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Data Acquisition Technique for EEG based Emotion Classification

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Abstract
Emotions exert an incredibly powerful force on human behavior. Strong emotions can cause one to take actions which one might not normally perform or avoid situations that one generally enjoy It is the emotion only through which one can express his/her feelings to other. Emotions can be felt in body as tingles, as hot spots and muscular tension. It is a phenomenon which is difficult to grasp. Emotions though a psychological phenomenon, can be easily quantified along valence and arousal axis. EEG signals are very helpful in detecting human emotions .The EEG signals can be acquired using various EEG acquiring devices with electrodes placed using different standards. This paper illustrates the technique used for acquiring EEG signals from 3 participants with electrodes placed as per 10-20 system. It also presents a review on the data acquisition techniques used for acquiring EEG signals for emotion recognition.

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 behavior. 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 behaviors. 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 color composed of primary colors. He found six basic emotions such as angry, sad, disgust, fearful, happy and surprise [6]. Fig.1 shows the basic emotions which are experienced in daily life such as happy, sad, angry, excited, frustrated, calm, astonished, shocked, funny and naughty.

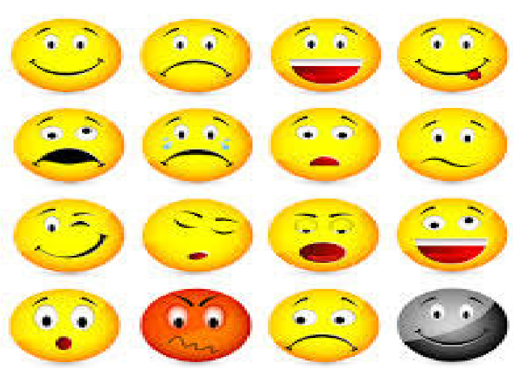

Fig.1 Some Basic Emotions [7]

2. 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 [8] [9].The circumplex model of affect proposed in his study is shown below in Fig.2.

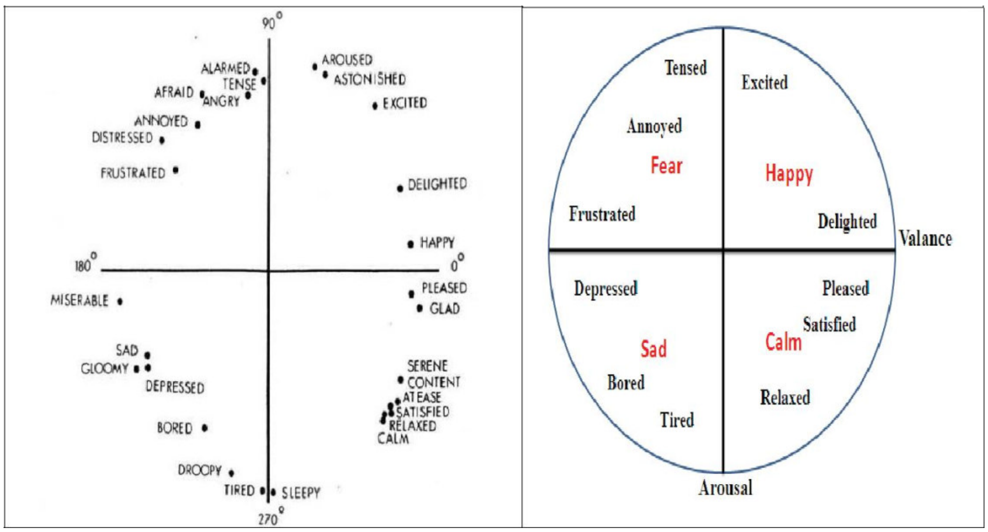

Fig.2 Circumplex Model

2.1 Emotions can be expressed in a 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.

2.2 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.3.

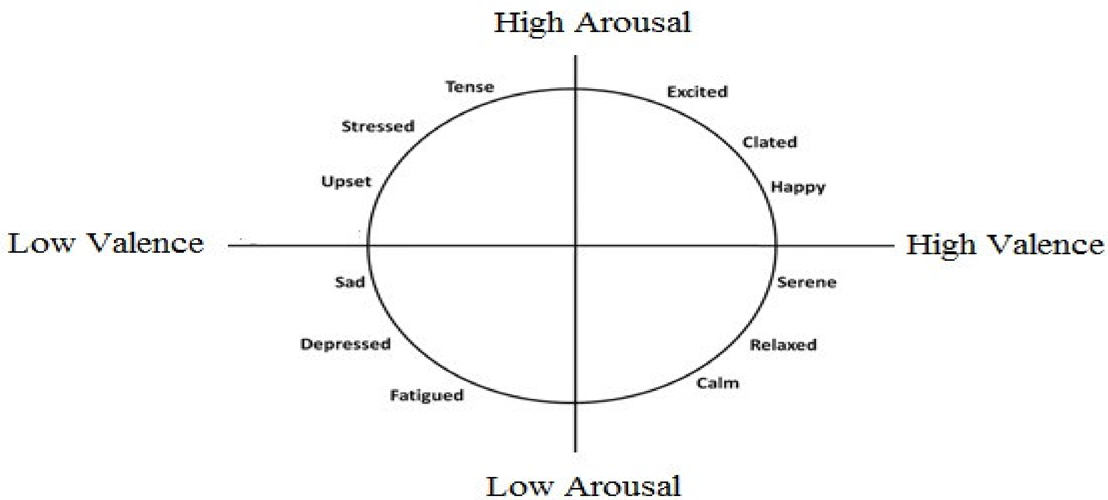

Fig.3 Division of Arousal and Valence in four Classes

3. Electroencephalography
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 [10]. 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 but the best way is through EEG as it has simple and portable hardware, high temporal resolution, and direct measurement of electrical activity [11] [12].

3.1 EEG signals comprises of four main brain waves
1. Alpha wave (Deep Relaxation Wave)
2. Beta Waves (Waking Consciousness and Reasoning Wave)
3. Delta waves (Deep Sleep Wave)
4. Theta Waves (Light Meditation and Sleeping Wave)
5. Gamma waves (Insight Wave) [13]

All the above brain waves are shown below in Fig.4

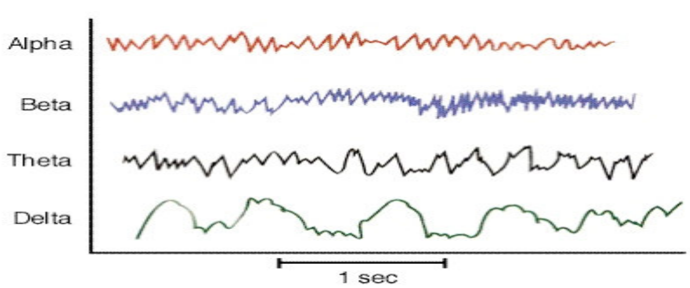

Fig.4 Brain Waves [13]

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 [14].

5. Hardware

There can be many ways to capture EEG signals from a human being. One method being the fNIRS (functional Near Infrared Spectroscopy) sensor which is used to capture frontal brain activity and to capture rest of the brain activity EEG sensor is used and rest of the sensors for capturing body processes. Bio semi Active 2 acquisition system was used by Savran et al. (2006) [15]. The hardware used in this acquisition is BIOPAC MP150 system. 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 [16].

6. Software

Delorme, Arnaud et.al (2003) in their paper "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 preprocessing operations like baseline removal, change of sampling rate, Artifact removal and filtering as well as operations like independent component analysis (ICA) and statistical analysis [17]. Acqknowledge software is used in this acquisition technique which uses the BIOPAC hardware for capturing signals. This software can easily interpret the coming signals from the BIOPAC hardware or can say acqknowledge software and BIOPAC MP150 hardware both are responsible for acquisition of EEG signals [18].

7. Acquisition of Data

In one of the research Yohanes et al. (2012) acquired EEG signals from 5 subjects using images provided by IAPS for evoking the emotions. Subjects chosen were all right handed male in the age group of 24 to 25.The acquisition was performed by using g.USBAmp and g.EEG with a sampling rate of 256Hz. Electrodes were placed according to 10-20 international system of placement of electrodes. Alpha band wave was extracted using butterworth filter with the bandwidth of 5-15Hz. Total of 3 sets were shown and each set contained 10 images. After the processing of the data the emotions were quantified into two classes happy and sad [19]. Savran et al. (2006) collected the data from 5 subjects and used images provided by IAPS for evoking emotions. The subjects were male and right handed. The acquisition was performed by using Biosemi Active 2 acquisition system with a sampling rate of 1024Hz except first participant whose sampling rate was 256Hz. Electrodes were placed according to 10-20 international system of placement of electrodes. The experiment was divided in three sessions and therefore each session has 30 blocks and total of 450 images were used to elicit emotions. Only 5 images were shown in each block and total time duration was 12.5 sec. Each image was displayed for 2.5 sec. After the processing of the data the emotions were quantified into three classes calm, positive exciting and negative exciting [15]. Many researchers used enterface data provided by Savran et al. for their analysis [20] [21] [22] [23]. Takahashi used three electrodes on head band for recognition of five emotions. He took potentials signals such as EEG, pulse and skin conductance. Emotions classified were joy, anger, sadness, fear and relaxation [24]. Frantzidis et al. (2010) took twenty - eight subjects both male and female between the age group of 28 ±7.5 for males and 27 ± 5.2 for females. The acquisition was performed at a rate of 500Hz. Electrodes were placed according to 10-20 international system of placement of electrodes. Reference electrodes were positioned at the mastoids. The impedance of the electrodes was maintained at less than 10 K Ohm. Two stimulus were shown to the subjects, one being pre and the other being post. Pre stimulus was a white cross with black background image which was shown before the main stimuli and between each image. Each image was shown for 2 sec. and pre stimulus was shown for 1 sec. Total of 160 images were taken as stimuli for Valence-Arousal dimensions. The processing of the signal was done by EEGLab tool. The EEG signals were initially band pass filtered using a low-pass IIR filter with cutoff frequency of 40 Hz, a high-pass IIR filter with cutoff frequency of 0.5 Hz, and a notch filter at 50 Hz. The emotions classified were along valence and arousal axis [25]. Murugappan et al. (2013) took 3 males and 17 females in the age group of 21 to 39. The recordings of EEG signals were taken through EEG Nervus with 64 channels at a sampling frequency of 256 Hz. All the electrodes were placed using 10-10 system of electrodes. The impedance of electrodes was kept below 5 KOhm. The stimuli were the video audio-video clips. After the processing of the signals five emotions were classified happy, disgust, surprise, fear and neutral [26].

8. Placement of Electrodes

The placement of electrodes over the scalp for data capturing can be done according to the international system for placement of electrodes such as 10-20 system, 10-10 system and 10-5 system. All the above researchers used 10-20 system for placement of electrodes.

8.1 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.5

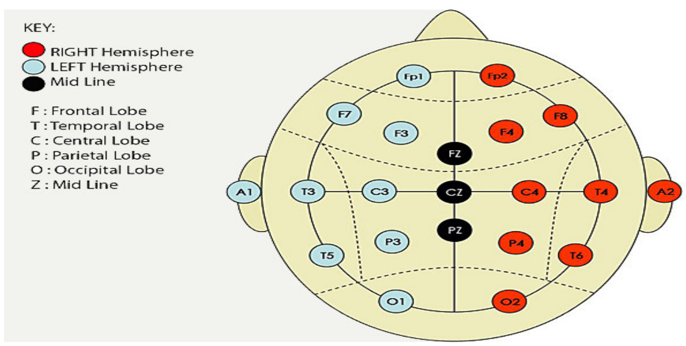

Fig.5 10-20 Electrode Placement [27]

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 [28].

8.2 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[29]. 10-10 system of placement of electrodes is shown below in Fig.6.

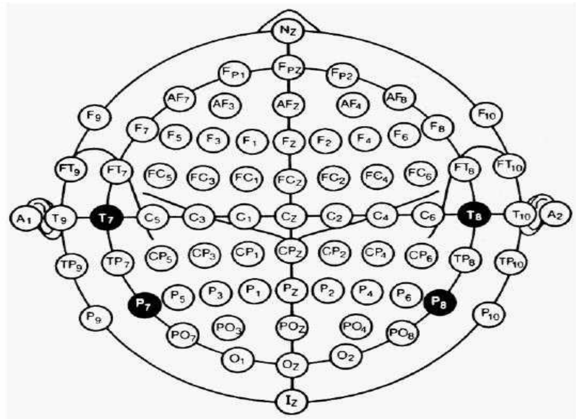

Fig.6 10-10 Electrode Placement [30]

8.3 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 [31]. 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 [32]. 10-5 system of placement of electrodes is shown below in Fig.7.

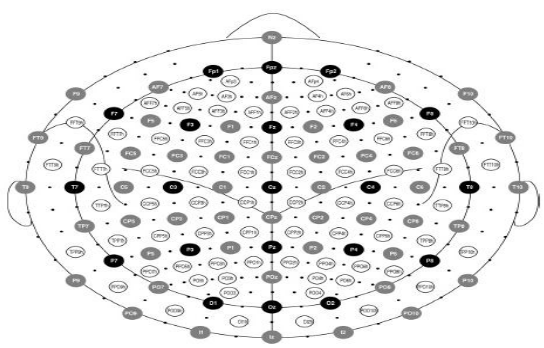

Fig.7 10-5 Electrode Placement [33]

9. Four main brain lobes which are shown in all the electrode systems are

1. Frontal Lobe: The frontal lobes of the brain are the most anterior, which means they are positioned right behind the forehead and at the top front of the head. The frontal lobe is separated from the parietal lobe by a space between tissues called the central sulcus and from the temporal lobe by a deep fold called the lateral sulcus. 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 being able to speak fluently without fault [34].

2. Parietal lobe: The parietal lobe is positioned above the occipital lobe and behind the frontal lobe and central sulcus. The central sulcus separates the parietal lobe from the frontal lobes, the parietal - occipital sulcus separates the parietal and occipital lobes, and the lateral sulcus separates it from the temporal lobe. The parietal lobe carries out some very specific functions. As a part of the cortex, it has a lot of responsibilities and has to be able to process sensory information within seconds. It is that part of the brain where information such as taste, temperature and touch are integrated or processed. Humans would not be able to feel the sensations of touch if the parietal lobe is damaged [35].

3. Occipital Lobe: The occipital lobes are the smallest of four paired lobes in human cerebral cortex. It is located in the rearmost 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 very fast to process the rapid information that our eyes are sending. Occipital lobe makes sense of visual information that we can able to understand. If the occipital lobe is impaired or injured one would not be able to process visual signals.

4. Temporal Lobe: The lateral 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 mainly revolves around hearing and selective listening. It receives sensory information such as sound and speech from the ears. This lobe is special because it makes sense of all the different sounds and pitches [36].

Lobes of the Human brain are shown in Fig 8.

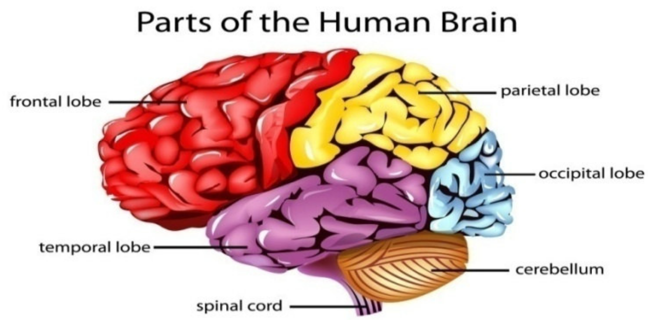

Fig.8 Human Brain [37]

10. Methodology for acquisition of EEG signals

EEG data is acquired from three subjects for the classification of emotions. All the subjects are male, right handed and physically fit and has no health issues. BIOPAC system is used as hardware for capturing brain signals for emotion classification. The system comprised 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. 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.9.

Fig.9 Equipments for EEG Recording [38]

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 [14]. The images are of different types such as snake, nature, children, mutilations, graves etc. Total of 80 images are used to capture emotions. The subject is allowed to wear EEG cap over the head. 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. 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 followed 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 [18]. 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. Acquisition of signal is shown below in Fig.10.

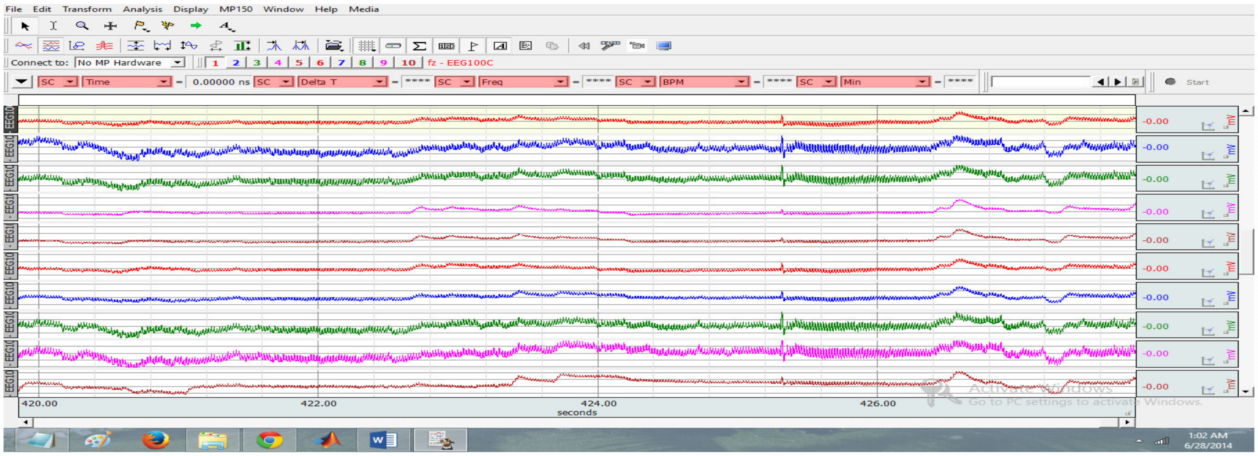

Fig.10 Acquisition graph showing acquired EEG Signal

11. 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. 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 filters used to remove noise and artifacts are low pass filter with bandwidth of 40 Hz, second filter used is high pass filter of 0.5Hz and last is the comb band stop filter with frequency of 50Hz.Fig 10.shows the acquired EEG signal. The unfiltered EEG signal is shown in Fig.11 and filtered EEG signal is shown in Fig.12.

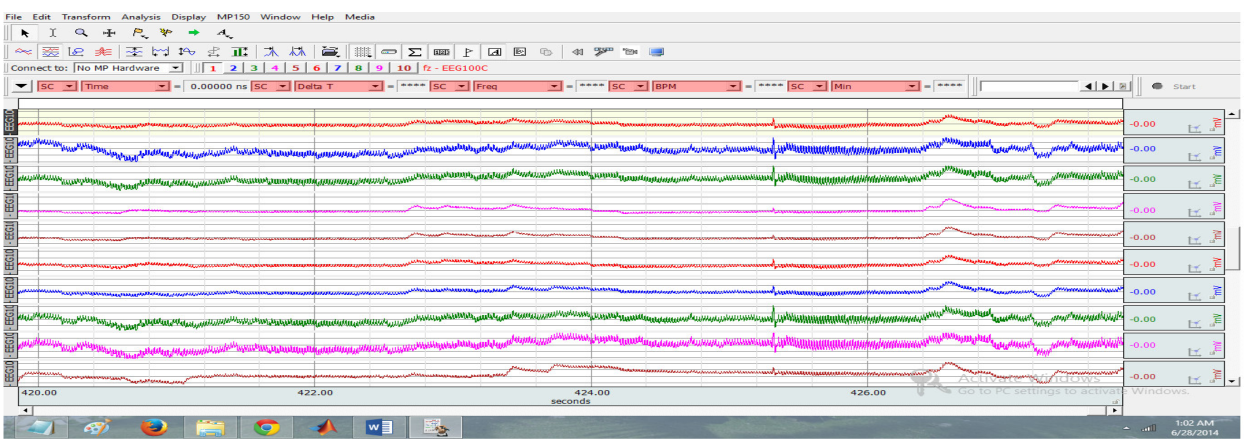

Fig.11 Unfiltered EEG Signal

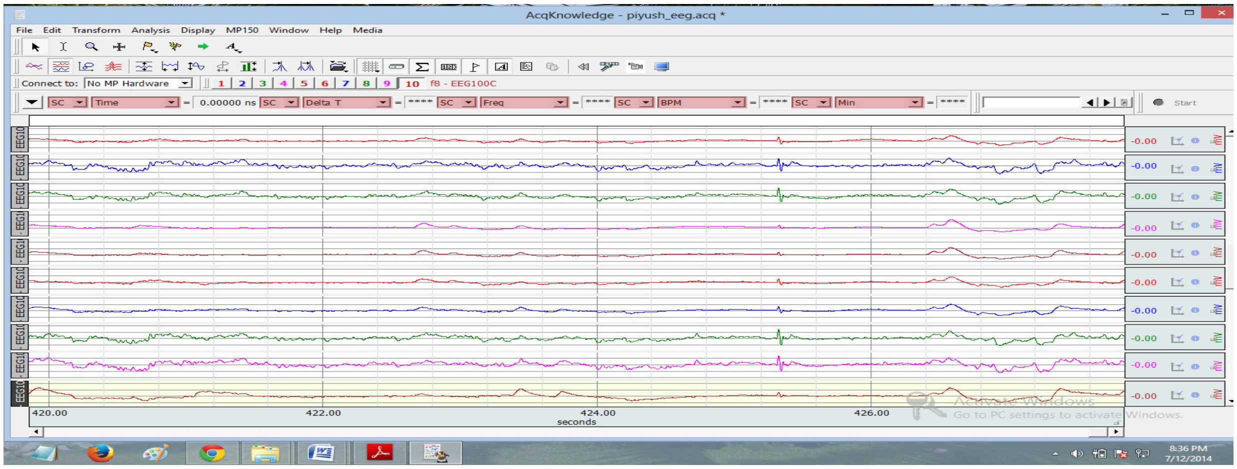

Fig.12 Filtered EEG Signal

12. Conclusion

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.

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