multimodal Bio-Potential Signals", IEEE Transactions on Industrial Technology, vol. 3, pp. 1654-1659, 2003.

[26] H. Robert, D. Dragos, and J.M.R. Leon, “Emotion Recognition using Brain Activity”, Int. Conference on Computer Systems and Technologies, pp. II.1-1 – II.1-6,2008.

[27]Generation of simulated EEG Wave, “ http://www.cs.bris.ac.uk/~rafal/phasereset/”

[28] How brain –computer interfaces work, available at “http://computer.howstuffworks.com/brain-computer-interface.htm”

[29] Viet Hoang Anh, Manh Ngo Van, Bang Ban Ha, Thang Huynh Quyet, “A Real Time Model Based Support Vector Machine for Emotion Recognition through EEG”, International Conference on Control, Automation and Information Science (ICCAIS), 2012.

[30] Valer Jurcak, Daisuke Tsuzuki, Ippeita Dan, “10.20, 10/10 and 10/5 systems revisted, Their validity as relative head surface based positioning systems”, Sensory and Cognitive Food Science Laboratory, National Food Research Institute,2-1-12 Kannondai, Tsukuba, pp 305-8642, Japan, 2007.

[31]DannyOude Bos,”EEG Based Emotion Recognition”,available at “http://en.wikipedia.org/wiki/Robert Plutchik

[32] Sean Jenkins, Raymond Brown and Neil Rutterford, “Comparing Thermographic, EEG, and Subjective Measures if Affective Experience During Simulated Product Interactions”, vol. 3, no.2, 2009.

[33] Chatrian, G.E., Lettich, E., Nelson, P.L., “Ten percent electrode system for topographic studies of spontaneous and evoked EEG activity”. Am. J. EEG Technol. 25, pp 83–92, 1985.

[34] Brain Master EEG Systems, available at “http://www.brainmaster.com/kb/entry/438/”.

[35] Suarez, E., Viegas, M.D., Adjouadi, M., Barreto, A., “elating induced changes in EEG signals to orientation of visual stimuli using the ESI-256 machine”, Biomed. Sci. Instrum. 36, pp. 33–38, 2000.

[36] Oostenveld, R., Praamstra, P., “The five percent electrode system for high-resolution EEG and ERP measurements”, Clin. Neurophysiology. 112, pp. 713–719, 2005.

[37] EEG Polarity 2, available at "http://searchinsleep.blogspot.in/2012/11/eeg-polarity-2.html"

[38] Mandeep Singh, Mooninder Singh and Surabhi Gangwar "Emotion Detection Using Electroencephalography (EEG): A Review", International Journal of Information Technology & Knowledge Management. vol.7, no.1, Dec.2013.

[39] A. Savran, K. Ciftci, Gu Chanel, J.C Mota, L.H Viet, B.Sankur , L.Akarun , A. Caplier, and M.Rombaut "Emotion detection in the loop from brain signals and facial images". IEE Computer society, vol.2 issue1 pp. 18-31, Doi(http://doi.ieeecomputersociety.org/10.1109/T AFFC.2011.15), jan-march 2012.

[40] C. A. Frantzidis, C. Bratsas, Papadelis, C. L., Konstantinidis, E., Pappas, C., & P.D Bamidis, "Toward emotion aware computing: An integrated approach using multichannel neurophysiological recordings and affective visual stimuli".IEEE Transactions on Information Technology In Biomedicine vol.14 no.3, pp.589-597, 2010.

[41] Mandeep Singh, Mooninder Singh and Nikhil Singhal, "Emotion Quantification along Valence Axis Using EEG Signals", International Journal of Information Technology & Knowledge Management, vol.7, no.1, Dec.2013.

[42] Mandeep Singh, Mooninder Singh and Surabhi Gangwar, "Feature Extraction from EEG for Emotion Classification", International Journal of Information Technology & Knowledge Management, vol.7, no.1 pp.11-15, Dec 2013

[43] Mandeep Singh, Mooninder Singh and Surabhi Gangwar, "Arousal Detection Using EEG Signals", International Journal of Information Technology & Knowledge Management, vol.7, no.1 pp.11-15, Dec 2013.

[44] Mandeep Singh, Mooninder Singh, Nikhil Singhal, "Emotion Recognition along valence Axis Using naïve bayes Classifier", vol. 7,no.1, pp.51-55, Dec 2013.

[45] Mandeep Singh, Mooninder Singh and Nikhil Singhal, "ANN Based Emotion Recognition Along Valence Axis Using EEG", International Journal of Information Technology & Knowledge Management, vol.7 no.1, Dec.2013.

[46] Fabio Babilioni, Luigi Bianchi, Francesco Semeraro, "Mahalanobis Distance-Based Classifier Are Able to Recognize EEG Patterns by Using Few EEG Electrodes", Proceedings of the 23rd Annual EMBS International Conference, October 25-28,Istanbul Turkey,2001

[47] G.Chanel, J. Kon, D. Grandjean, and T.Pun “Emotion assessment: Arousal evaluation using EEG's and peripheral physiological signals”. Technical Report, Computer Vision Group, Computing Science Center, University of Geneva, Dec. 2005.

[48] Abdul-Bary Rouf Suleiman, Toka Abdul-Hameed Fatehi, “ Feature extraction techniques of EEG signal for BCI applications”, Faculty of Computer and Information Engineering Department College of Electronics Engineering, University of Mosul, Iraq, 2007.

[49] M. M. Bradley & P.J. Lang, “The International Affective Picture System (IAPS) in the Study of Emotion and Attention”, Handbook of Emotion Elicitation and Assessment, Oxford University Press, 2007.

[50] Sander Koelstra, “A database for emotion analysis using physiological signals”, IEEE Transactions on Affective Computing, vol. 3, no.1, Jan-Mar 2012

[51] K. Ishino and M. Hagiwara, “A Feeling Estimation System Using a Simple Electroencephalograph”, Proc. ICSMC, vol.5, pp. 4204-4209, 2003.

[52] Y. P. Lin, C. H. Wang, T. L. Wu, S. K. Jeng, and J. H. Chen, “EEG-based emotion recognition in music listening: A comparison of schemes for multiclass support vector machine”, Proc. ICASSP, pp. 489-492, 2009.

[53] Y. Liu, O. Sourina, M. K. Nguyen, “Real-Time EEG-Based Human Emotion Recognition and Visualization”, Proc. CW, pp. 262-269, 2010.

[54] K.Takahashi, “Remarks on emotion recognition from bio-potential signals”, 2nd International Conference on Autonomous Robots and Agents, pp. 186–191, 2004.

[55] Arnaud Delorme, “EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis”, Journal of Neuroscience Methods 134, 2004.

[56] MP System Hardware Guide, available at “http://www.biopac.com/manuals/mp_hardware_guide.pdf”

[57] EEG Electro Cap Systems, available at “http://www.adinstruments.com/products/eeg-electro-cap-systems”.

[58] Acqknowledge 4 software guide, available at “http://www.biopac.com/Manuals/acqknowledge%204%20software%20guide.pdf”

[59] Mandeep Singh, Mooninder Singh, Ankita Sandel, "Data Acquisition Technique for EEG based Emotion Classification", International Journal of Information Technology & Knowledge Management, vol. 7, 2014

[60] Mandeep Singh, Mooninder Singh, Ankita Sandel, "Emotion Classification along Valence Axis using ERP Signals", International Journal of Information Technology & Knowledge Management, vol.7, 2014

[61] Mandeep Singh, Mooninder Singh, Ankita Sandel, "Emotion Classification along Valence Axis using Averaged ERP Signals", International Journal of Information Technology & Knowledge Management, vol.7, 2014

[62] Event Related Potential, available at, "http://en.wikipedia.org/wiki/Event-related_potential".

LIST OF PUBLICATIONS

1. Mandeep Singh, Mooninder Singh, Ankita Sandel, “Data Acquisition Technique for EEG based Emotion Classification”, International Journal of Information Technology & Knowledge Management, vol. 7, 2014 [in press]

2. Mandeep Singh, Mooninder Singh, Ankita Sandel, “Emotion Classification along Valence Axis using ERP Signals”, International Journal of Information Technology & Knowledge Management, vol.7, 2014 [in press]

3. Mandeep Singh, Mooninder Singh, Ankita Sandel, “Emotion Classification along Valence Axis using Averaged ERP Signals”, International Journal of Information Technology & Knowledge Management, vol.7, 2014 [in press]