IJCSN International Journal of Computer Science and Network, Volume 5, Issue 4, August 2016
ISSN (Online) : 2277-5420 www.IJCSN.org
Impact Factor: 1.02

EEG Based Classification of Hand Movements using BCI

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Abstract - Brain interface computer (BCI) is new area of disabled people. Detection of imagination of left is made in my project and it can used for external devices such as robotic arm. The electrical activity can be picked up from scalp electroencephalogram electrodes. Here we have collected signals using Enobio 8 software. The collected signals are given to NE_Viewer filter to get Filtered data. The filtered data is then taken to extract from time domain information in both ALPHA and BETA bands using wavelet transform. The ALPHA and BETA waves are used and extracted some of the parameters such as power, standard deviation, and variance. The LDA classifier is used to classify the Imagination of left and right hand movements. In our project we have taken 40 samples for training data set and for testing phase we have taken 10 samples for testing and we have achieved 90% of accuracy.

Keywords - *EEG, BCI*

1. Introduction

Brain Computer Interface (BCI) is a emerging technology. It provides direct channel between human brain and computer interface and it acts as direct communication between the brain and any external device. It is also called mind machine interface (MMI), direct neural interface (DNI), synthetic telepathy interface (STT) or brain machine interface (BMI).

The electroencephalography (EEG) signals are medical specialty signals, these signals contains a additional data regarding the brain response. This EEG signal is obtained by recording the electrical of the brain by putting the multiple electrodes on the scalp. The primary human electroencephalogram was recorded by a German life scientist and medical specialist Hans Berger in 1924.

Source of EEG

In brain the billions of neurons can maintain the brain's activity, these neurons are communicated with alternative neurons or electrically charged or polarized by membrane transport proteins that pumps sodium, potassium and calcium ions across their membranes. In these ions the similar charges can repel one another and at an equivalent time once the various ions pushed out of the many neurons then they'll push their neighbours, United nations agency push their neighbours so on in an exceedingly style of wave, this method is understood as volume physical phenomenon. Once these wave of ions reaches the electrodes placed on the scalp of the brain, then they'll push or pull on the metal on the electrodes. From that point the metals simply conduct the push associated pull of electrodes and therefore the distinction within the push and pull voltages between 2 electrodes is measured by victimization an meter.

10-20 SYSTEM

The International 10.20 system is associate internationally recognized methodology to explain and apply the situation of electrodes on scalp of top throughout EEG experiment. This methodology was developed to result standardized reliableness in order that subject's studies might be compared overtime and compared to every different. This method is predicted on the link between the situation of associate conductor and also the underlying space of cerebral mantle. The numbers '10' and '20' refers distance between neighbouring electrodes area 10% or 20% of the full front-back or right-left distance of bone. The fig1.3 shows the traditional 10-20 electrode placement 21 electrodes are placed.

The earlobe electrodes are named as A1 and A2 and that they are connected to the left, right earlobe and A1, A2 are used because the reference conductor. It contains a letter to spot the various lobe and range to spot the hemisphere location. The letters F,C,P,T and O stands for frontal, central, parietal, temporal and occipital lobes. No central lobe exits, the 'C' letter is employed just for identification functions. A 'z'(zero) refers to an conductor placed on the plane. Even numbers (2, 4 , 6, 8) refers to conductor positions on the correct hemisphere. Odd numbers (1,3,5,7) talk over with conductor position on the hemisphere.

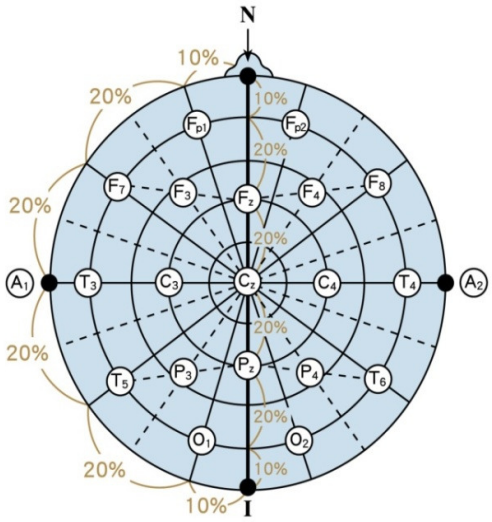

Fig 1.10-20 Electrode position system

2. Methodology

The methodology starts by collecting the EEG samples from normal persons called as data collection, then the process followed by pre-processing of the collected data, features extraction from the data and classification of the data.

- Data Collection
- Data Pre-Processing
- Feature Extraction
- Classification

3. EEG Signal Acquisition

The Data Collection starts with using the EEG headset to collect the EEG signals from around 29 healthy participants or subjects between the age of 20 to 30 years with the duration of 30 seconds. In that 40 datasets or samples are taken for training the system called as training phase and other samples are taken for testing phase. An 8-channel EEG module ENOBIO 8 was used for recording the EEG signals. Firstly, we give the instructions to the participants to think about the hand movements that is right and left hand movements, by closing their eyes and without any body movements. Secondly, we place the headset using international 10-20 system so that the electrodes are placed properly to collect the brain signals. The EEG headset is connected to the system via Bluetooth. In that system, we use NIC software to extract the brain signals. These signals are then used to classify the hand movements. The each extracted signals are saved in the form of '.easy' or '.ascii' format in the system for each hand movement. The data is recorded at frequency upto 2-40 Hz with sampling rate of 500 samples per second with a resolution of 24 bit allows us to record EEG in delta, theta, alpha, beta and gamma bands. In recorded dataset the signals or data is stored in the form of instantaneous values for each hand movement in arrays. Each data array contains 8 columns correspond to 8 channels or electrodes they are, 'F3', 'F4', 'T7', 'C3', 'F8', 'C4', 'T8', and 'Pz' and rows correspond to number of samples. With the increase of time duration the number of samples or number of rows are increases.

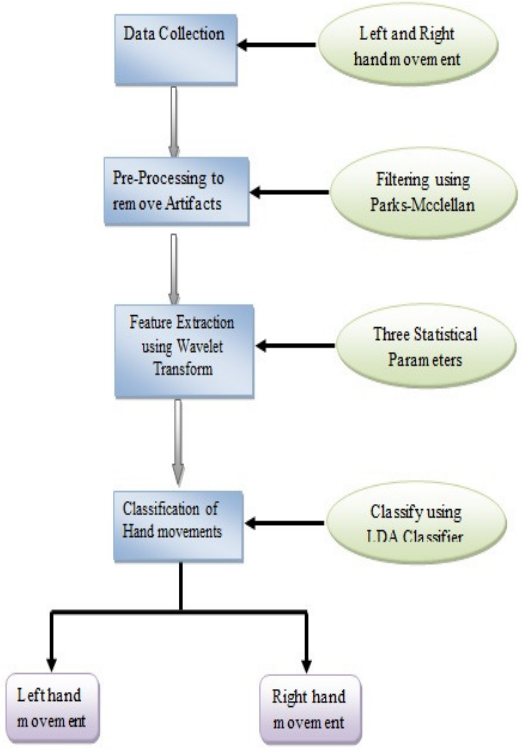

Fig 2Flow Chart of classification of Hand Movements using EEG

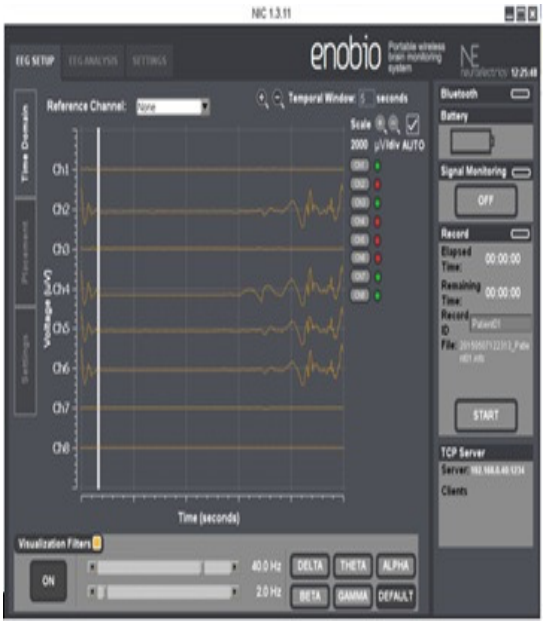

Fig 3 Collecting Data using NIC software

4. Signal Pre-Processing

After signal acquisition stage, signals are to be pre-processed because the acquired brain signals are most affected by noise and artifacts (unwanted signals). Signal pre-processing is also called as Signal Enhancement, it is the process of removing noise from original signals and reconstructs those signals. The artifacts that contaminated the EEG signals are divided into physiological artifacts obtained from muscle activity, pulse, eye blinking, eye movements (EOG), heart beat (ECG), and non-physiological artifacts obtained from power line interference noise, sweat and neuronal activity obtained from background are also mixed with brain signals.

To extract the feature matrix from the EEG signal the artifacts have to be removed. Hence the goal of this pre-processing step is to reconstruct the original brain activity by removing contained artifacts. To remove this we apply filtering process by designing a Parks-McClellan optimal FIR filter.

4.1 Filtering

To remove unwanted signal from the recorded EEG each samples has to be passed through a FIR filter. The linear phase FIR filter is designed by using Parks-McClellan algorithm. The Parks-McClellan algorithm design filters with an optimal fit between the desired and actual frequency responses by using the Remez exchange algorithm and Chebyshevapproximation theory. The filters are optimal hence the maximum error between the desired frequency response and the actual frequency response is minimized. Filters designed in this way exhibits an equiripplebehaviour in their frequency responses therefore sometimes they are called as equiripple filters.

The Parks-Mcclellan FIR filter is designed by using function 'firpm' in the MATLAB code it exhibits discontinuities at the head and tail of its impulse response due to the equiripple nature. The EEG wave contains delta (0-3Hz), theta (3-7Hz), alpha (8-13Hz), beta (13-30Hz) and gamma (above 30Hz). Therefore, a band pass FIR filter of 1-40 Hz is applied to signal. This designed FIR filter removes the DC offset of each electrode, drifts due to electrode impedance over time and power lines 50HZ noise and some artifacts are removed manually. The filter order, vector of pairs of normalized frequency points specified in the range between 0 and Nyquist frequency and vector containing the desired amplitudes are the arguments used in the designing of a filter.

4.2 Feature Extraction

After pre-processing the EEG signals the features are have to extract from EEG signals for hand movement classification. Feature extraction is the process of extracting useful information from the signal. Features are characteristics of a signal that are able to distinguish between different hand movements. EEG bands delta, theta, alpha, beta and gamma are extracted for each hand movements. For wavelet decomposition of a signal 'wavedec' function is used, wavedec is an inbuilt function in MATLAB.

4.3 Wavelet Transform

The wavelet transform is a transform of this type. It provides the time-frequency representation.

Often times a particular spectral component occurring at any instant can be of particular interest. In these cases it may be very beneficial to know the time intervals these particular spectral components occur. For example, in EEGs, the latency of an event-related potential is of particular interest (Event-related potential is the response of the brain to a specific stimulus like flash-light, the latency of this response is the amount of time elapsed between the onset of the stimulus and the response). Wavelet transform is capable of providing the time and frequency information simultaneously, hence giving a time-frequency representation of the signal.

We pass the time-domain signal from various high pass and low pass filters, which filters out either high frequency or low frequency portions of the signal. This procedure is repeated, every time some portion of the signal corresponding to some frequencies being removed from the signal. Suppose we have a signal which has frequencies up to 1000 Hz. In theIn the first stage we split up the signal in to two parts by passing the signal from a high pass and a low pass filter (filters should satisfy some certain conditions, so-called **admissibility condition**) which results in two different versions of the same signal: portion of the signal corresponding to 0-500 Hz (low pass portion), and 500-1000 Hz (high pass portion). Assuming that we have taken the low pass portion, we now have 3 sets of data, each corresponding to the same signal at frequencies 0-250 Hz, 250-500 Hz, 500-1000 Hz. Then we take the low pass portion again and pass it through low and high pass filters; we now have 4 sets of signals corresponding to 0-125 Hz, 125-250 Hz,250-500 Hz, and 500-1000 Hz. We continue like this until we have decomposed the signal to a pre-defined certain level. Then we have a bunch of signals, which actually represent the same signal, but all corresponding to different frequency bands.

4.4 Extracted Statistical Parameters

4.4.1 Standard Deviation

The standard deviation normalizes the data and it gives us an idea of how far apart our data is from the mean. If we have large standard deviation, it means that data is

farther from our mean. If we have small standard deviation, it means that data is closer to mean. The standard deviation is defined as a measure of the spread of a set of values from the average value. To calculate the standard deviation the 'std' function is used in the MATLAB command line. If X is a variable with mean μ_x, then the standard deviation is given as,

$$\sigma_x = \left(\frac{1}{N-1}\right)\sum_{n=1}^{N}(x_n - \mu_x)$$

4.4.2 Variance

The variance is a determinant of measure of how far a set of numbers is spread out. It is specially a raw material of statistics and it helps and allows us to compute the dispersion of a set of variables around their mean. To calculate variance value for each channel in EEG samples the 'var' function is used in the MATLAB command line. If a random variable is X, its expected value is E(X), then the variance of X(1) is the covariance of X with itself, it is given as,

$$\mathrm{Var}(X) = \mathrm{Cov}(X, X) = \mathbf{E}[(X - \mu)^2]$$

5. Classification

After extracting the desired features, we still have to find which hand movement is done. This process will be done by a classifier. A classifier is a system that divides some data into different classes, and is able to learn the relationship between the features and the hand movement that belongs to that part of the EEG signal.

5.1. LDA Classifier

Linear discriminant analysis (**LDA**) is a generalization of **Fisher's linear discriminant**, a method used in statistics, pattern recognition andmachine learning to find a linear combination of features that characterizes or separates two or more classes of objects or events. The resulting combination may be used as a linear classifier, or, more commonly, for dimensionality reduction before later classification.

LDA is closely related to analysis of variance (ANOVA) and regression analysis, which also attempt to express one dependent variable as a linear combination of other features or measurements. However, ANOVA uses categorical independent variables and a continuousdependent variable, whereas discriminant analysis has continuous independent variables and a categorical dependent variable (*i.e.* the class label). Logistic regression and probit regression are more similar to LDA than ANOVA is, as they also explain a categorical variable by the values of continuous independent variables. These other methods are preferable in applications where it is not reasonable to assume that the independent variables are normally distributed, which is a fundamental assumption of the LDA method.

LDA is also closely related to principal component analysis (PCA) and factor analysis in that they both look for linear combinations of variables which best explain the data.LDA explicitly attempts to model the difference between the classes of data. PCA on the other hand does not take into account any difference in class, and factor analysis builds the feature combinations based on differences rather than similarities. Discriminant analysis is also different from factor analysis in that it is not an interdependence technique: a distinction between independent variables and dependent variables (also called criterion variables) must be made.

LDA works when the measurements made on independent variables for each observation are continuous quantities. When dealing with categorical independent variables, the equivalent technique is discriminant correspondence analysis.

LDA Algorithm

Listed below are the 5 general steps for performing a linear discriminant analysis.

1. Compute the d-dimensional mean vectors for the different classes from the dataset.
2. Compute the scatter matrices (in-between-class and within-class scatter matrix).
3. Compute the eigenvectors (e1,e2,..,ed) and corresponding eigenvalues (λ1,λ2,.,λd) for the scatter matrices.
4. Sort the eigenvectors by decreasing eigenvalues and choose **k** eigenvectors with the largest eigenvalues to form a **k×d** dimensional matrix **W** (where every column represents an eigenvector).
5. Use this **k×d** eigenvector matrix to transform the samples onto the new subspace. This can be summarized by the mathematical equation: **Y=X×W** (where X is a n×d-dimensional matrix representing the n samples, and y are the transformed n×k-dimensional samples in the new subspace).

6. Results and Discussion

Test case:

Table : Detection of left and right hand movement using LDA classifier

Participant	Expected Output	Obtained Output	Result
1	Left	Left	Pass
2	Left	Right	Fail
3	Left	Left	Pass

4	Left	Left	Pass
5	Left	Left	Pass
6	Right	Right	Pass
7	Right	Right	Pass
8	Right	Right	Pass
9	Right	Right	Pass
10	Right	Right	Pass

From the table the total accuracy obtained from LDA classifier got larger the accuracy. Hence the LDA classifier reaches 90% to 95% efficiency, so it is a best classifier.

7. Conclusion

In our project we are only concentrating on classification of hand movements of human body, left and right hand movement. We instruct the subjects in the beginning only to focus on these hand movements. The signals were recorded from eight channels according the 10-20 international system. We are using NIC software for collecting and storing EEG samples. The collected signals were pre-processed and the artifacts were removed by designing Parks-McClellan FIR filter. We have recorded samples from participants and divided those samples into two sets, the training set and the testing set. The training set consists of samples of 29 participants and testing set consists of 5 participants. We use wavelet transform method for extracting the features, power, standard deviation, variance, these features are used in classification method. Here we are using Linear Discreminant Analysis (LDA) to classify hand movements.

The total accuracy achieved is 90 % from LDA classifier when we classified EEG signals into the hand movements into left and right hand movement. Therefore, we could conclude that basic LDA classifier is a good choice for classifying hand movements by using EEG signals based on BCI interface.

Future Enhancement

The future work includes a further research on EEG and its link with hand movements. Cognitive response can also be thought of as future work using EEG signals and understanding the different stages of how the brain processes on every situation according to environment.In the experiment the duration of recording the signals was 30 seconds and maybefor the subject it was very hard to evoke the expected hand movement thought during that.

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