Implementation of Single Channel EEG Based Brain Computer Interface

Binary Classification of mental states using Support Vector Machine

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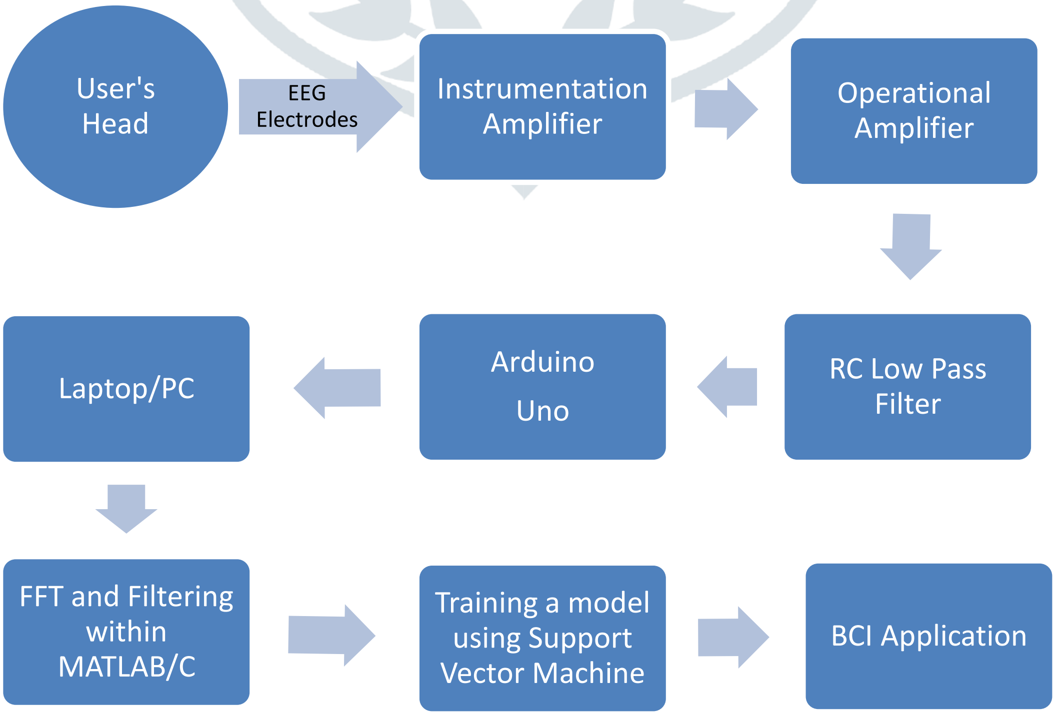
***Abstract*— Brain Computer Interface (BCI) is a device that enables use of brain's neural activity to communicate with others or other machines without direct physical contact. Brain Computer interface was initially used to help people affected by motor neuron diseases. BCI is accomplished through Electroencephalography (EEG) that measures the electrical activity produced by the neurons in the brain. The existing BCI solutions are really expensive and complex so we wanted to find a way to build a simple and cost effective BCI. A single channel EEG acquisition system was designed and implemented on few healthy subjects. We used Support Vector Machine algorithm to train and classify the signals obtained from the subjects and obtained an accuracy of 70%.**

Index Terms: Electroencephalography, BCI, Support Vector Machine, Arduino, Python, Fast Fourier Transform

I. INTRODUCTION

EEG values range from 0.1 µV to 1mV and frequency range is from 0 to 30Hz.Different frequency bands correspond to different mental states of a person, for e.g. the frequency range from 8-12Hz are called alpha waves and high alpha activity implies long closure of the eyes or the person is relaxing. To implement Brain Computer Interface we have used two frequency bands, alpha waves and beta waves that conforms to the range 13-30Hz.Neurosky has developed a wireless single channel EEG headset for BCI that classifies attention and relaxation states of a person. Although it works efficiently it is really expensive and hence we came up with a simple cost effective BCI acquisition system. Traditional EEG system requires a lot of initial set up including the use of electrode paste/gel. We have used disposable monitoring electrodes that require only surface cleaning with alcohol swab before use. The voltages captured by the electrodes are amplified using an amplification circuit we built. The amplified time domain signal is then converted to frequency domain by applying fast Fourier transform. The features are extracted and trained using a machine learning algorithm. The trained model is then used to predict the mental state of the user.

II. METHODOLOGY

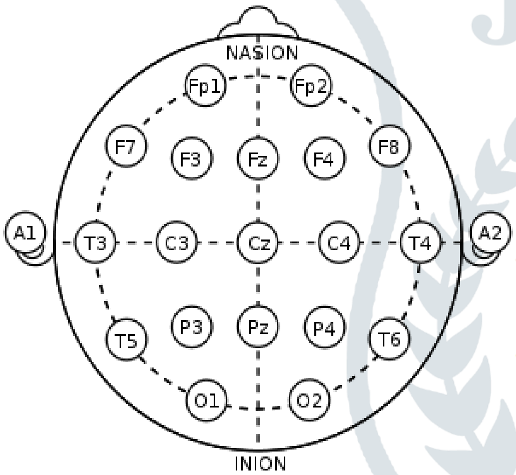


The above figure represents the sequence of events that take place in the proposed BCI system.

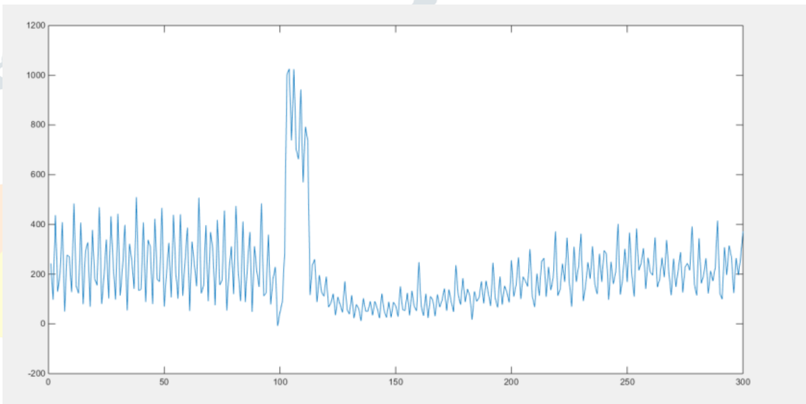
a) Hardware and Pre-processing

The amplification circuit consists of an instrumentation amplifier AD620N, and a couple of operational amplifiers CA3130. EEG voltages lie in the range of micro volts and the instrumentation amplifier provides a gain of around 23 and it also acts as a common mode noise filter. The AD620N takes the reference electrode and computes the common mode noise and subtracts it from the remaining electrode values. This reduces the electrical noise and other artefacts. The total gain of the circuit is around 1500. We have also included a RC low pass filter in the circuit to filter out frequencies more than 50Hz (power supply noise). To test the circuit we prototyped the circuit on a breadboard initially and then soldered the components on to a general purpose PCB. We used Ag/AgCl disposable monitoring electrodes and a low noise cables to connect the electrodes to the circuit. The skin preparation plays a crucial role in acquiring the EEG signals. A pre-injection alcohol swab was used to clean the surface of the skin. The electrode placement was done at positions FP1 (positive electrode), A1 (negative electrode) and A2 (reference electrode) according to the International 10-20 system. The amplified signals are sent to the PC through Arduino. Arduino samples the EEG voltage and sends it to the serial port at a sampling frequency of 60Hz.

The data from the serial port is captured in real time using “Processing IDE” and written to a csv (comma separated values) file. This forms the training data which still contains some artefacts and noise. To remove these we used the inbuilt filter in MATLAB called Butterworth and implemented it as a low pass filter. The filtered EEG data is in the time domain, so we used the Fast Fourier Transforms to get EEG spectrum. The power values of the spectrum along with the corresponding frequencies forms the training data.



The International 10-20 System



EEG Plot – Voltage V/s Time

b) Machine Learning

The filtered data is subjected to feature extraction. The features that correspond to concentration and relaxation state were identified. We used Support Vector Machine algorithm to train and classify the training set. Support vector Machine is a supervised learning algorithm that works efficiently with binary classification. The model was trained using linear and Gaussian kernel and obtained an accuracy of 60 and 70 respectively. We used the trained model to predict the mental state of the person in real time.

c) Applications

Pong

We designed two applications, a pong game and a typing application. The pong game was designed using SimpleGUI module. The pong game consists of a moving ball and two paddles, one controlled by keyboard and other controlled by the person wearing the EEG electrodes. The paddle moves up when the person is concentrating and goes down when the person is relaxing. The paddle movement is determined by the probability value that is calculated based on the mental state of the person. The person with the lesser score is declared as a winner.

Typing

This application is also based on the SimpleGUI module. A 5x6 character matrix was designed to hold the English alphabet and a few special characters. The cursor moves around the matrix and the movement of the cursor is controlled by the person wearing EEG electrodes. When the person concentrates the cursor moves down and when he/she is relaxing the cursor moves right in the matrix. This way he/she can spiral into the character required.

III. RESULTS

The applications were tested on few healthy subjects and we obtained an accuracy of 70 %. We obtained simplified and satisfactory binary classification of mental state of a person using a low cost single channel EEG acquisition system. We were able to train the model in MATLAB and implement the prediction algorithm in python within the application.

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