Brain Computer Interface Based Upper Limb Prosthesis

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Abstract- *Amputation causes loss of motor skills which makes everyday activities more difficult. The day-to-day activity of the amputee patient has to be improved, by communicating and controlling the environment through EEG signal. EEG-based brain controlled prosthetic arm is a non-invasive technique that can serve as a powerful aid for severely disabled people in their daily life, especially to help them move their arm voluntarily. In this paper, EEG-based brain controlled prosthetic arm has been developed using BCI to yield the movements of the arm: Right and left hand movements, up and down movement, wrist rotation, grasping and releasing of fingers. BCI system consists of an EEG Signal data, which will be processed in MATLAB. The extracted brain signals act as command signals that are transmitted to the Microcontroller via USB connection. The prosthetic arm module design consists of Arduino coupled with servo motors to perform the command. The movement of the hand can be controlled using MATLAB support package for arduino hardware. The low-cost BCI system could allow the disabled people to control their prosthetic arm to lead a self-reliant life with the help of their brain signals.*

Keywords- BCI (Brain Computer Interface), EEG (Electroencephalogram), MATLAB Support Packge For Arduino Hardware , Prosthetic arm.

I. INTRODUCTION

Amputation is the removal of limb by trauma medical illness or surgery. As a surgical measure, it is to control pain or a disease process in the affected limb such as malignancy or gangrene. The major physical effects of amputation are loss of motor skill and mobility problem. The prosthetics helps to restore the missing part of the body and improve the ordinary and day to day activities. Bio signal is defined as any signal measured and monitored from a biological being, these are generated by electrical potential differences across a tissue or cell. Brain Computer Interface (BCI) is a system that allows the user to communicate with its environment with the use of EEG signals. BCI Technology is divided into three categories: Invasive BCIs, where electrodes are implanted into the gray matter of the brain. Partially-invasive BCIs, implanted inside the skull but only resting on the top of the brain.

Non-invasive BCIs, involving plastic devices which slip over the head like a shower cap. In this project only non-invasive BCI method of EEG signal recording was used. The brain generates rhythmical potentials which originate in the individual neurons of the brain. These potentials get summated as millions of cell discharge synchronously and appear as a surface waveform, the recording of which is known as the EEG. The frequencies of the EEG activity range from 0.5 up to about 50Hz.The EEG signals picked are up by the electrodes, measures the potential difference between the recording electrode and a reference electrode, and amplifies the difference.

Then the data is converted into a series of numerical values. The data is transformed into a matrix format having the rows represent the labelled electrodes and columns represent the recorded data in microvolts.EEG signal is passed through several analysis and processing methods in order to filter the signal and remove the unwanted noise.

II. METHODOLOGY

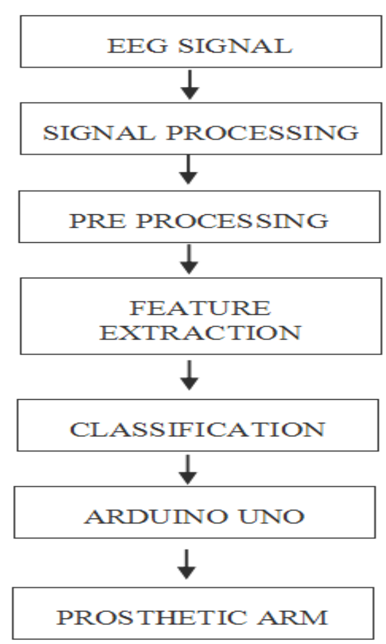


Fig.1 Work flow

A. EEG Signal

The electroencephalogram (EEG) is a recording of the electrical activity of the brain from the scalp. The recorded waveforms reflect the cortical electrical activity. The main frequencies of the human EEG waves are: delta, theta, alpha, beta, gamma. EEG data is acquired using EEG data acquisition system by giving a visual stimulus to the subject.

B. Pre Processing

In pre-processing stage, the signal is down sampled from 1024 to 256. Then various frequency bands of the EEG signal are separated by a 2nd order Butterworth bandpass filter. For analysis, the useful frequency bands are mu (8-13 Hz) and beta (16-30 Hz).

C. Feature Extraction

Feature extraction is the transformation of original data set with a reduced number of variables which contains most discriminatory information. The major features for BCI application are Mean, Standard deviation, ERD, ERS.

D. Classification

The Support Vector Machine (SVM) classifier is designed to classify the EEG motor imagery signal. SVM is a supervised machine learning algorithm which can be used for classification or regression problems. In BCI, the SVM is most accurate classification technique. The goal of SVM is to find the separation between two classes, such that the distance between the hyperplane and the closest points from both classes is maximal.

E. Arduino Uno

The Arduino Uno is an open source microcontroller platform based on simple input-output board (I/O). It has 14digital input/output pins. Of the 14 pins, 6 can be used as PWM outputs, 6 as analog inputs. It has a 16 MHz quartz crystal and a USB connection. The Arduino Uno is inexpensive, supports cross-platform, open source, easy programming environment.

F. Prosthetic Arm

The prosthetic arm is made up of 3D printed material with 6 servo motors. The command signals are sent to Arduino microcontroller module. Arduino Uno is programmed to control motors for right and left hand movements, up and down movements, grasping and releasing of fingers by fixing the threshold value.

III. DATA ACQUISITION

A. EEE Data Acquisition

The motor imagery EEG signal is recorded by giving a visual stimulus to the subject. The visual stimulus is created as a video of 10 seconds, first 2 seconds of blank screen followed by 3 seconds of rest which indicates a plus on middle of the screen and last 5 seconds of right or left hand movement's imagination by indicating right or left arrow on the screen. EEG data was collected from 6 normal subjects aged between 23 to 25 with each 5 left trials and 5 right trials. Totally 60 set of motor imagery EEG signals are acquired. During each trial EEG signals are recorded for both rest and imagination conditions. The order of left and right hand cues are random. The EEG motor imagery signals are sampled with 1024Hz then the EEG signal is down sampled by 256 for further processing. The cue flow is shown in the figure 2.

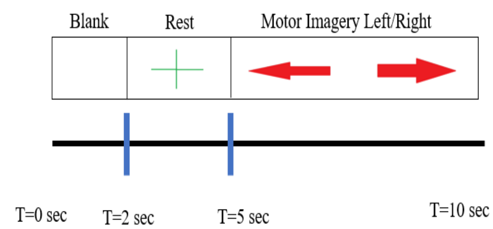


Fig 2 EEG Cue

IV. PREPROCESSING AND CLASSIFICATION

A. Pre Processing

In pre-processing stage, the signal is down sampled from 1024 to 256. Then various frequency bands of the EEG signal are separated by a 2^{nd} order Butterworth band pass filter. For analysis, the useful frequency bands are mu (8-13 Hz) and beta (16-30 Hz).

B. Feature Extraction

Feature extraction is the transformation of original data set with a reduced number of variables which contains most discriminatory information. The major features such as Mean, Standard deviation and ERD are extracted from EEG signal which are of primary importance in BCI applications.

C. Mean

The mean is the average value of the data, it averages the entire data and represents it in a single value.To find the mean, add up the values in the data set and then divided by the number of values that added.

$$\mu = 1/N \sum_{i=1}^{N} Xi$$

Where, Xi is the signal

N is the Number of samples in the signal

D. Standard Deviation

The standard deviation measures the dispersion of a dataset relative to its mean and is calculated as the square root of the variance by determining the variation between each data point relative to the mean. If the data points are farther from the mean, there is a higher deviation and more spread out within the data.

$$\sigma = \sqrt{1/N \sum_{i=1}^{N} (xi - \mu)^2}$$

Where, μ is the mean of the signal Xi

N is the Number of samples in the signal

E. Event Related De-synchronization and synchronization

Event-Related De-synchronization is that the underlying cortical area is activated for instance processing information or preparing a movement. It represents an amplitude decrease of rhythmic activity. Event Related synchronization is that the underlying cortical area is in a resting or idling state in which, at a specific moment of time, no information is processed. ERS represents an amplitude increase of rhythmic activity.

$$\text{ERD\%} = \frac{\text{A} - \text{R}}{\text{R}}$$

Where A is the power within the frequency band of interest

R is the band power of the signal before the imaginary movement.

F. Classification

Classification is done using the Support Vector Machines(SVM) classifier. SVM is a discriminative classifier defined by separating hyperplane. The hyperplane is a line dividing a plane in two parts where in each class lay in either side. SVM finds the separation between the two classes such that the distance between the hyperplane and the closest points from both classes is maximal. SVM classifies the given EEG signal as left or right hand signal.

G. EEG Command Signal

The EEG command signal is depending on the output from the classifier. The output of the classifier is given to microcontroller, from the microcontroller the left and right hand signals are sent as command signal to the prosthetic arm.

H. Control Signal

The movements are Right and left hand movements, flexion and extension movements, grasping and releasing of fingers. The classified EEG signal from SVM classifier in MATLAB is given to the motor as a command signal. The command signals are as follows

- Servo motor 1: Left and right movements
- Servo motor 2: Flexion and extension movements
- Servo motor 3: Wrist rotation
- Servo motor 4: Grasping and releasing of fingers

When there is no signal there will be no movement.

V. DESIGNING OF PROSTHETIC ARM

The prosthetic arm is made up of acrylic polymer. The joints of the arm are controlled by motors to bring proper movement with respect to the command signal.

For upward, downward, wrist rotation, grasping and release movements, DC motor is employed. For left and right movements, servo motors are used. The classified EEG signal from MATLAB is interfaced with servo motor for efficient left and right movements.

VI. RESULTS

Fig .3 Experimental setup

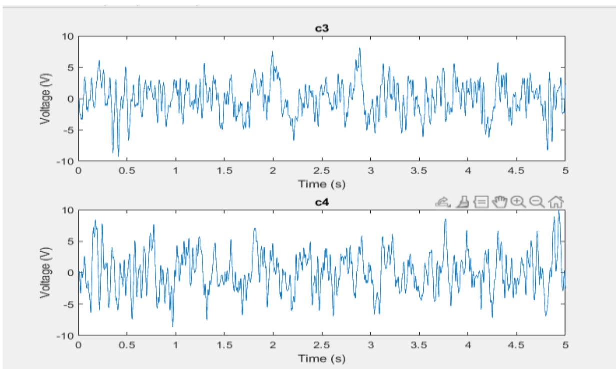


Fig.4 Motor imagery EEG raw signal

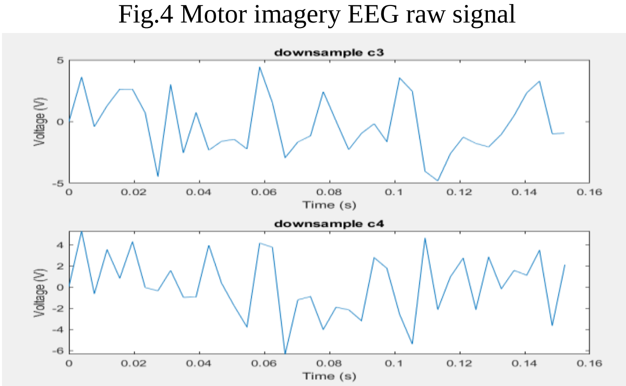


Fig.5 Downsampled EEG signal

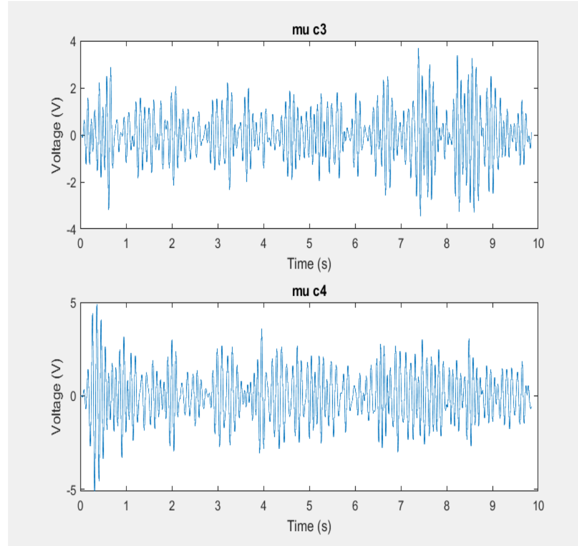


Fig.6 Motor Imagery Mu Signal

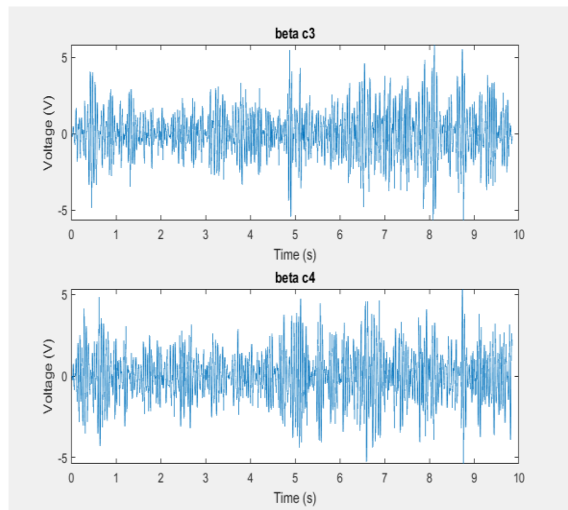


Fig.7 Motor Imagery Beta Signal

Down Hand Movement

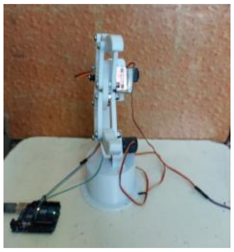
Left Side Movement

Grasping Movement

Up Hand Movement

Right Side Movement

Releasing movement



Wrist Rotation

Fig.8 Various movements of prosthetic arm

VII. CONCLUSION

Thus the prosthetic arm is controlled using collected motor imagery EEG signal. The EEG signal is acquired, then the various frequency bands of EEG signal are separated.The useful frequency bands for analysis are mu (8-13 Hz) and beta (16-30 Hz) and the major features for BCI such as mean, standard deviation and ERD are extracted. SVM classifier is used to get a better accuracy.From EEG signal Right and left hand movements, up and down movements, wrist rotation, grasping and releasing of finger movements are classified by the classifier. Then the motor imagery signals are combined to control the prosthetic arm using command signals.

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