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Research paper

EEG Signal Analyzing and Simulation Under Computerized Technological Support

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Abstract

Electroencephalogram (EEG) is a method for acquiring the brain signals for diagnostic purposes. It tracks and records the brain wave patterns. This is a non-invasive technique. The idea behind is to categorize the EEG signal based on the frequency range. The steps include collecting EEG signals, pre-processing, feature extraction, feature selection and classification. The pre-processing eliminates the noises from the signal. EEG signal can be disintegrated by using discrete wavelet transform. The feature extraction methods are used to obtain the time-domain features of the EEG signal. Finally, the classification method determines the variations in the mental state of the person.

Keywords: *EEG (Electroencephalogram), DWT (discrete wavelet transform), WT (Wavelet transform).*

1. Introduction

Brain Computer Interface (BCI), it is the technique that enables the communication of the users and systems. A method which is used for communication is EEG signals. An Electroencephalogram (EEG) is used to detect the brain signals. Technology is very fast and well in advance, many researches are happening in medical and non-medical fields and scope is widened in all areas. The various applications of BCI are industry, technology, entertainment etc. As the EEG signal doesn't pass any kind of electric signals to the body. So, it can be conclude that it is secure for diagnosis. The EEG signals are commonly segregated into five frequency wave bands such as alpha, beta, gamma, delta and theta.

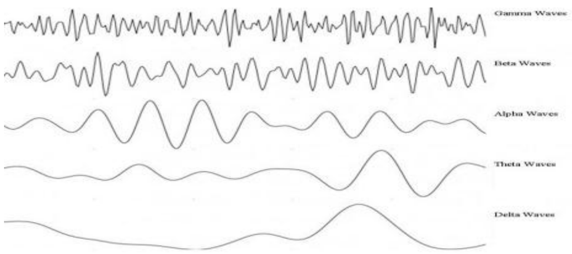

Fig. 1: Standard Brain Wave Patterns

This work comprises of several steps such as pre-processing, feature extraction, feature selection and classification. Pre-processing rejects noises from the EEG signals. Feature Extraction and Selection are the discriminating characteristics of the improved signal, decreasing the size of data. Features are extracted based on Time-domain, frequency-domain features. Selected fields are decomposed into sub-band signals (alpha, beta, gamma, theta, and delta). Classification translates the produced features into active or inactive state.

Table 1: Characteristics of EEG Waves

WAVES	FREQUENCY
Alpha	8-13 Hz
Beta	> 13 Hz
Delta	4-7 Hz
Theta	< 3.5 Hz
Gamma	25-100 Hz

2. Literature Survey

Onder AYDEMIR et al, (2011) [1] Proposed and discussed on the topic of wavelet transform method for decomposing EEG signal to accede into coefficients and they extracted the features associated to inputs. Marcin Kołodziej et al [2] introduced a new method on DWT and HOS for feature extraction. Selection method of EEG signal for BCI design is presented is based on Genetic algorithms. Dipti Upadhyay (2013) [3] EEG signals were classified by using wavelet transform. At different subsequent levels the wavelets were decomposed. Ramaswamy Palaniappan, (2006) [4] Focused only on Gamma bands and weighted performance of classification and time taken for training of bi-state mental task. Fardin Afdide et al, (2015) [5] a work on fully Matlab based toolbox was used for designing, prototyping, testing and using BCI in virtual environments. Sasikumar et al [6] demonstrated the concepts about open source plug-ins, running under the platform MATLAB environment. M. Kalaivani et al (2014) [7] proposed work can be a useful tool in studying normal and abnormal patients. M. BALAMAREESWARAN et al (2015) [8] proposed a technique for the reconstructed signal using wavelet transform reduces the number of bits needed for transmission. ABDUL-BARY RAOUF SULEIMAN et al [9] discussed the accuracies for different feature extraction methods. Amjed S. Al-Fahoum et al, (2014) [10] discussed five well-known methods for frequency domain and time-frequency domain methods. C. E. Mohan Kumar et al, (2014) [11] with the use of wavelet transform and an electrode pair demonstrated the feature extraction scheme. Chetan Umale, et al (2016) [12] Different feature extraction techniques and classification algorithms for EEG signal analysis was discussed. Andrzej Majkowski et al (2012) [13] experimented to train the users and get the biofeedback. Nair et.al, (2015) [14] provided densely populated regions can be identified using density based clustering algorithm with minimal input parameters and noisy outliers. Nair et.al, (2015) [15] provided grouping of biological data using k-means clustering provides a dataset of genetic disorder from the phenotypical appearance in human body.

3. Methods

3.1. Analysis of Signals

a. Collection of Signals

b. Pre-Processing

c. Feature Extraction

d. Feature Selection

e. Classification

The main objective is to study the five Brain-Wave Frequencies and how they affect the state of mind by analyzing the EEG signals. The analysis is by following the above modules.

3.2. Proposed System

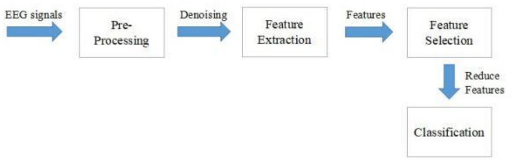

Fig. 2: Modules for the analysis of EEG Signals

A raw EEG Signal is collected and passed to the first module called Pre-Processing. The Pre-Processing includes the EEG data analysis and removal of noises from the signal. The next module is Feature Extraction which extracts the required features for further analysis. From the Feature Extraction next comes the Feature Selection which selects the relevant features and that is passed to the Classification Process. Finally in the Classification, which is mainly used to determine the fluctuations of Brain Waves from their original frequency band. This work is demonstrated by using MATLAB.

4. Simulation Environments

4.1. Collecting EEG Signals

EEG Signal is collected from EEG Database which is available in internet.

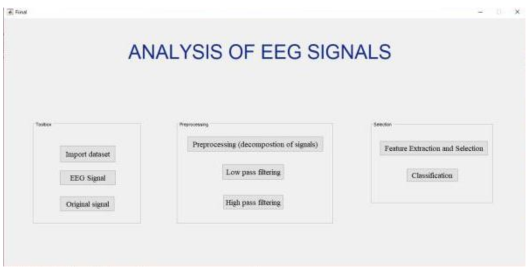

Fig. 3: Basic GUI

Import an EEG Dataset, view the EEG Signal and the original signal means the zoomed view.

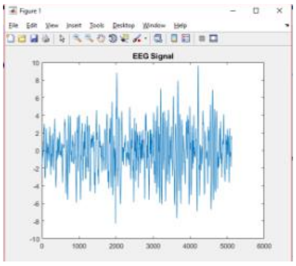

Fig. 4: EEG Signal

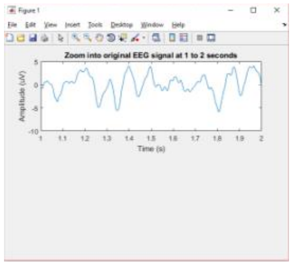

Fig. 5: Zoomed View

4.2. EEG Signal Processing

Before Pre-Processing, EEG data analysis has to be done. Data analysis is by using FFT (Fast Fourier Transform) algorithm. This is for analyzing the discrete data and they decompose the data into frequency components. Pre-Processing is done in order to remove the external noises which are added during the recording such as breathing during test time. The noises which are removed by applying the Filtering process viz. High and Low pass filtering. Pertaining to the DWT (Discrete Wavelet Transform) the decomposition of the signals is done. The brainwaves are smoothened and sharpened by using High Pass and Low Pass filtering respectively. This gives more clarity for the future work. For EEG Signal analysis, Fast Fourier Transform (FFT) Method is used. Power spectral density (PSD) estimation is able to characterize the EEG signals. By this can represent the EEG samples. PSD is calculated by Welch's method.

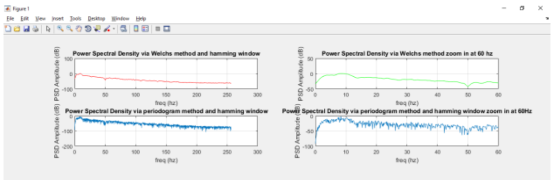

Fig. 6: EEG data Analysis

Output:

The maximum power occurs at 8.3 Hz

The power estimate is 0.67

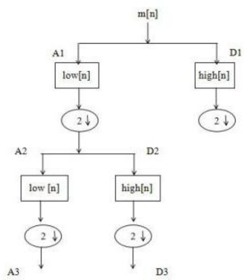

Fig. 7: Decomposition of Signals

This is based on the Time-domain signal.

The DWT decomposition is described as:

$$ac_{(s)}(t)=p(x)*wf_{s,t}(x) \quad (1)$$

$$dc_{(s)}(t)=p(x)*sf_{s,t}(x) \quad (2)$$

$wf_{s,t}(x)$ $sf_{s,t}(x)$ is Wavelet function and Scale function respectively.

Which is defined as

$$wf_{s,t}(x)=2^{y/2}\, low_z(x-2^{s}t) \quad (3)$$

$$sf_{s,t}(x)=2^{y/2}\, high_z(x-2^{s}t) \quad (4)$$

$2^{y/2}$ is the factor and referred to as an inner product normalization, s, t are scale parameter and translation parameter respectively.

$ac_{(s)}(t)$ is the approximation coefficient and $dc_{(s)}(t)$ detail coefficient at resolution z.

m[n] - Mother wavelet

high[n] - High_pass filter

low[n] - Low_pass filter

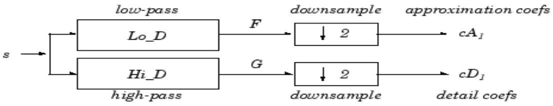

Fig. 8: DWT algorithm for Downsampling

Decomposition steps:

1. Select the EEG signal
2. Decompose into High pass and Low pass
3. Down sampling those signals

(The process of removing alternate coefficients)

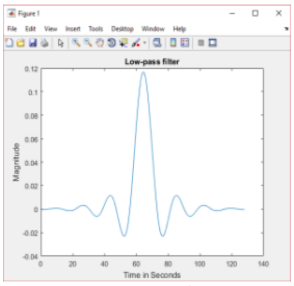

Fig. 9: Low pass filter

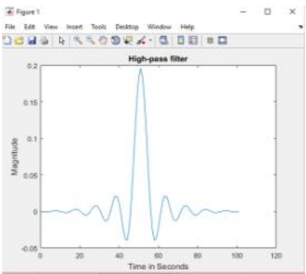

Fig. 10: High pass filter

4.3. Feature Extraction

Feature Extraction is enhancing the characteristics of the improved signal and decreasing the size of the data. For Feature Extraction, implemented WT (Wavelet Transform), DWT algorithm supports removal of noises but doesn't smoothen the main features of the data. So WT algorithm helps to smooth the signals and extract the relevant features that are required. WT algorithm is better because it is suitable for non-stationary signals (EEG). This compresses the data and helps in maintaining the quality of signals. They retain features that are often smoothened out by other techniques. WT algorithm handles without information of signal loss. It is used to simplify the data from the huge set of data.

4.4. Feature Selection

Feature Selection employs by removing the features that are not relevant and they shouldn't be redundant. It reduces the size of data by selecting relevant features. Demonstrated on selecting the features based on the Time Domain Analysis i.e. Mean, Median, Mode, Standard Deviation, Minimum and Maximum. Decompose into Sub-band signals by selecting relevant feature and pass these values into the next module i.e. Classification.

Waves	Mean	Median	Mode	Std	Min	Max
["Gamma"]	0.00050455	0.032	-21.427	2.1963	-21.427	28.03
["Beta"]	-0.00074837	-0.012	-5.1332	1.3505	-5.1332	6.6855
["Alpha"]	-0.0014	0.0016	-5.6813	0.94433	-5.6813	4.3669
["Theta"]	0.002	-0.00066236	-5.0097	0.7438	-3.6097	2.7348
["Delta"]	0.0344	0.0047	-11.872	2.3361	-11.872	4.1637

Fig. 11: Selected Features

4.5. Classification

Classification undergoes on the technique of classifying the EEG signals into sub-band signals. Then finding its frequency range and approximation coefficient. Demonstrated on the technique of Wavelet Transform algorithm. This works on wavelet decomposition of the signal. Decompose the signal and plot the waves of EEG signal dividing into sub-band levels of Alpha, Beta, Gamma, Theta, Delta waves. Determined the maximum frequency that appears in each sub-band levels.

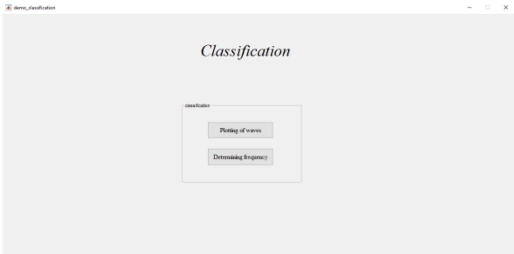

Fig.12: Classification of EEG Signals

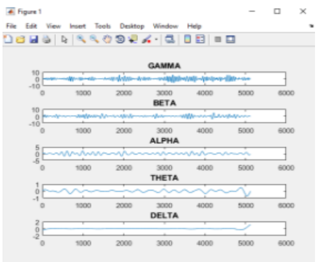

Fig. 13: Plotting of Waves

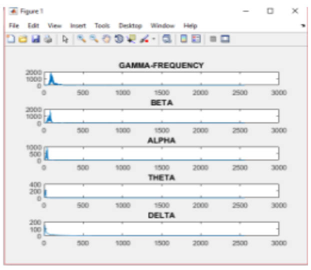

Fig. 14: Determining its Frequency

Figures shown above are decomposed that is based on Approximation coefficient and frequency range.

Output:

Gamma: Maximum occurs at 83.00 Hz

Beta: Maximum occurs at 77.00 Hz

Alpha: Maximum occurs at 38.000000 Hz

Theta: Maximum occurs at 19.000000 Hz

Delta: Maximum occurs at 9.000000 Hz

5. Results and Conclusion

The above work was implemented in MATLAB environment. Created a GUI and implemented by following all the modules for the processing of EEG signals, extracted and selected some relevant features that are passed into the classification module. This module classifies the EEG signal into five sub-band waves depending on its frequency. Analyze the frequency of each sub-band and shows the highest frequency peak. This can be developed in different algorithm to get the digitization output of the EEG signal and arrives at a point to explain the mental state of a person.

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