Mind Controlled Automation With P300 Waves

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Abstract:

In Biomedical instrumentation, BCI technology is an emerging field and has the large scope for research in Automation and Control system. In this paper we have obtained EEG signals for distinguishing and analysing thoughts in the frontal lobe.

Electroencephalography (EEG) equipment are becoming more available on the public market, which enables more diverse research in a currently narrow field. The Brain-Computer Interface (BCI) community recognize the need for systems that makes BCI more user-friendly, real-time, manageable and suited for people that are not forced to use them, like clinical patients, and those who are disabled. Thus, this project is an effort to seek such improvements, having a newly available market product to experiment with: a single channel brain wave reader. However, it is important to stress that this shift in BCI, from patients to healthy and ordinary users, should ultimately be beneficial for those who really need it, indeed. The main focus have been building a system which enables usage of the available EEG device, and making a prototype that incorporates all parts of a functioning BCI system. These parts are 1) acquiring the EEG signal 2) process and classify the EEG signal and 3) use the signal classification to control appliances.

Keywords: BCI(Brain computer Interface), EEG(electroencephalogram), FFT, PCA(Principal Component Analysis).

I Introduction

Ever since Hans Berger demonstrated the electroencephalography technique for the first time in 1929, doctors and scientists have used it to investigate how the brain functions. But now there has also been speculation about the possibility of using electroencephalograms (EEGs) to decode people’s intentions and use their brain activity to control devices directly. This is the definition of a brain-computer interface (BCI), it’s simply a communication system that monitors brain activity and translates certain characteristics, corresponding to users’ intentions, into commands that operate a device. BCI systems could be very useful for people who are dependent on others, as a result of either advanced age or a severe disability, as it would open up a new channel of communication for them.

Brain–computer interfacing (BCI), i.e., the ability to transfer and use information from distinct brain states for communicating with a machine has in the past years received considerable attention, Tom Carlson, Member IEEE, and Jos´e del R. Mill´an, Senior Member IEEE March 2013 have developed a BCI system which controls a wheelchair using P300–based approaches[1]. Erik Andreas Norwegian University of Science and Technology have classified the EEg siganls based on neural network[2]. Feature Generation of EEG Data Using Wavelet Analysis by Catherine Chesnutt, B.S. may (2012)[3]. EEG signal classification for BCI applications by wavelets and interval type-2 fuzzy logic systems Thanh Nguyen Australia (2015)[4]. Omar AlZoubi1,2, Irena Koprinska1 and Rafael A. Calvo School of Information Technology have classified the BCI data based on Common Spatial Patterns (CSP)[5]. Senthilmurugan.M, Latha.M and Dr.Malmurugan.N used Inverse Model for classifying EEG data [6]. Extraction of SSVEP signals of a capacitive EEG helmet for human machine interface by Oehler M, Neumann P[7]. Luo A, Sullivan TJ J Neural Eng. 2010 Apr presented a user-friendly SSVEP-based brain-computer interface using a time-domain classifier[8].

The main parts of the brain associated with the BCI system are as follows[9]

***Frontal Lobe**:* It is one of four lobes in the cerebral hemisphere. This lobe controls creative thought, problem solving, intellect, judgment, behaviour, attention, abstract thinking, physical reactions, muscle movements, coordinated movements, smell and personality.

***Parietal Lobe**:* Located in the cerebral hemisphere, this lobe focuses on comprehension. Visual functions, language, reading, internal stimuli, tactile sensation and sensory comprehension will be monitored here.

***Temporal Lobe**:* It controls visual and auditory memories. It includes areas that help manage some speech and hearing capabilities, behavioural elements, and language. It is located in the cerebral hemisphere.

***Occipital Lobe**:* The optical lobe is located in the cerebral hemisphere in the back of the head. It helps to control vision.

In our work in Mind Controlled Automation, we use non-invasive EEG techniques to read the raw electrical signals from the frontal lobe, which are amplified and transmitted over a Bluetooth module to a computing system which performs a feature extraction and classification algorithm to distinguish the incoming signal for control.

II BCI System design

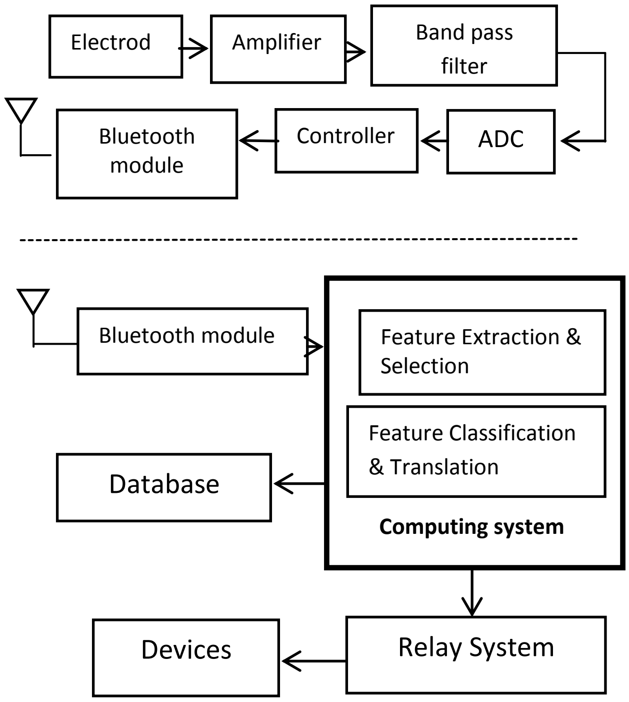

Fig.1: **BCI Block Diagram**

Figure.1 describes the various blocks used for the implementation of Mind controlled automation. The system consists of two isolated system.

- The transmitter section (which will be mounted on the users head using a cap). It consists of the following:

Electrodes: The system consists of two AgCl dry EEG electrodes, one placed on the forehead used to capture raw EEG data and the other placed behind the ear as a reference.

Amplifier: The system consists an instrumentation amplifier that amplifies the low power signal(>50uV) up to a certain level which can be used to process.

Filter: A band pass filter is used to pass all frequencies in the alpha range (8-13Hz).

ADC: Digitizes the incoming analog signal which is fed into the controller

Controller: It's used to serially transmit the incoming data to the Bluetooth module.

Bluetooth module: Bluetooth is a standardised protocol for sending and receiving data via 2.4GHz wireless link. It is a secure protocol and is perfect for short range , low power, low cost, wireless transmissions between electronic devices.

- The receiver section consists of the following :

Receiver: Consists of receiver Bluetooth module that passes the incoming signal to the computing system.

Database: Consists of predefined classified signals(Acts as a look up table)

Computing system: It consists of a controller which will perform the feature extraction algorithm and the classification algorithm on the incoming data and Compares the classified data against the database. The weightage will decide the control signal.

Feature extraction: Once the brain signals have been digitized they are processed by one or more feature extraction methods. These processes are intended to extract specific characteristics of the signals, which encode the messages or commands elicited in the user's brain by either evoked or spontaneous inputs. Feature extraction methods could either extract information from the signal in time domain, e.g. evoked potential amplitudes or transform the brain signals to be analyzed in different domains, like the frequency domain or time-frequency domain.

Feature Selection: The features extracted for its use in BCI systems will provide a better or worse separability for the classes used for control depending on where on the scalp they are coming from and where in its domain they are, e.g. features found in the motor cortex are more likely to provide better separability for classes of a BCI systems based on motor imagery than the features found on the visual cortex, and on the other hand features found on the visual cortex are more likely to provide better separability for classes of a BCI system based on SSVEP than features found on the motor cortex. Also, for motor imagery based BCI systems, features found on the alpha and beta band are more likely to provide better separability of classes than features found in other frequency bands. So beside the extraction of features

using a specific method, is also necessary to select the appropriate features to be used for classification. Feature selection methods are divided into filters methods, e.g. R2 , SEPCOR and wrapper methods, e.g. genetic algorithms .

Feature Translation
After features have been extracted and selected, the next step is classification. Several types of classification procedures are used in BCI systems, which can be categorized as linear and non-linear. Linear examples of classifiers are Bayesian Classifiers, PCA, LDA and FLD. Examples of non-linear classifiers are Neural networks and SVM. Whether a BCI system uses a linear or a non-linear classifier, its job is not finished after classification, since the output device needs device commands that can relate the classification results with the performance of specific tasks.

Relay system: Its function is to control the switching of the appliances.

III Database creation

The Feature extraction is done on a database created using B-Alert X series mobile EEG system which consists of 20 channels which produces high-quality signals. This database comprises of both male and female subjects and comprises of two tasks
1st - imagine to turn on/off a light for 30 sec over 10 min duration.
2nd - imagine to turn on/off a fan for 30 sec over 10 min duration.
It is basically divided into two sets: session 1 and session 2. There is a 1 day intervals between the two sessions, were the same recording protocol is applied.

signals of 30 seconds each are stored in the data base.

IV Feature extraction and Classification

The feature extraction of the EEG signal is done using a technique called Fast Fourier Transform, which is one of the well-known translation techniques. Introducing FFT algorithm one can express the Time domain EEG signals in terms of Frequency domain. This allows recognizing the dominant frequency in the signal. Another transform namely Wavelet Transform (WT) gives the time-frequency domain representation of the signal, this transform is mostly used since the EEG signal is non-stationary. In our analysis we are more concentrated on the frequencies of the signals and hence preferred FFT over WT.

Principal Component Analysis (PCA)[10]
PCA is a statistical features extraction method that uses a linear transformation to convert a set of Observations possibly correlated into a set of uncorrelated variables called principal components. Linear transformation generates a set of components from the input data, sorted according to their variance in such a way that the first principal component has the highest possible variance. This variance allows PCA to separate the brain signal into different components. PCA projects the input data on a *k*-dimension eigen space of *k* eigenvectors, which are calculated from the covariance matrix Σ of the training data
$p = [p1\ p2 \ldots pn]$. pi is i-th d-dimension training sample, and n is the number of samples.
The covariance matrix Σ is computed as:

$$\Sigma = \sum_{i=1}^{n} (p_i - m)(p_i - m)^t$$

where, $m = \frac{1}{n} \sum_{i=1}^{n} p_i$ is the mean vector of the training samples p_i. The covariance matrix Σ is a real and symmetric d x d matrix, therefore Σ has d different eigenvectors and eigenvalues. By means of the eigenvalues, it is possible to know which eigenvectors represent the most significant information contained in the dataset. The eigenvectors with the highest eigenvalue represent the principal components of the training dataset p. PCA selects that k, with $k < d$, eigenvectors having the largest eigenvalues. These selected eigenvectors serve to build a projection matrix ***A*** that will be used to extract the feature vector from the test data q. The k eigenvectors are sorted into columns in Matrix ***A*,** such that the first column of ***A*** corresponds to the largest eigenvalue. Finally, PCA computes the feature vector v from the data in matrix ***A***, by projecting the test data q onto the new subspace, such that:

$$V = A^t (q - m)$$

where, $m = \frac{1}{n} \sum_{i=1}^{n} p_i$ represents the mean vector of training samples pi.

V Results

Our database consists of 16 subjects (8 men/8 women) each having signal duration of 20 min (i.e. 20 signals for each task that is “light on”,” light off” , “fan on “ , “fan off”). A total of 1280 signals of 30 sec durations are stored in the database.

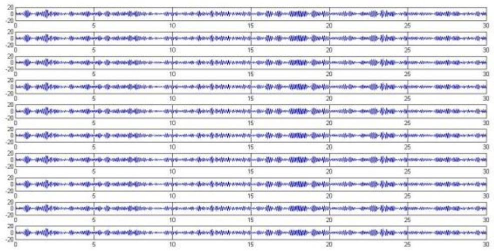

Fig.2: Time-Domain signal of recorded data (subject1 session 1 light)

Figure 2 is a time domain filtered signal, captured using Matlab Tools.

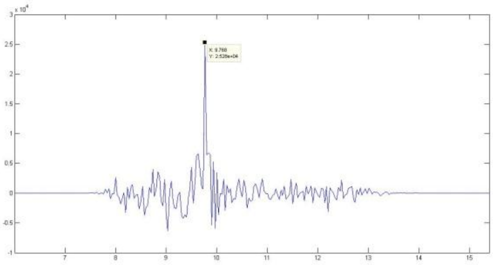

Fig.3: FFT signal for light on

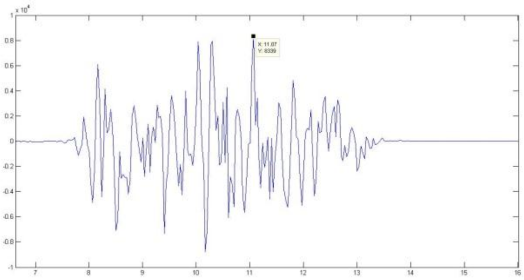

Fig.4: FFT signal for light off

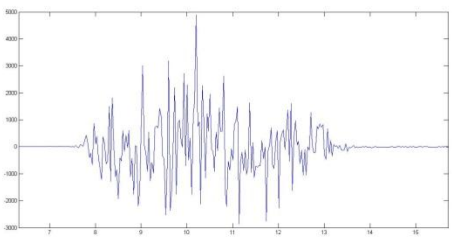

Fig.5: FFT signal for fan on

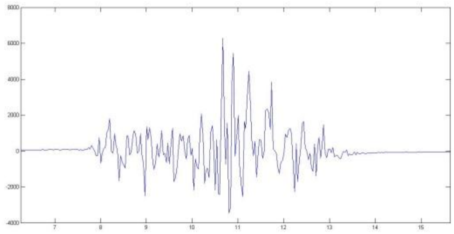

Fig.6: FFT signal for fan off

Figures 3-6 are the frequency-domain representation of the filtered signal. These are individual FFT's of each signal. These signals will then be used to classify and control appliances using the PCA algorithm.

Heat Map:

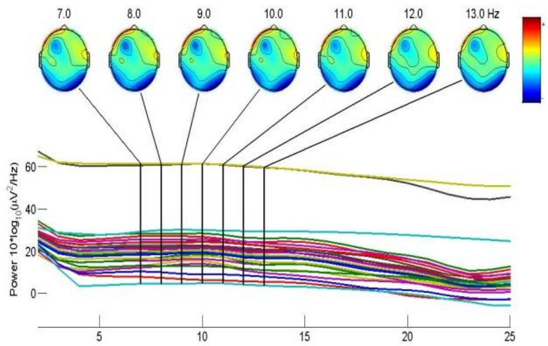

Fig.7: Heat Map Signal

Heat map tells which part of the brain has highest activity during thinking. The Red part indicates highest activity while blue part indicates lowest brain activities. Here we see left frontal part Reddish which indicates that this part is involved in thinking.

VI Conclusion

In this paper we have computed the time domain analysis and frequency domain analysis on each individual signal for both the sessions. The classification algorithm using PCA is yet to be performed. Future trends to improve the system will include LDA algorithm along with PCA for better data reduction and classification.

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