Dayananda Sagar University

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Kudlu Gate, Bengaluru-560068

A Project Report

on

"DETECTION OF BRAIN ANOMALIES IN REAL TIME USING P300"

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

BACHELOR OF TECHNOLOGY

in

ELECTRONICS AND COMMUNICATION ENGINEERING

by

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CERTIFICATE

*This is to certify that the **Project** entitled **"DETECTION OF BRAIN ANOMALIES IN REAL TIME USING P300"** has been successfully carried out by **SIRI S N(USNDSU15EC0056)** in partial fulfilment of the requirement for the award of the degree **BACHELOR OF TECHNOLOGY** in **ELECTRONICS & COMMUNICATION ENGINEERING** by **DAYANANDA SAGAR UNIVERSITY** during the academic year 2018-19.*

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ABSTRACT

Human brain is the most complex organ of the body and it is at the centre of the driving block of human nervous system. In fact, more than 100 billion nerve cells are interconnected to build the functionality of human brain. Such a complicated architecture allows the brain to control the body as well as carry out the executive functions, such as making reasons, processing thoughts, and planning for next tasks. In neuroscience and neuro-engineering, the electrophysiological techniques are used for studying electrical properties by measuring the electrical activities of neurons in the form of electroencephalogram (EEG). In the non invasive procedure places the electrodes on the scalp. One of the ways to study the brain is to stimulate it by presenting a paradigm.

An ERP is an electrophysiological response or electro-cortical potentials triggered by a stimulation and firing of neurons. A specific psychological event or a sensor can be employed to generate the stimulation. In general, visual, auditory, and tactile are three major sources of ERP stimulation. These include the P300 patterns and Steady State Visual Evoked Potentials. The P300 (P3) wave is an event related potential (ERP) component elicited in the process of decision making. It is considered to be an endogenous potential, as its occurrence links not to the physical attributes of a stimulus, but to a person's reaction to it.

The P300 of the Event related potential (ERP) opens a new gateway to the diagnosis of the defects in the brain. Convergence of the Evoked potential study with the strong signal processing software tools such as Matlab have brought the medical industry to shift to a whole new technological dimension which has driven research all around the world providing freedom of designing, developing and testing different parts of the brain wave signals within seconds in a very economical manner which profits a country like ours where, healthcare is unaffordable to millions yet. Development of a data acquisition tool and the analysis of the EEG signal in real time necessitating the requirement of developing a low cost, high performance and high SNR system for data acquisition

Hence, in this project we would be developing an optimized algorithm with the help of EEGLAB, ERPLAB and Wavelet transform to detect the P300 signal. And, develop a data acquisition system for acquiring the EEG data. Firstly, through simulation and then finally, through PCB designing.

Keywords- EEG, ERP, P300, Wavelet Transform, Data Acquisition System.

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CHAPTER 1

INTRODUCTION

The human brain is the master of the body which is said to control the normal functioning of every organ to even the microscopic cell of the body. Any irregularities or defects in the brain can go undetected for years together, which could have developed in the congenital stage, making its screening, diagnosis and treatment a very difficult task. Modern day technologies include CT scan, Electroencephalography (EEG), Electromyography, Memory screening test, MRA (Magnetic resonance angiography), MRI, Multiple sleep latency test, Myelogram, Neurovascular ultrasound, Positron emission tomography, Single Photon Emission Computed Tomography (SPECT) and last but not the least Evoked Potential study for diagnosis of different defects of the brain. Out of all of them, the combination of EEG with Evoked Potential Study has proved to be economical, faster with far less health complications involved while screening for the patient as well as the doctor. In addition to diagnosis, it also aids in developing recovery strategies for the patient.

Discovery of the P300 spurred the use of event-related potential (ERP) methods to assess the neural underpinnings of cognition. This quest is pursued today with a convergence of methods that are beginning to hone the fundamental circuitry and identify the neurotransmitter systems activated when the P300 is observed. Although early understanding of the P300 was derived primarily from functional analysis, this once unitary phenomenon is now thought to be composed of several parts that reflect an information-processing cascade when attentional and memory mechanisms are engaged. The P300 was first reported over 40 years ago. Its discovery stemmed from the confluence of increased technological capability for signal averaging applied to human neuroelectric measures and the impact of information theory on psychological research. The original studies manipulated stimulus information to assess how electric brain patterns varied among conditions. Subsequent results elucidated the roles of stimulus probability and task relevance, which provided the basis for its functional analysis often from data obtained with the “oddball” paradigm. Although the actual origin of the P300 is still unclear, it is suggested that P300 is elicited by the decision making or learning that a rare event has occurred, and some things appear to be learned if and only if they are surprising. The variable latency is associated with the difficulty of the decision making.

Hence, P300 of the Event related potential (ERP) opens a new gateway to the diagnosis of the defects in the brain. Convergence of the Evoked potential study with the strong signal processing software tools such as Matlab have brought the medical industry to shift to a whole new technological dimension which has driven research all around the world providing freedom of designing, developing and testing different parts of the brain wave signals within seconds in a very economical manner which profits a country like ours where, healthcare is unaffordable to millions yet. This brings about a whole new shift in the medical industry to collaborate and contribute to the growth of technology. In this project, we would be utilizing real time processing software tools such as Matlab to improve the efficiency in the extraction and analysis of P300, after the in depth understanding of its origin and utilization. We would be developing efficient and strong processing algorithms using EEGLAB library of Matlab. We would also step into developing data acquisition tools especially keeping in mind the cost and performance parameters.

1.1 Objective and Scope of the project

Thereby, exploiting the novelty of P300 of the Brain related Event Related Potential, we lay the objectives as follows:

- Extraction and analysis of P300 response from visual Event Related Potential (ERP) through an optimized algorithm.
- Development of a data acquisition tool and the analysis of the EEG signal in real time.

1.2 Definition of The Problem

Neurological disorders pose a large burden on worldwide health. The most recent estimates show that the neurological disorders included in the Global Burden of Disease (GBD) Study–Alzheimer's and other dementias, Parkinson's disease, multiple sclerosis, epilepsy, and headache disorders (migraine, tension-type headache [TTH], and medication-overuse headache [MOH])–represent 3 percent of the worldwide burden of disease. And dementia, epilepsy, migraine, and stroke rank in the top 50 causes of disability-adjusted life years (DALYs).

The neurological burden of disease is expected to grow exponentially in low- and middle-income countries (LMICs) in the next decade. Patients with neurological disorders often require significant social and economic support because of physical, cognitive, and psychosocial limitations. Despite the high prevalence of disability, there is increasing recognition that services and resources are disproportionately scarce, especially in LMICs. In addition, knowledge of the cost-effectiveness of interventions to improve neurological care in these settings remains limited.

CHAPTER 2

BACKGROUND/LITERATURE SURVEY

Human brain is the most complex organ of the body and it is at the centre of the driving block of human nervous system. In fact, more than 100 billion nerve cells are interconnected to build the functionality of human brain. Such a complicated architecture allows the brain to control the body as well as carry out the executive functions, such as making reasons, processing thoughts, and planning for next tasks. Interestingly, electrophysiology and hemodynamic response are the two techniques that have been used to study this complex organ to understand the mechanism the brain applies to finish works. Typically, electrophysiological measurements are performed by placing electrodes or sensors on the biological tissue. In neuroscience and neuro-engineering, the electrophysiological techniques are used for studying electrical properties by measuring the electrical activities of neurons in the form of electroencephalogram (EEG). EEG may be measured by two different approaches: invasive and non invasive. Invasive procedures need a surgery to place the EEG sensor deep under the scalp. In comparison, non invasive procedure places the electrodes on the scalp. One of the ways to study the brain is to stimulate it by presenting a paradigm [1]. The EEG is typically described in terms of (1) rhythmic activity and (2) transients. The rhythmic activity is divided into bands by frequency. To some degree, these frequency bands are a matter of nomenclature, but these designations arose because rhythmic activity within a certain frequency range was noted to have a certain distribution over the scalp or a certain biological significance. The different frequency bands are Delta(0-4Hz), Theta(4-8Hz), Alpha(8-13Hz), Beta(13-30Hz) and Gamma(30-100Hz) [4].

An ERP is an electrophysiological response or electrocortical potentials triggered by a stimulation and firing of neurons. A specific psychological event or a sensor can be employed to generate the stimulation. In general, visual, auditory, and tactile are three major sources of ERP stimulation. For instance, ERP can be elicited by a surprise appearance of a character on a visual screen, or a “novel” tone presented over earphones, or by sudden pressing of a button by the subject, including myriad of other events. Presented stimulus generates a detectable but time-delayed electrical wave in EEG. EEG is recorded starting from the time of presenting the stimulus to the time when EEG settles down. Depending on the necessity, simple detection method such as ensemble averaging or advanced processes such as linear discriminant analysis or support vector machine algorithms are applied on EEG to measure the ERP [2].

The P300 wave is a centro parietal positivity that occurs when a subject detects an informative task relevant stimulus. The P300 name derives from the fact that its peak latency is about 300ms when a young adult subject makes a simple sensory discrimination It has also been called the P3 Wave because it is the third major Positive peak in the late sensory evoked potential and Late positive component(LPC) . Classically, the P300 response is divided into 2 sub components: P3a and P3b. The P3a component is mainly distributed in frontal regions and its usual latency ranges from 220 to 280milliseconds. P3a amplitude exhibits rapid habituation which depends on novelty of stimuli. P3a reflects automatic cognitive processing and the orientation response. This Novelty P300 is sometimes called the P3a. In contrast, the P3b component presents a centro parietal topography and a longer latency usually comprised between 280 – 600milliseconds. For eliciting the P3b component, the subjects must produce an active discrimination either by pressing a button or silent counting. The P3b is linked to the closure of cognitive processing before starting the motor response and is maximally distributed over parietal sites. The P3a component reflects involuntary switching of attention (or attentional reallocation) to distraction from the primary task. Another interpretation is that the P3a could reflect the inhibition of response processes that normally follow the detection of target stimuli. The P3b is thought to reflect immediate memory mechanisms triggered when the mental model of the stimulus environment is refreshed and updated. In studies on ERPs, measurement of the P300 is generally centered on the P3b [3].

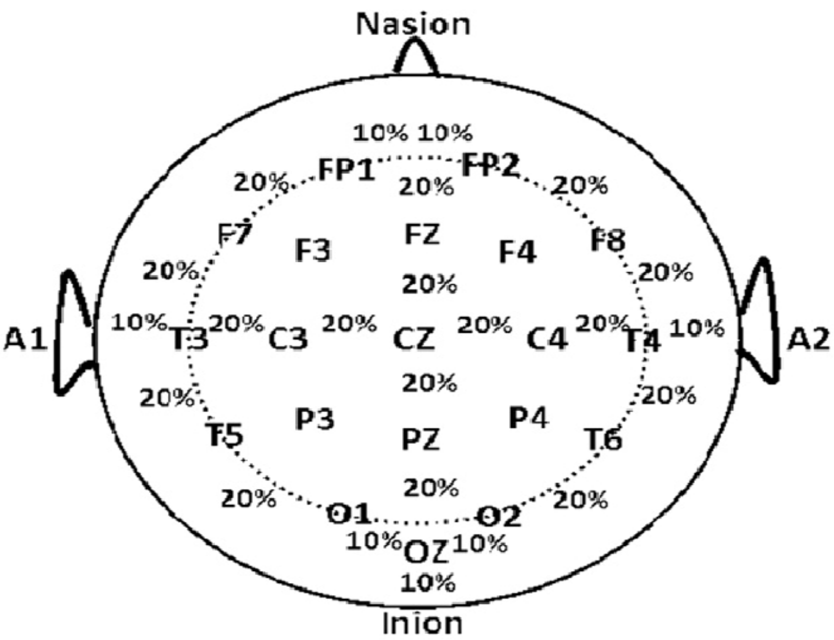

Figure 2.1: Depiction of the 10-20 international electrode system. P300 occurs in F,P and C.

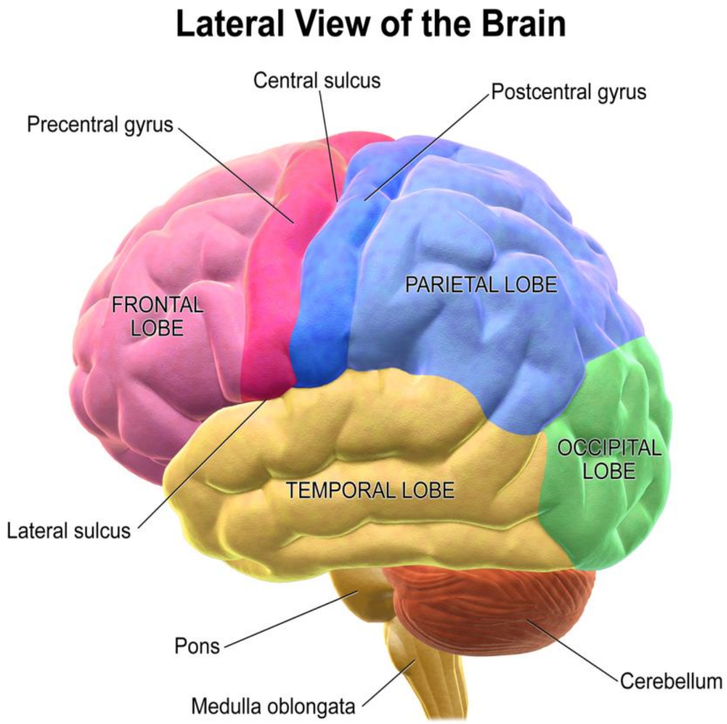

Figure 2.2: The different lobes of the brain. P300 occurs in the frontal and centro-parietal regions.

To generate the P300 ERP, three different types of paradigms are being used: (1) single-stimulus, (2) oddball, and (3) three-stimulus paradigm. In each case, the subject is instructed to follow the occurrence of the target by pressing a button or mentally counting. The single-stimulus paradigm irregularly presents just one type of stimuli or target with zero occurrence of any other type of target. A typical oddball paradigm can be presented to the subject with a computer screen, a group of light-emitting diodes (LEDs), or other medium to generate a sequence of events that can be categorized into two classes: frequently presented standard (nontarget or irrelevant) and rarely presented target stimuli. In an oddball paradigm, two events are presented with different probabilities in a random order, but only the irregular and rare event (the oddball event) embosses the P300 peak into the EEG about 300 ms after the stimulus onset. The three-stimulus paradigm is a modified oddball task which includes nontarget distractor (infrequent nontarget) stimuli in addition to target and standard stimuli. The distractor elicits P3a which is large over the frontal/central area. In contrast, target elicits a P3b (P300), which is maximum over the parietal electrode sites. Though P3a and P3b are subcomponents of P300, P3a is dominant in the frontal/central lobe with a shorter latency and habituates faster [2].

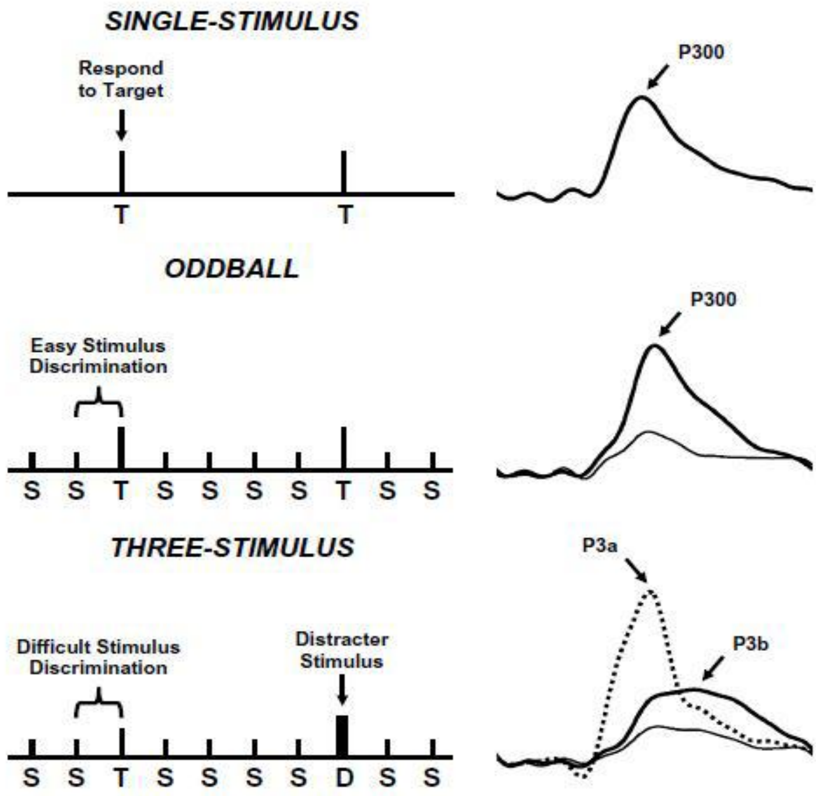

Figure 2.3: Depiction of P300 components with variation of standard and target stimulus.

P300 event-related brain potential (ERP) measures are affected by target stimulus probability, the number of non-targets preceding the target in the stimulus sequence structure, and interstimulus interval (ISI). Each of these factors contributes to the target-to-target interval (TTI), which also has been found to affect P300. The present study employed a variant of the oddball paradigm and manipulated the number of preceding nontarget stimuli (0, 1, 2, 3) and ISI (1, 2, 4 s) in order to systematically assess TTI effects on P300 values from auditory and visual stimuli. One possible explanation for the influence of ISI on P300 is suggested by the similar declines in amplitude observed with decreases in ISI for sensory ERPs. These effects have been interpreted as the result of “recovery cycle” limitations inherent in the mechanisms responsible for component generation. Relatively small potentials will be produced with short ISIs, because the system requires time to recover from very recent ERP production. With longer ISIs, however, the generation processes can reacquire the necessary resources to produce large ERPs because they have “recovered” from their previous use. Response time studies also indicate that the time interval between task stimuli is an important determinant of processing outcomes because decreases in ISI increases recovery cycle time. Given the influence of recovery cycle on sensory ERP amplitudes and behavioural responses to the time intervals between stimulus presentations, it is reasonable to suppose that similar effects might be observed for the P300 component as is implied by the presence of relatively small amplitudes for this potential when very short ISIs are employed. If a recovery cycle mechanism does contribute to P300 amplitude, changes in target stimulus probability and ISI should interact with one another because P300 size will vary inversely with target stimulus probability and Number of preceding non-targets generally produced stronger effects than ISI in a manner suggesting that TTI determined P300 measures: Amplitude increased as TTI increased for both auditory and visual stimulus conditions, whereas latency tended to decrease with increased TTI.[6]

Experimental Variable	Effect on P300 Amplitude	Effect on P300 Latency
Biological effectors		
Eating food	Food intake increases the amplitude of the P300	No effect on latency [16]
Body temperature	No effect	Shorter latency with increased temperature [16]
Heart rate	No effect	Shorter latency with increased heart rate [16]
Seasonal variation	In seasons with more light, P300 amplitude is increased (females had higher amplitudes than males)	No effect [16]
Tonic exercise	With exercise, amplitude increases	Latency decreases [16]
Alcohol intake	Decreased amplitude	Increased latency [16]
Task-related effectors		
Memory and perceptual load	Decrease in amplitude	Not applicable [17]
Rarity of target	Same amplitude for 15% and 45% stimulus probability	Not applicable [18]
Inter-stimulus interval (ISI)	Over 60% increase in amplitude from 1 sec to 2 sec ISI	Not applicable [18]

Table 1: Summary of P300 effectors (Biological and task related)

When it comes to the development of the algorithm, it is completed in two stages. The first stage is pre-processing. It comprises of: 1) Referencing-The average signal from the two mastoid electrodes was used for referencing, 2) Filtering-The MATLAB function isused to compute the filter coefficients and the function firfilt was used for filtering, 3) Single trial extraction- Single trials of duration 1000 ms were extracted from the data, 4)Windsorizing-. Eye blinks, eye movement, muscle activity, or subject movement can cause large amplitude outliers in the EEG. To reduce the effects of such outliers, the data from each electrode were windsorized. For the samples from each electrode the 10th percentile and the 90th percentile were computed. Amplitude values lying below the 10th percentile or above the 90th percentile were then replaced by the 10th percentile or the 90th percentile, respectively, 5) Scaling- The samples from each electrode were scaled to the interval [−1, 1], 6) Electrode selection. Four electrode configurations with different numbers of electrodes were tested, 7) Feature vector construction- The samples from the selected electrodes were concatenated into feature vectors. The dimensionality of the feature vectors was Ne ×Nt, where Ne denotes the number of electrodes and Nt denotes the number of temporal samples in one trial. Due to the trial duration of 1000 ms and the downsampling to 32 Hz, Nt always equalled 32. Depending on the electrode configuration Ne equalled 4, 8, 16, or 32. [7]

The application of a recently proposed denoising implementation for obtaining event-related potentials (ERPs) at the single-trial level is shown. We study its performance in simulated data as well as in visual and auditory ERPs. For the simulated data, the method gives a significantly better reconstruction of the single-trial event-related responses in comparison with the original data and also in comparison with a reconstruction based on conventional Wiener filtering. Moreover, with wavelet denoising we obtain a significantly better estimation of the amplitudes and latencies of the simulated ERPs. For the real data, the method clearly improves the visualization of both visual and auditory single-trial ERPs. This allows the calculation of better averages as well as the study of systematic or unsystematic variations between trials. Since the method is fast and parameter free, it could complement the conventional analysis of ERPs. [8]

The basic data acquisition system comprises of 4 stages: 1) Initial input stage amplifier, 2) broad band amplification stage, 3) gain controller, and 4) final band-pass filtered amplification. [9]

Digital Signal Processing using the Arduino platform and MATLAB is done to achieve the connection between physical and computation worlds. The AVR's registry analysis gives us the insight to how we should control our Arduino in order to achieve the best performance.[10]

In the later years, a brain-computer interface (BCI) P300 speller was developed which is a novel technique that helps people spell words using the electroencephalography (EEG) without the involvement of muscle activities. However, only time domain ERP features (P300) are used for controlling of the BCI speller. Reports were done in the time-frequency EEG features for the P300-based brain-computer interface speller. A signal preprocessing method integrated ensemble average, principal component analysis, and independent component analysis to remove noise and artifacts in the EEG data. Results showed that the proposed signal processing method can effectively extract EEG time-frequency features in the P300 speller, suggesting that ERSP and ITC may be useful for improving the performance of BCI P300 speller [5].

Chapter 3

SYSTEM ANALYSIS AND DESIGN

3.1 Software Requirements

3.1.1 Matlab

MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment and proprietary programming language developed by MathWorks. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, C#, Java, Fortran and Python.

Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing abilities. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems. In this project, it is used to generate the code for detecting the P300 signal using its functions, plugins and toolboxes.

3.1.2 EEGLAB

EEGLAB is an interactive Matlab toolbox for processing continuous and event-related EEG, MEG and other electrophysiological data incorporating independent component analysis (ICA), time/frequency analysis, artifact rejection, event-related statistics, and several useful modes of visualization of the averaged and single-trial data. It is a plugin that can be used with Matlab. In this project, it is used to develop the algorithm.

3.1.3 ERPLAB

ERPLAB Toolbox is a free, open-source Matlab package for analyzing ERP data. It is tightly integrated with EEGLAB Toolbox, extending EEGLAB's capabilities to provide robust, industrial-strength tools for ERP processing, visualization, and analysis. A graphical user interface makes it easy for beginners to learn, and Matlab scripting provides enormous power for intermediate and advanced users. In this project, ERPLAB is used to develop the enhanced version of the algorithm that was developed using EEGLAB.

3.1.4 TINA- TI

TINA allows simulation, design, and real-time testing of hardware description language (HDL), such as VHDL, Verilog, Verilog-A, and Verilog-AMS, and for microcontroller (MCU) circuits, as well as mixed electronic circuits including switched-mode power supply, RF, communication, and optoelectronics circuits. With the integrated and third-party flowchart tools, generation and debugging of MCU code is also possible both in digital and mixed circuit environments. TINA Design Suite includes an integrated layout module for designing multilayer PCB's with split power plane layers, auto-placement & auto-routing, rip-up and reroute, manual and "follow-me" trace placement, DRC, forward and back annotation, pin and gate swapping, keep-in and keep-out areas, copper pour, thermal relief, fan-out, 3D view of the PCB design, Gerber file, and CNC (G-code) output. In this project, it was used to design the circuit and test the output via simulation. And then design the PCB if the output is verified.

3.1.5 Eagle 3D Autodesk

EAGLE is a scriptable electronic design automation (EDA) application with schematic capture, printed circuit board (PCB) layout, auto-router and computer-aided manufacturing (CAM) features. EAGLE stands for Easily Applicable Graphical Layout Editor (German: Einfach Anzuwendender Grafischer Layout-Editor) and is developed by CadSoft Computer GmbH. The company was acquired by Autodesk Inc. in 2016 EAGLE contains a schematic editor, for designing circuit diagrams. Schematics are stored in files with .SCH extension, parts are defined in device libraries with .LBR extension. Parts can be placed on many sheets and connected together through ports. In this project, it was used to design the PCB for the data acquisition system.

3.1.6 Audacity

Audacity is a free and open-source digital audio editor and recording application software, available for Windows, macOS/OS X and Unix-like operating systems. Audacity was started in the fall of 1999 by Dominic Mazzoni and Roger Dannenberg at Carnegie Mellon University and was released on May 28, 2000 as version 0.8. In addition to recording audio from multiple sources, Audacity can be used for post-processing of all types of audio, including podcasts by adding effects such as normalization, trimming, and fading in and out In this project, it was used to develop the stimulus audio tones.

3.2 Hardware Requirements- Analog Design

The analog hardware is composed of an active electrode stage and an amplifier circuitry which mainly includes instrumentation amplifiers, filters and isolator components inside. These will be explained in detail in the following subsections.

3.2.1 Active Electrodes

Instead of simple passive ring electrodes, in this design, the use of active electrodes is preferred due to their practicality. When using the passive electrodes in EEG, a preparation stage is needed in which the electrodes have to be covered with a conductive gel. This is a time consuming procedure especially when the number of the electrodes is high. Moreover, the conductive paste usually dries out after 2-3 hours of use and additional pasting is needed in order to continue to EEG recording. Active electrodes eliminate the need for pasting and thus can be used for the measurements much longer than the passive ones. As EEG signals are very low amplitude signals, they are more prone to noise. Also, for the passive electrodes, it is difficult to match the contact impedance between the scalp and the electrode leads for all channels. This results in the amplification of the displacement currents in the preamplifier stage. The active electrodes are usually used as voltage follower devices to improve the signal strength at the scalp by increasing the current driving capability of the signal. There are also studies on the design of active electrodes with gain. However, it is difficult to overcome the problem of DC offsets in EEG. Therefore, in this study, it is preferred to use active electrodes as simple voltage buffering elements. Additionally, a first order high pass filter with a low cutoff frequency is used to remove the DC component in the signal in order not to saturate the preamplifier.

3.2.2 Preamplifier

Since the amplitude of the signal to be measured is considerably low, special type of amplifiers are preferred in EEG systems. These are called instrumentation amplifiers (IA) and have a high common mode rejection ratio (CMRR) property in their design, providing a less noise affected signal in the amplification. There are usually two stages in the structure of IA. The first stage is the buffering stage where the signal is electrically isolated from the signal source and common mode voltage is reduced. In the second stage, there exists a difference amplifier in which the difference between two isolated signals is amplified.

Since instrumentation amplifier includes at least three operational amplifiers (opamp) in its design, it occupies a larger size compared to other components in the circuits. However, there are also commercial instrumentation amplifiers that provide all the components in an instrumentation amplifier in a single package. These packages have comparatively smaller size and provide the gain adjustment with a single external resistor.

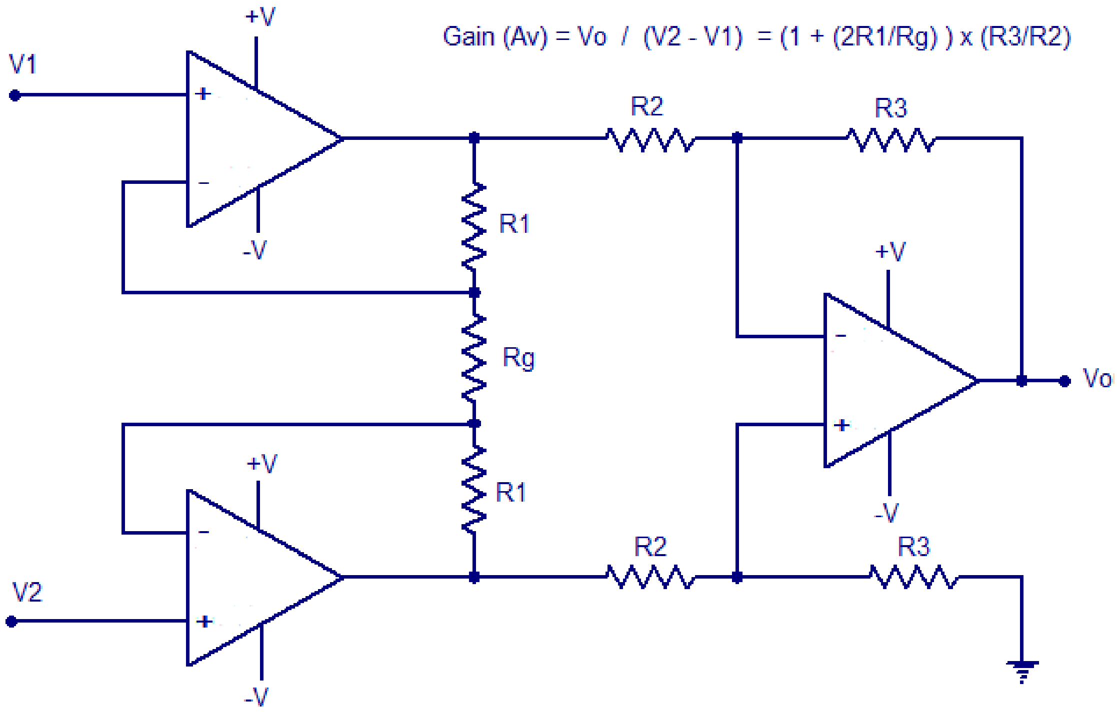

Fig 3.1: Three Op-Amp based Instrumentation Amplifier.

3.3 Conceptual view and design of the proposed system

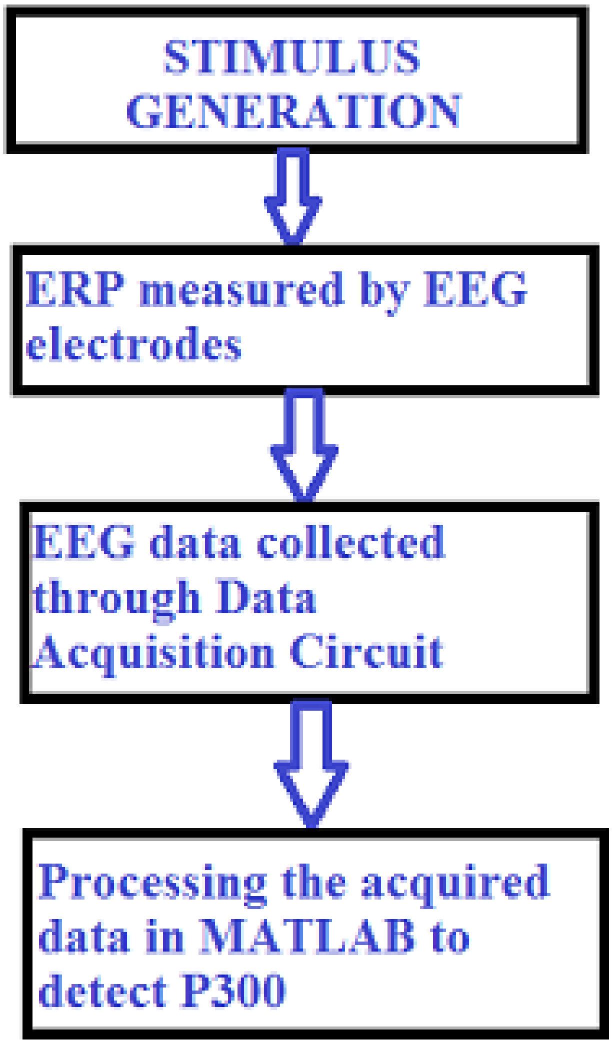

Figure 3.2 : The complete design of the system

The figure 3.1 depicts the complete design of the project system flow. using The stimulus is generated by utilization of the audacity software in the form of a ramp up signal for 0.1ms then followed by constant amplitude signal for 0.9ms and ramp down signal for 0.1ms, for 4 different frequencies which lie in the audible range and lie between 1000 Hz to 1200 Hz. This is done to ensure recovery of brain to distinguish between tones by use of ramp signals.

The EEG data that is acquired from the EEG electrodes placed according to the 10-20 system are transmitted to the data acquisition system. Then the Arduino is used as an ADC converter and data is sent to Simulink.

Further, preprocessing and wavelet analysing is done with Matlab on the acquired data for detecting the P300 signal.

CHAPTER 4

IMPLEMENTATION

4.1 Methodology Adopted

With respect to our first objective, that is, extraction and analysis of P300 response from visual Event Related Potential (ERP) through an optimized algorithm, we have completed a good amount of literature survey to understand the P300 of the Event related potential in EEG to first understand how effectively it can be generated, by utilizing visual stimulus and where are its wide areas of occurrence within the lobes of the brain for the placement of electrodes, in order to understand the optimization of the circuit. Then we started with the understanding of EEGLAB following up with the SCCN tutorials, which is a library of Matlab. Basically, starting with Graphic user interface of EEGLAB of Matlab and then stepped into scripting as it provides the freedom to process a single dataset in multiple ways or a large number of datasets at one time. Then further, we would be utilizing the plug-in for EEGLAB known as the ERPLAB, to optimize our algorithm for better computation. And finally Wavelet transform would be used to detect the P300 signal.

And with respect to our second objective, that is, development of a data acquisition tool and the analysis of the EEG signal in real time, we would developing a low cost, high performance and high SNR system for data acquisition. Firstly, with the simulation software, secondly, with the prototyping board and finally, with PCB designing and printing.

4.2 System Implementation

The figure 3.1 depicts the complete design of the project system flow. using The stimulus is generated by utilization of the audacity software in the form of a ramp up signal for 0.1ms then followed by constant amplitude signal for 0.9ms and ramp down signal for 0.1ms, for 4 different frequencies which lie in the audible range and lie between 1000 Hz to 1200 Hz. This is done to ensure recovery of brain to distinguish between tones by use of ramp signals.

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Further, preprocessing and wavelet analysing is done with Matlab on the acquired data for detecting the P300 signal.

The analog hardware is composed of an active electrode stage and an amplifier circuitry which mainly includes instrumentation amplifiers, filters and isolator components inside.

4.3 Algorithm Implementation

The initial phases of the algorithm development required datasets. Hence, the dataset was used from the EEGLAB and ERPLAB sample data directory.

The description of the experiment conducted to acquire the dataset available in ERPLAB and the dataset description is given in the appendix A.

A graphic user interface was developed using Matlab for performing wavelet denoising. The details are present in the appendix B.

4.3.1 Pre-processing

1) Referencing-The average signal from the two mastoid electrodes was used for referencing.

2) Filtering-The MATLAB function is used to compute the filter coefficients and the function firfilt was used for filtering.

3) Single trial extraction- Single trials of duration 1000 ms were extracted from the data.

4) Windsorizing-. Eye blinks, eye movement, muscle activity, or subject movement can cause large amplitude outliers in the EEG. To reduce the effects of such outliers, the data from each electrode were windsorized. For the samples from each electrode the 10th percentile and the 90th percentile were computed. Amplitude values lying below the 10th percentile or above the 90th percentile were then replaced by the 10th percentile or the 90th percentile, respectively.

5) Scaling- The samples from each electrode were scaled to the interval [−1, 1].

6) Electrode selection. Four electrode configurations with different numbers of electrodes were tested.

7) Feature vector construction- The samples from the selected electrodes were concatenated into feature vectors. The dimensionality of the feature vectors was $N_e \times N_t$, where Ne denotes the number of electrodes and Nt denotes the number of temporal samples in one trial. Due to the trial duration of 1000 ms and the downsampling to 32 Hz, Nt always equalled 32. Depending on the electrode configuration Ne equalled 4, 8, 16, or 32.

8) Epoching: Time based epochs are selected with stimulus at 0 and 1s window on the either side.

4.3.2 Wavelet Denoising and Wavelet Transform

The Discrete Wavelet Transform (DWT) is a transformation that can be used to analyze the temporal and spectral properties of non-stationary signals. The DWT is defined by the following equation:

$$W(j,k) = \sum_j \sum_k f(x) 2^{-j/2} \psi(2^{-j} x - k)$$

The set of functions $\psi_{j,k}(n)$ is referred to as the family of wavelets derived from ψ (n) , which is a time function with finite energy and fast decay called the mother wavelet. The basis of the wavelet space corresponds then, to the orthonormal functions obtained from the mother wavelet after scale and translation operations. The definition indicates the projection of the input signal into the wavelet space through the inner product, then, the function f(x) can be represented in the form:

$$f(x) = \sum_{j,k} d_j(k) \psi_{j,k}$$

Where, $d_j(k)$ are the wavelet coefficients at level j.

B-splines wavelets have another advantage of the wavelet transform over Fourier based methods is that the functions to be matched with the signal are not necessarily sinusoidal ones (or modulated sinusoidal in the case of the STFT). In fact, there are many different functions suitable as wavelets, each one having different characteristics that are more or less appropriate depending on the application. Irrespective of the mathematical properties of the wavelet to choose, a basic requirement is that it looks similar to the patterns we want to localize in the signal. This allows a good localization of the structures of interest in the wavelet domain and moreover, it minimizes spurious effects in the reconstruction of the signal via the inverse wavelet transform. For this study, we choose quadratic biorthogonal B-splines as mother functions (in Fig. 4.1) due to their similarity with the evoked responses. B-splines are piecewise polynomials that form a base in L2. The following properties that make them optimal in signal analysis are: (anti-) symmetric, smooth, they a nearly optimal time–frequency resolution and they have compact support.

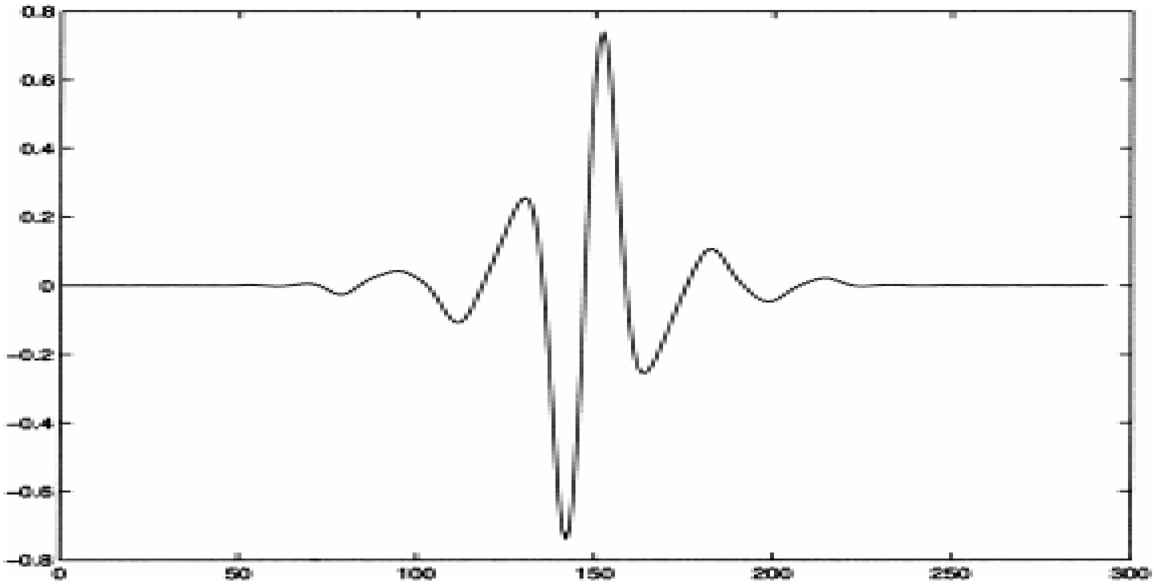

Fig 4.1: Depicts a B-spline wavelet.

The signal is decomposed in six frequency bands: five ‘detail’ levels (D1–D5) and one final approximation (A5). D1 corresponds to the highest frequency band and A5 to the lowest. Each coefficient shows the correlation of the signal with a wavelet function at different scales and times. the P100–N200 response is mainly correlated with the first post-stimulus coefficient in the details D4–D5. The P300 is mainly correlated with the coefficients at about 400–500 ms in A5. This correspondence is easily identified because: (1) the coefficients appear in the same time (and frequency) range as the ERPs and (2) they are relatively larger than the rest due to phase-locking between trials (coefficients reflecting background oscillations cancel in the average)

CHAPTER 5

EVALUATION AND TESTING

5.1 Results

With respect to our first objective, that is, extraction and analysis of P300 response from visual Event Related Potential (ERP) through an optimized algorithm, we have completed a good amount of literature survey to understand the P300 of the Event related potential in EEG to first understand how effectively it can be generated, by utilizing visual stimulus and where are its wide areas of occurrence within the lobes of the brain for the placement of electrodes, in order to understand the optimization of the circuit. Then we started with the understanding of EEGLAB following up with the SCCN tutorials, which is a library of Matlab. Basically, starting with Graphic user interface of EEGLAB of Matlab and then stepped into scripting as it provides the freedom to process a single dataset in multiple ways or a large number of datasets at one time. Then further, we would be utilizing the plug-in for EEGLAB known as the ERPLAB, to optimize our algorithm for better computation. And finally Wavelet transform would be used to detect the P300 signal.

And with respect to our second objective, that is, development of a data acquisition tool and the analysis of the EEG signal in real time, we would developing a low cost, high performance and high SNR system for data acquisition. Firstly, with the simulation software, secondly, with the prototyping board and finally, with PCB designing and printing.

5.1.1 Preprocessing Result

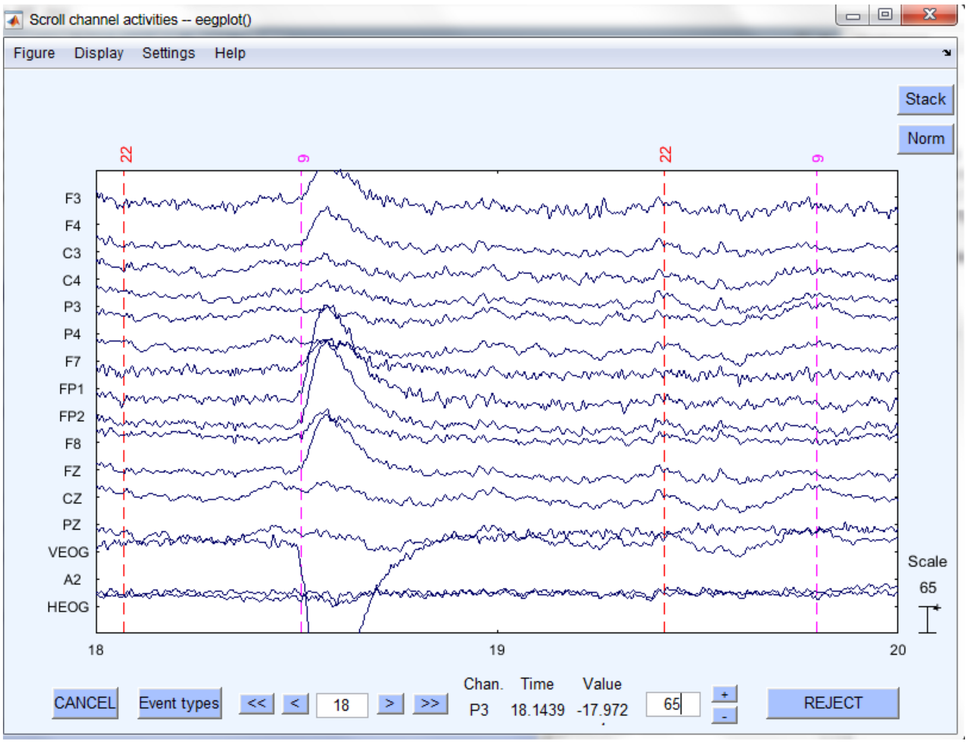

Figure 5.1: Raw EEG data

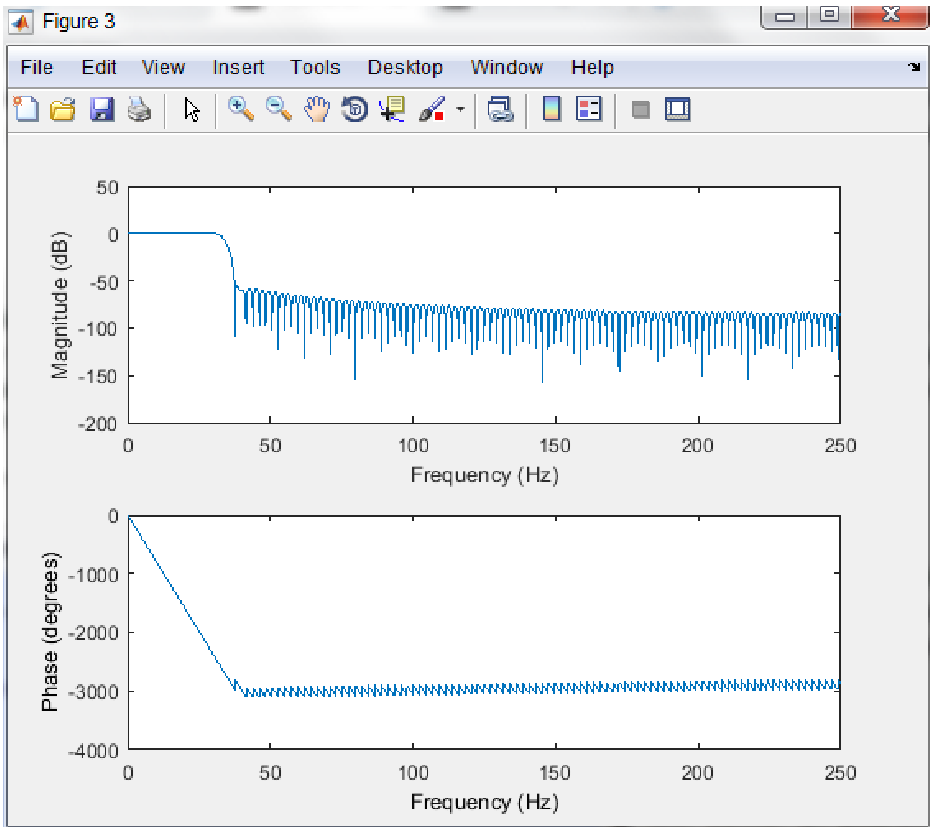

Figure 5.2: FIR filter between 0-30Hz

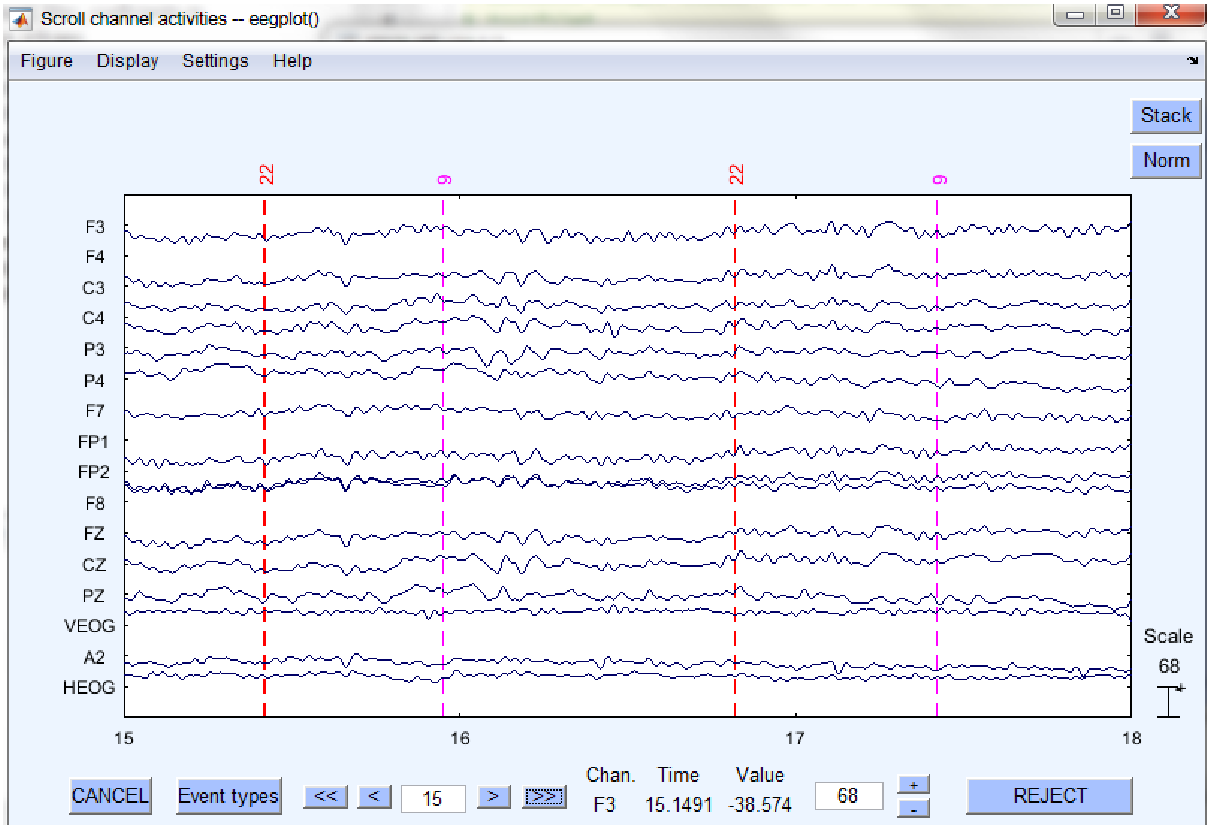

Figure 5.3: EEG data acquired on filtering between 0-30Hz

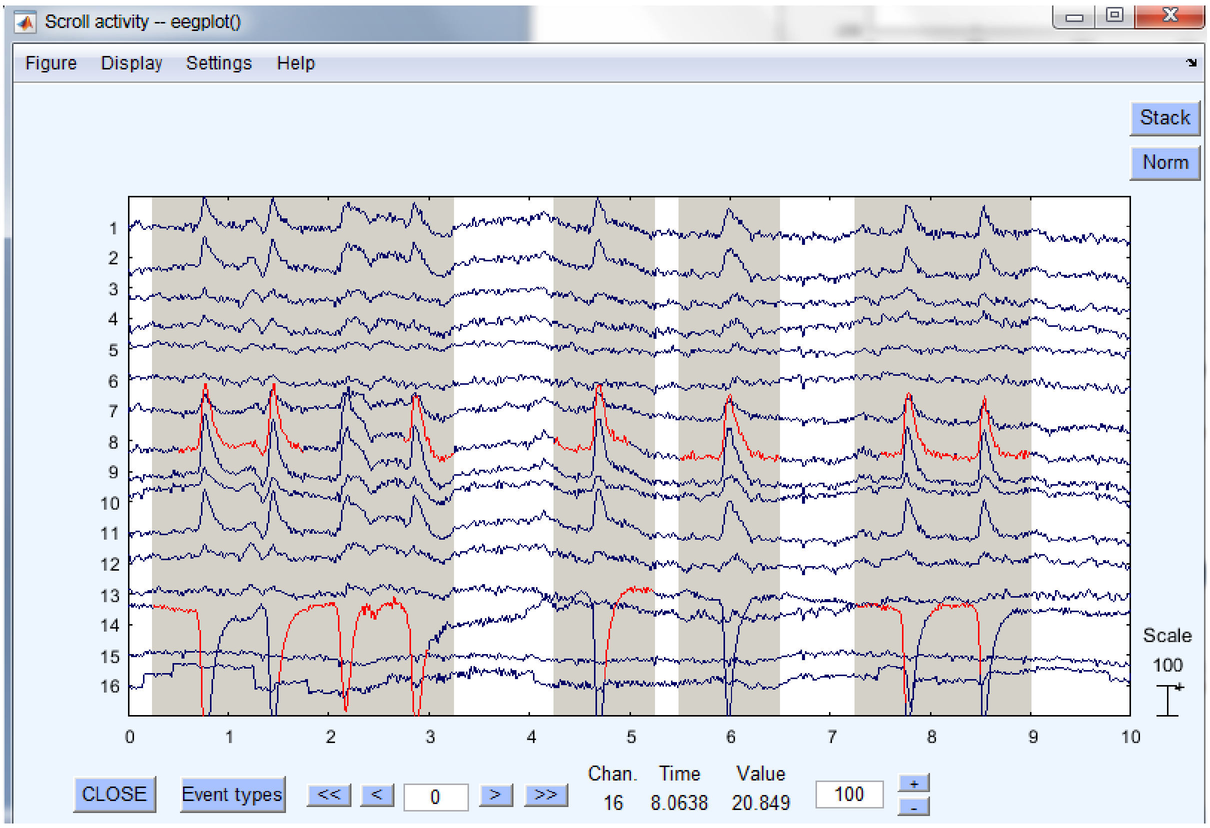

Figure 5.4: Artifacts detected which is the eye-blinking.

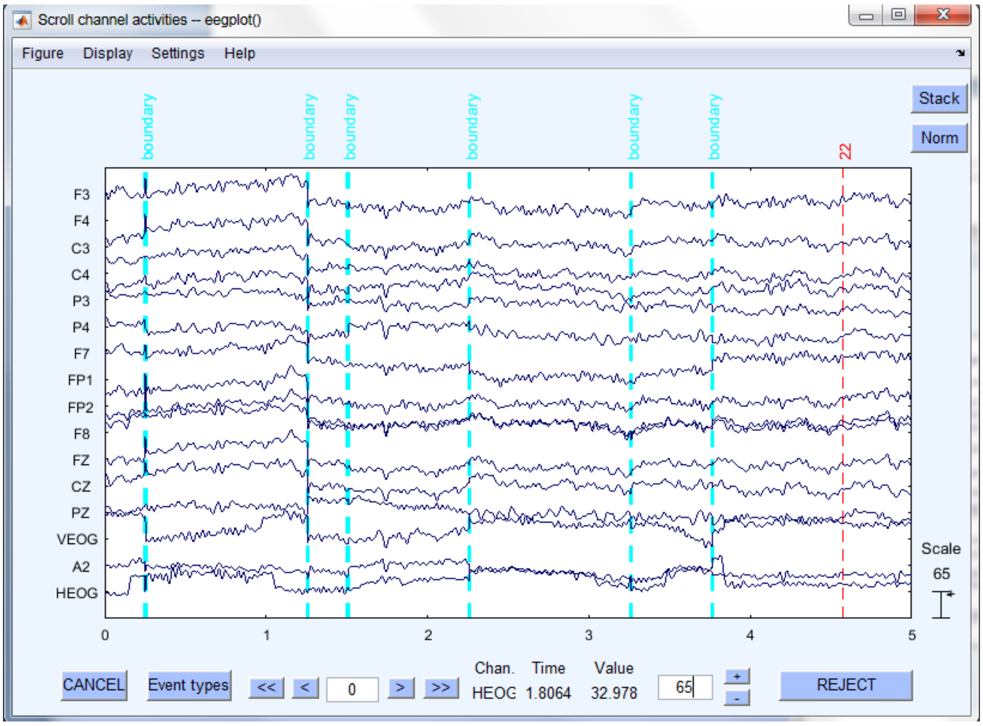

Figure 5.5 Artifacts removed and data independent of them.

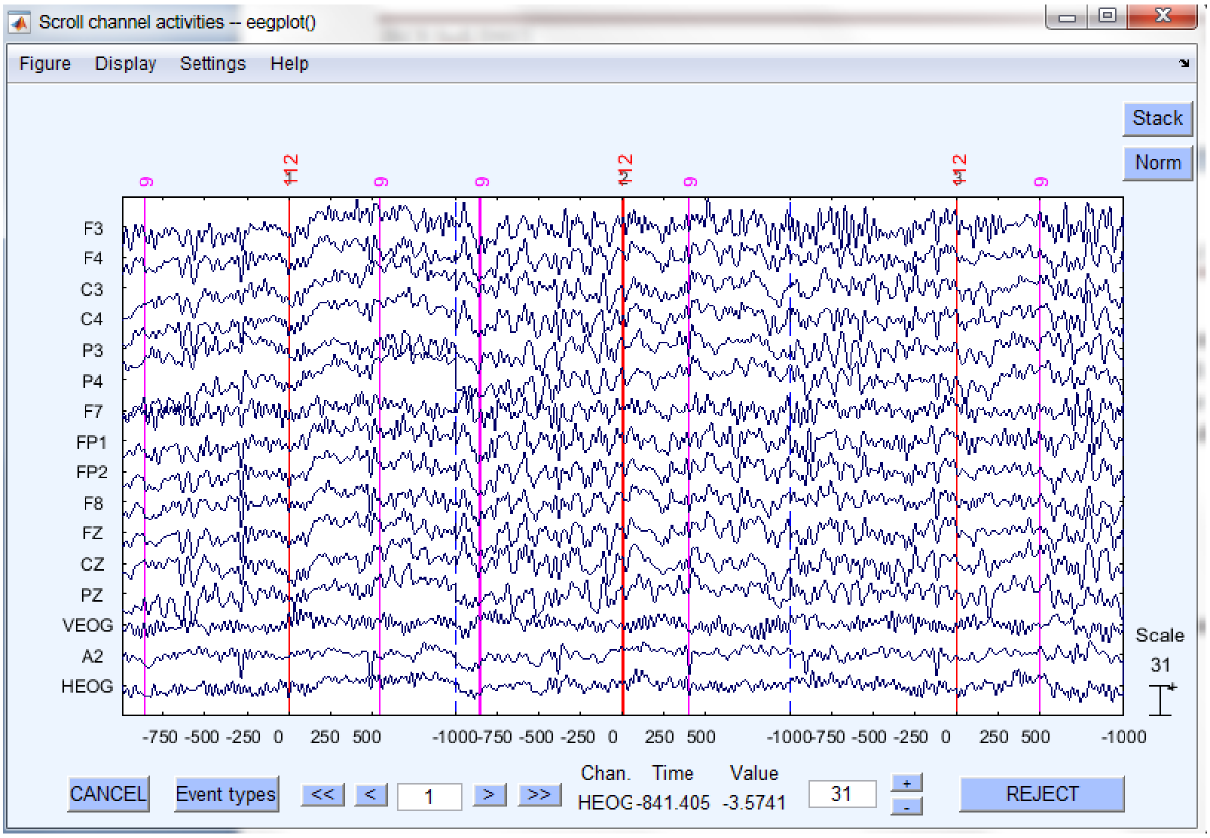

Figure 5.6: Epoch based EEG data

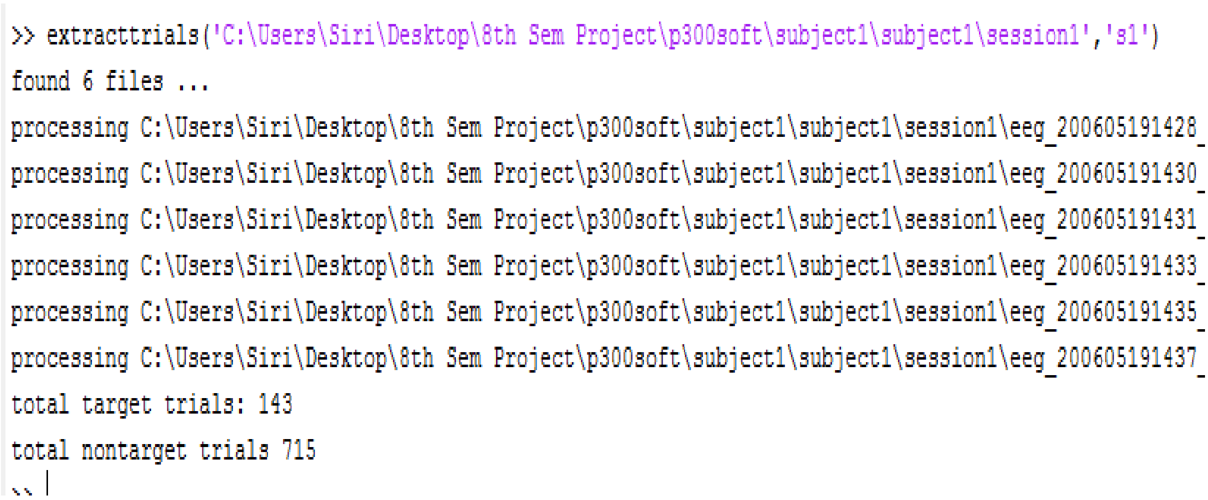

Figure 5.7: Computation of targets and non-targets in the data.

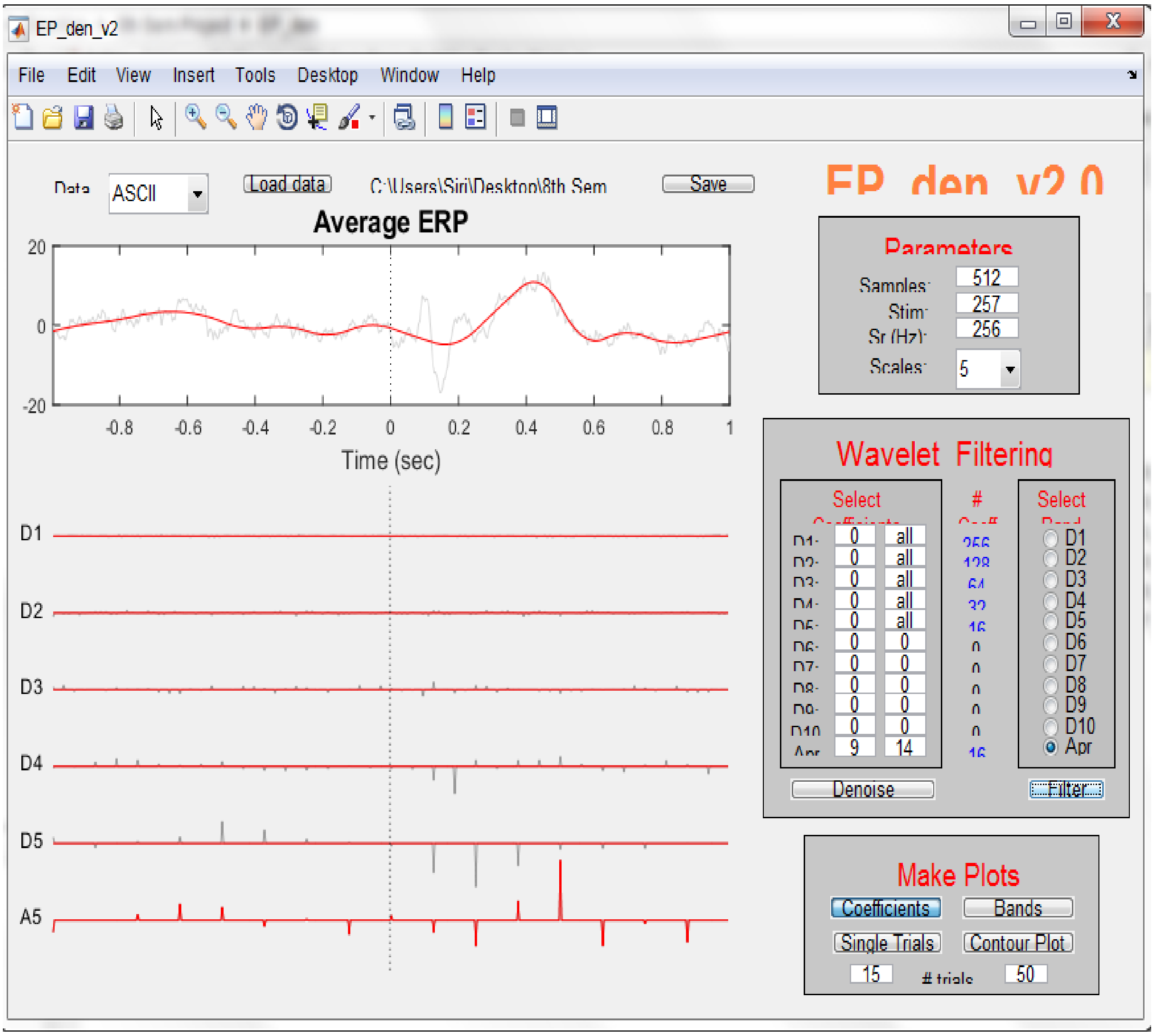

Figure 5.8: P300 peak detected in A5 on Wavelet denoising and transform

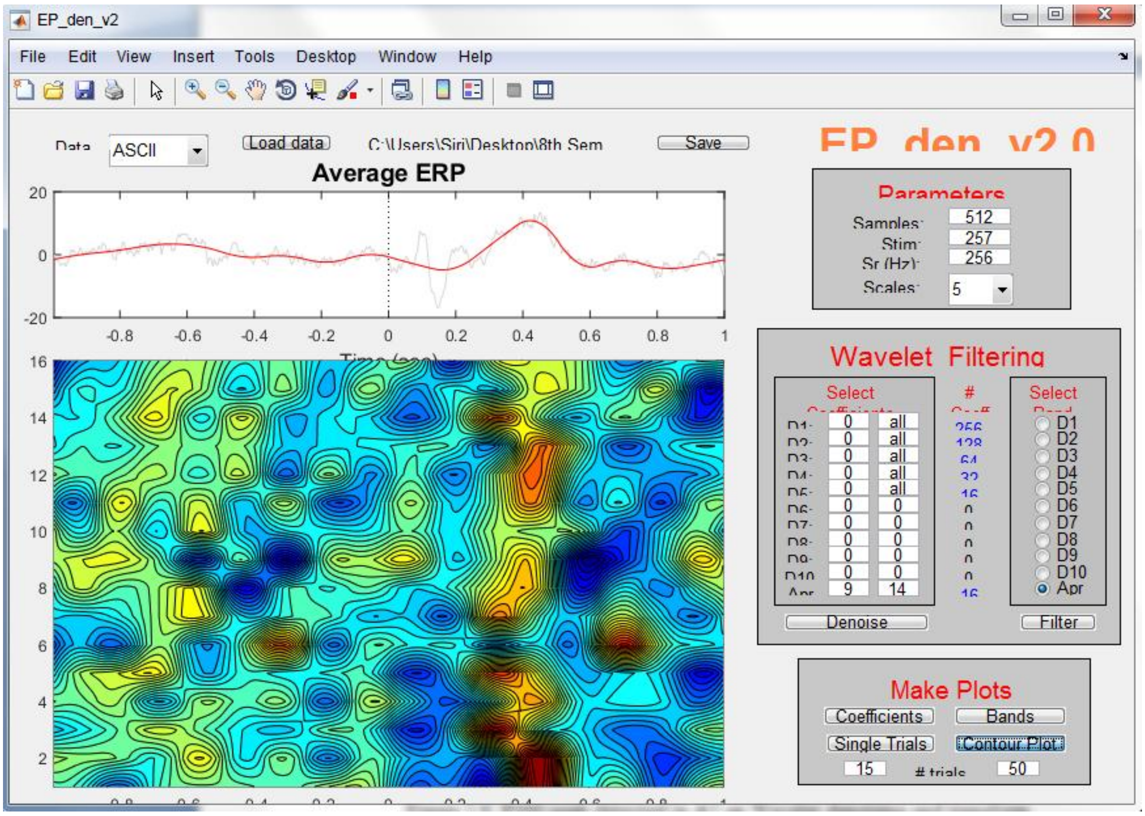

Figure 5.9: Red band indicates the occurrence of the P300.

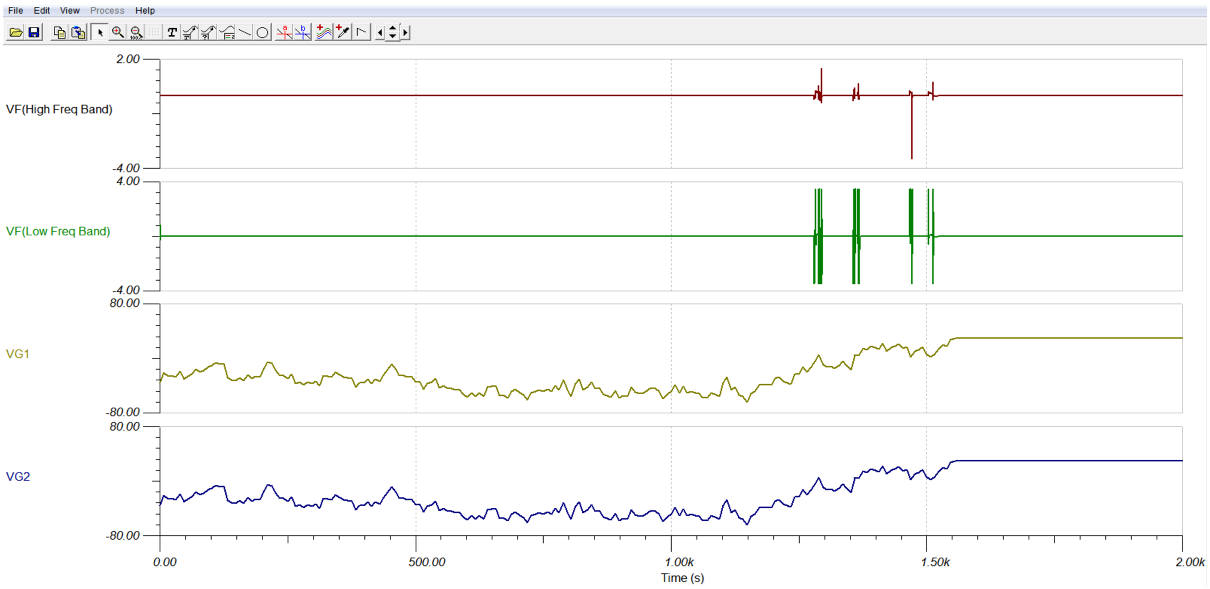

Figure 5.a: Depicts the simulation output of the designed PCB using TINA TI

CHAPTER 6

FUTURE WORKS

6.1 Extension of the project to meet future requirements

We would be extending this project to build a well developed system for a Brain Computer Interface. This would aid in supporting people who suffer from neuro-physiological diseases such as Alzeihmer's, ALS, etc to lead normal lives.

6.2 Application of the system

P300 BCI is particularly suitable for selection applications. For instance, the most typical application of P300 BCI is P300 speller. In such an arrangement, the visual paradigm is made up of a matrix consisting of letters of the alphabet. Depending on the requirement, a speller can be optimized for quick selection or accuracy of the spelled letters. Similarly, other P300 BCI investigations have made extensive progress to develop other attractive applications such as painting artwork, controlling smart home, designing games, stroke rehabilitation, lie detection, and furnishing Internet tasks. However, recognizing the importance of P300 speller, a detail description of P300 speller is presented in the following sections.

6.2.1 Smart home

A smart home populates different electronic devices which can be controlled using a P300 BCI. A virtual reality-based smart home was the test-bed of such BCI application. This BCI system allowed to execute a group of modest controlling commands such as moving the cart or wheelchair, receiving or making phone calls, operating television, switching the light on and off, playing song in multimedia player, or controlling the doors and windows.

6.2.2 Internet use

P300 BCI can be used to select the Internet keys to provide assistance to amyotrophic lateral sclerosis (ALS) patients browsing the websites. Subjects can surf through Internet pages and select the desired links to browse the Internet or read the news.

6.2.3 Painting task

It was observed by the researchers that performing natural tasks bring better quality to life in ALS patients. A P300 BCI application known as “Brain Painting” (BP) offers a medium of entertainment for the patients by improving their playful mood.

6.2.4 BCI gaming

P300 BCI has been used to design paradigm to control simple games that do not require strong time constraints such as to play chess, etc. If the P300 ERP is stronger, the game character can move larger distance. In fact, proper design to utilize the P300 wave’s strong dependence on attention would allow the scientists to study attention training and effects of engaging in a particular task.

6.2.5 Stroke rehabilitation

One of the sufferings of post-stroke patients is that they would like to say what they want but trouble of cortical circuits will not allow them to express it through natural motor pathways. P300 BCI paradigm was used to provide a communication channel to the participants diagnosed with post-stroke aphasia. P300 BCI not only allowed to activate their language circuits, but also made their post stroke recovery faster.

CONCLUSION

An ERP is a change in voltage which is time-locked to a specific sensory, motor, or cognitive event. ERP provides a distinctive pattern as an indication of how the stimulus is processed. Many BCI applications have been developed based on ERP as a response to stimulus to support the lives of people who suffer from various neuro-physiological or brain related anomalies. Among these, P300-based BCI is the most prominent ERP BCI. Over the last two decades, countless P300 BCI works have been initiated in laboratory experiments with the help of modern high speed computational and sensor technologies. Because of its non-invasive nature and stable performance, P300 applications range from the potential improvement of the lifestyle to the financial benefits. In fact, fundamental research on recording hardware, signal processing methods, stimulus presentation parameters, supporting interaction paradigm, and neurophysiology will further refine the P300-based BCI design. Though a BCI design is accomplished with keeping a specific application in mind, further insightful study and research can revive opportunities towards exploring other usability areas which are still not unearthed. To bring the BCI system from the laboratory to the real world application it is required that its performance should be as accurate as possible. Thus, the main goal of this project is the detection of P300 wave accurately. For this purpose discrete wavelet transform proves to be a very robust feature extraction technique to extract the most related features from the original EEG signal obtained from brain. The interfacing paradigm of a P300 BCI can be designed to capture the ERP-evoked potentials in a manner so that many human factors are properly taken care of to diminish their overall negative impact. Many new applications are also emerging with efficient design of the control interface and associated signal processing scheme.

The low cost, high SNR and highly efficient data acquisition system that was built for the project, makes healthcare affordable to millions in our country. It brings about a new horizon to promote research and development in our colleges in the field of healthcare as there is much need in this field.

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APPENDIX A

The experiment conducted and the dataset description:

This study was conducted to examine the P3 wave and the lateralized readiness component (LRP) in a group of schizophrenia patients and a group of matched control subjects. All subject identity information had been stripped from the data files. In the experiment, a letter or digit was presented every 1300-1700 ms. Subjects were instructed to press a button with one hand for digits and with the other hand for letters. For a given trial block, either the letters or the digits were rare (20%) and the other category was frequent (80%). Thus, the stimulus category and the probability were counterbalanced. The probability manipulation was designed to isolate the probability-sensitive P3b component. Different event codes were used for the digits when they were rare, the digits when they were frequent, the letters when they were rare, and the letters when they were frequent.

The experiment was also designed to isolate the LRP by counterbalancing the stimulus category and probability with the left and right hand responses. That is, subjects responded to letters with the left hand and digits with the right hand for half of the experiment, and they responded to digits with the left hand and letters with the right hand for the other half. This is also indicated by the event codes for each stimulus (i.e., the event code for the stimulus also indicates the appropriate response for that stimulus)

ERPLAB Toolbox makes no distinction between stimulus event codes and response event codes. This gives the user more power, but it also gives the user responsibility for using the event codes in a sensible way. The event codes for responses in this example experiment indicated whether the response was correct (event code = 9) or incorrect (event code = 8) rather than directly indicating whether a left-hand or right-hand response was made. However, the combination of the stimulus event code and the response event code makes it possible to determine whether the subject pressed the left button or the right button.

Here is a table showing the stimulus event codes

Event Code	Category	Probability	Correct Response
11	Letter	Frequent	Left Hand
21	Digit	Rare	Right Hand
112	Letter	Rare	Left Hand
122	Digit	Frequent	Right Hand
12	Letter	Rare	Right Hand
22	Digit	Frequent	Left Hand
111	Letter	Frequent	Right Hand
121	Digit	Rare	Left Hand

Table A.1: Depiction of the different events.

The data in this experiment were recorded from a 16-bit Neuroscan Synamps system with a bandpass of 0.05-100 Hz and a sampling rate of 500 Hz. Each scalp site was recorded relative to a right-earlobe reference. Recordings were also obtained from a vertical electrooculogram (VEOG) electrode located beneath the left eye and from an electrode on the left earlobe (both referenced to the right earlobe). A horizontal electrooculogram (HEOG) signal was recorded as the potential between electrodes located just lateral to each eye.

Letters and digits were presented in an unpredictable order within each trial block, but separate blocks were used for each combination of probability response assignment. That is, there were separate trial blocks for: (1) 80% letters (left-hand response) and 20% digits (right-hand response); (2) 20% letters (left-hand response) and 80% digits (right-hand response); (3) 80% letters (right-hand response) and 20% digits (left-hand response); (4) 20% letters (right-hand response) and 80% digits (left-hand response). Each block was originally recorded in a separate file

APPENDIX B

Matlab wavelet denoising GUI:

The main reason Graphic User Interfaces or GUIs are used is because it makes things simple for the end-users of the program. If GUIs were not used, people would have to work from the command line interface, which can be extremely difficult and frustrating. GUIDE is the Matlab toolbox to develop any kind of GUI.

It mainly has two kinds of files:

1) A .fig file which represents the front end. This file allows for the development of the buttons, figures of plotted graphs, check boxes, sliders, static text etc to be displayed on the front end architecture. Each of the mentioned features have their own "tags" to recognise their call back functions.

2) The .m file generates the backend function of the GUI. They are call back functions associated to the tags on the front end.

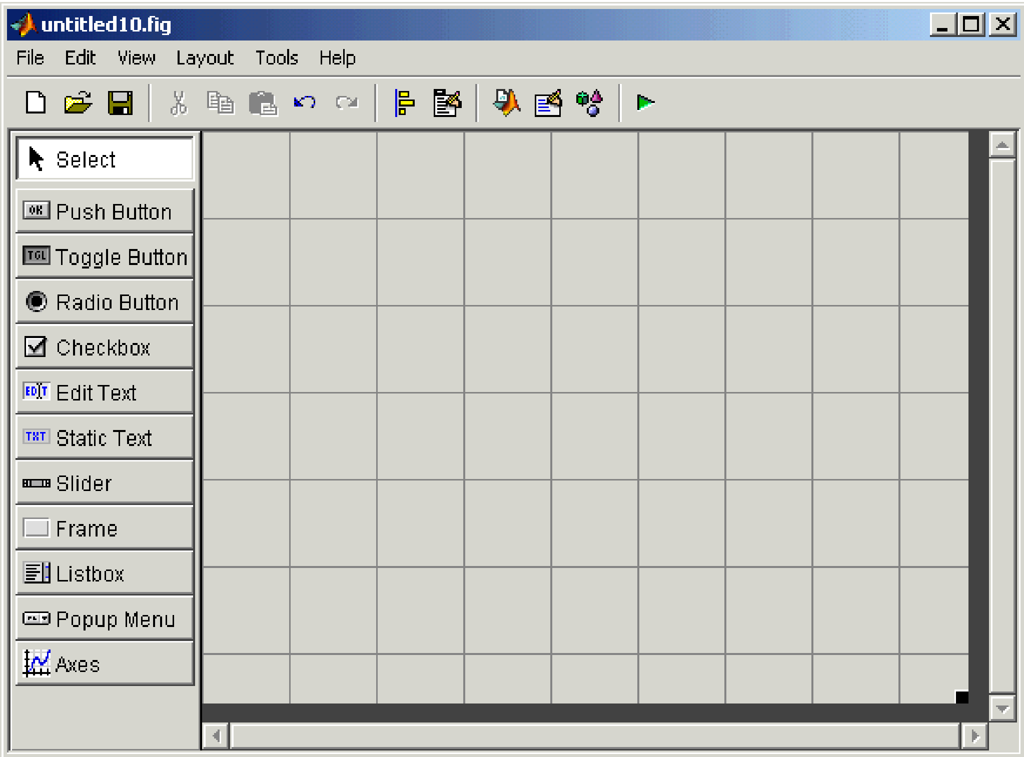

Fig B.1: GUI development in Matlab

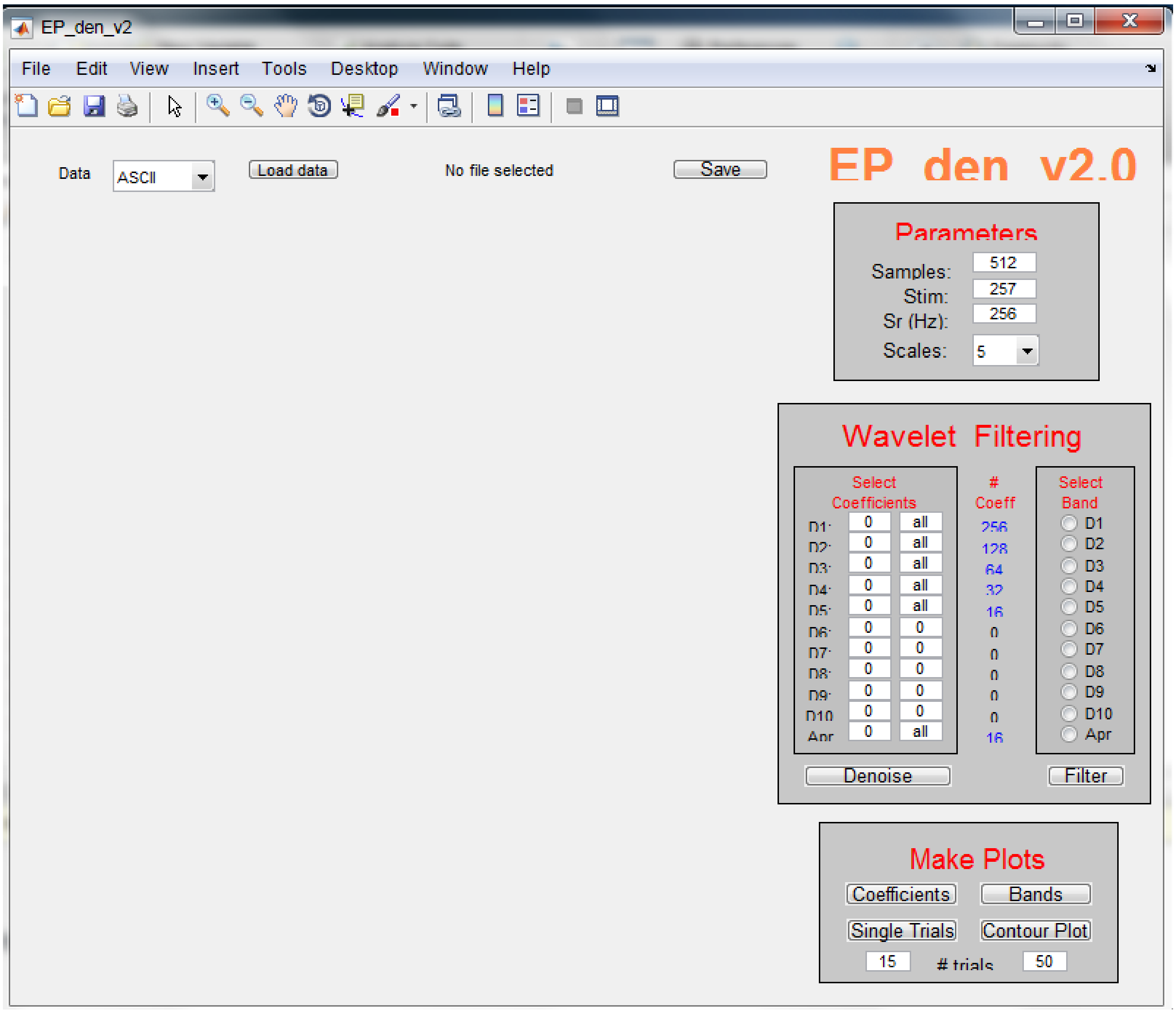

Fig B.2: The final GUI developed for Wavelet Denoising in the project.