An Advanced Design for Depression Analysis through EEG Signal

Shamla Mantri[1], Dr. Pankaj Agrawal[2], Dr. Dipti Patil[3], Dr. Vijay Wadhai[4], Sharwin Bobde[5]

[1]PhD Research Scholar, Electronics Engineering Dept., GHRCE, Nagpur, India
[2]Associate Professor, Dept. of Electronics and Communication, GHRAET, Nagpur, India
[3]Associate Professor, MKSSS's Cummins College of Engineering for Women, Pune, India
[4]Principal, KJEI's Trinity Academy of Engineering, Pune, India
[5]Student, IT Department, MITCOE, Pune, India

Abstract: ***This paper describes a method to diagnose a subject with clinical depression. The approach taken utilizes EEG data from which specific channels are selected to obtain voltage fluctuations from Occipital and Parietal lobes of the brain. Studying these parts of the brain is highly informative about the subjects state of mind when he is awake and help us understand how he processes information, on these basis we can deduce if the subject is depressed or not. These channels are used to extract required alpha wave signals. Then Fast Fourier Transform is applied on the alpha wave and its fundamental frequency and corresponding amplitude of the alpha wave are obtained. The obtained information is used to determine if the test subject is depressed or not using a rule based classifier. The classifier classifies a subject as depressed if the fundamental frequency is below 8 Hz and normal if it is 8 Hz or above.***

Keywords: EEG, Depression, Alpha Wave, Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT), Rule Based Classifier.

1. Introduction

Clinical depression is a very serious problem that affects the lifestyle and productivity of our community. Depression is a very common illness worldwide, especially in first world countries. It is estimated that it affects 350 million people. In severe cases it can even result in suicide. Over 8, 00,000people die due to suicide yearly. Suicide is the second leading cause of death in teenagers and young adults after accidents [1]. This research is a step forward in faster diagnosis and managing depression.

This system focuses on analysis of alpha wave to determine if a subject is suffering from depression. Studies have shown that band entropy, frequency and recurring patterns of brain waves can give insight into a subjects mental condition[2][3]. Moreover studies have shown that in cases of depression patients have shown hypo-activation in the left hemispherical region of the brain [4][5].This system uses an alpha wave extraction system, Fast Fourier Transform and Rule Based classifier to determine if a subject is depressed or normal and based on the results we can further classify them as mildly, moderately or severely depressed. This system is completely automated and extremely fast, the delay is mainly dependent on the recording frequency of the EEG equipment.

2. Data Acquisition

The EEG data used in this project was from two open source datasets. Both were obtained from Physiobank. The first one is CHB-MIT Scalp EEG Database. It contains EEG data from 23 subjects in 24 cases. In one case the data was obtained from the same female subject one and a half years later. The subjects consisted of 5 males, age 3 to 22, and 17 females, age 1.5 to 19. All signals were sampled at 256 samples per second. Most files contain 23 EEG signals.

The second is EEG Motor Movement/Imagery Dataset. This dataset contains 109 cases from volunteers. Subjects performed different motor/imagery tasks while 64-channel EEG signals were recorded at 160 samples per second. Each subject performed 14 experimental runs: two one-minute baseline runs and three two-minute runs of each of four tasks. The tasks involved performing certain physical actions or intend to perform them in response to specific visual stimulus.

3. Pre-Processing

3.1 Data Preparation

The main goal was to obtain Alpha wave readings. Alpha waves originate from the Occipital and Parietal lobe of the forebrain, located in the rear region. Alpha waves are the waves which represent brain activity in wakeful state, hence the variations in these waves help us identify if a subject is depressed or not. The data is saved in a data frame with the subject's EEG observations with voltage corresponding to time instant when they were recorded for each channel. Unnecessary data such as units was trimmed off to facilitate calculation. For acquiring Alpha waves 8 channels are selected from the EEG readings with 64 channels EEG data and 4 from 32 channel EEG data. These channels record electrical activity in the Occipital and Parietal lobe of the brain that needs to be studied. The data of required channels is saved in a separate data frame. This new data frame only contains the data required for analysing the required Alpha wave.

4. Processing

4.1 Combining Data to Produce Alpha Wave

Alpha waves of the brain have frequency normally ranging from 8 Hz to 13 Hz [6]. The power of alpha band provides significantly more information about depression compared to other EEG frequency bands [7]. To obtain the required

Alpha wave we need to combine the data of the required channels that record voltage readings from the Occipital and Parietal regions of the brain. Figure 1 shows a plot of 4 required channels from a 32 channel recording headset. To combine the data from different required channels we need to obtain the average of the instantaneous voltages. The vector of resultant averages is the voltage reading for the resultant alpha wave corresponding to respective time instances. It can be seen in Figure 2.

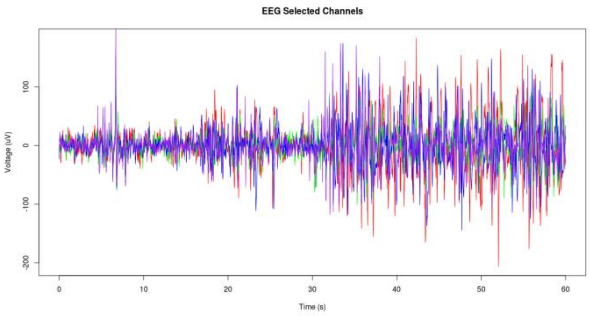

Figure 1 - Plot of selected EEG channels' instantaneous voltage simultaneously.

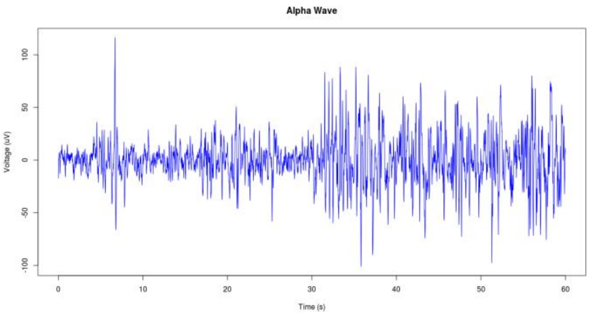

Figure 2 - Plot of extracted alpha wave from the selected EEG channels

4.2 Feature

Fast Fourier Transform (FFT) is an algorithm for obtaining Discrete Fourier Transform (DFT). It is a transform that converts a signal from time domain to frequency domain. It is used to understand the nature of the signal/wave. It breaks down the original signal into several individual sine waves. Through this we can find the fundamental frequency of the wave and the fluctuations in the signal over time. This shows the fluctuations in the voltage readings of the input wave. Therefore we are able to understand the functioning of the required parts of the brain better and then depending on that we can decide the diagnosis.

4.3 Applying FFT on the Alpha Wave

To analyse the wave we need to convert the complex information into a simple form. All waves signals can be represented as a set of individual sine waves. These sine waves differ in amplitude and frequency from each other. These sine waves on addition by principle of superposition again represent the original wave. Therefore the original signal determines the individual sine waves and the individual sine waves determine the shape of the original signal. By breaking up a complex signal such as an EEG signal into simpler, easy to analyse fragments, we can efficiently map the properties of the original wave [8].

Now we need to calculate the fundamental frequency of the Alpha wave. This feature will help us deduce the final diagnosis. For this we implement the Fast Fourier Transform (FFT) on the wave. The result of FFT represents amplitude and frequency of individual sine waves that make up the original alpha wave. We plot the FFT output as value against the index. This represents the amplitude vs. the frequency of the sine waves obtained. From the individual waves we need to select the sine wave with maximum amplitude. The sine wave with the largest amplitude, here the voltage, is the defining factor of the original signal. This sine wave determines the original signal's amplitude and frequency [8]. Thus the amplitude and Frequency of this sine wave will be the principal amplitude and frequency of the original signal.

The unit of amplitude is µV, and the frequency is in Hertz (Hz).

For selecting the fundamental wave some rules need to be applied to get the correct answer. FFT is an algorithm and it may produce outputs that are not suitable for the above method to find the fundamental wave. Therefore following adjustment was made. Only observations with frequency between 0 and 500 Hz are considered, this helps give the correct output. Due to FFT's line symmetry we get 2 peaks or the peak with higher frequency as the one with maximum amplitude. In this case only the first peak is to be considered. In some cases some waves formed an frequency domain in which a wave with extremely high frequency had maximum amplitude. But on further analysing the wave we found that by ignoring this wave we get the correct fundamental frequency, this exceptional wave only gave shape to the fundamental wave and must be ignored. It also reduced the computation time of the algorithm.

4.4 Classification

After obtaining results through FFT we need to classify the subjects according to their state of mind, depressed or normal. Here we have used a Rule Based Classifier. This means that subjects were classified according to some pre-determined rules. Many researchers have used learning classifiers for this task like SVM, kNN, Naive Bayes, ANN etc. in other studies[9][10]

When the subject is depressed, energy of alpha band extracted from the EEG reduces [11][12]. This property of alpha wave helps us understand more about a subject's clinical condition, through which we can derive the rule for our classifier. It has been observed that in proper recording conditions if a patient has alpha wave fundamental frequency less than 8 Hz then there is a high probability that the subject is depressed [10]. Here the rule was that if the fundamental frequency is less than 8 Hz then the subject is depressed and normal if it was 8 Hz or above. This rule is based on extensive practice of medical professionals.

5. Post_Processing

5.5 Observation

Out of 70 subjects we selected, 43 were labelled depressed and the other 27 were labelled normal (not depressed). This means that almost 61.42% of the subjects in the study were depressed and 38.58% were normal.

5.5 Analysis

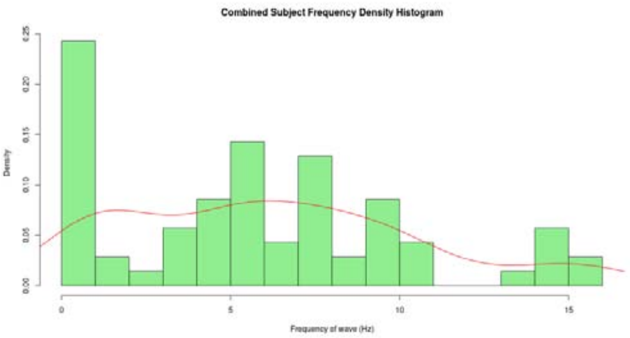

Figure 3 -Frequency Histogram and density line plot of observations.

In Figure 3 We can see that maximum observations lie between 0 to 11 Hz. Most subjects in this study have Alpha wave frequency 1Hz which represents severe depression. The density plot also shows that observations are denser from 1 to 8 Hz, as they account for 68% of the observations.

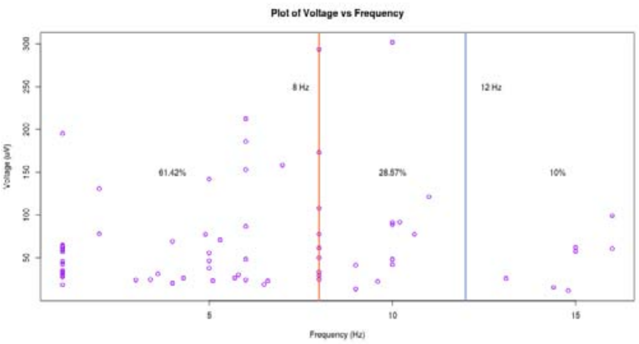

Figure 4 -Scatter plot of Voltage vs. Frequency

In Figure 4 the line at 8 Hz represents lower normal level i.e. any reading less than 8 Hz is considered as depressed. The 12 Hz line has been plotted for reference as the normal range for alpha wave.

Therefore 61.42% of the subjects in this study were depressed and 38.58% weren't. Moreover 28.57% subjects had frequency between 8 to 12 Hz and 10% had frequency more than 12 Hz.

6. Conclusion

We have successfully classified 70 subjects as either depressed or normal. The fundamental frequencies of the alpha waves of the subjects varied from 1 Hz to 16 Hz. In this study a majority(61.42%) of the subjects were labelled depressed (having frequency less than 8 Hz). 28% of the subjects were within likely occurring circumstances i.e. 8 Hz to 12 Hz. Exactly 10% of the subjects had their frequency more than 12Hz.

The research has proven extremely beneficial for technological advancement in fields of Engineering, Neurology and Psychology. It is an extremely fast processing method based on medical knowledge instead of machine learning concepts. It can take labelled as well as unlabelled data as input. It can be easily implemented by medical professionals and non-professionals in their practise at a very low cost. Diagnosing depression can be done early and accurately and hence providing better preventive care in facilities or institutes very easily. With advancement in this field we can help our social structure by reducing depression related incidents and suicides. A better lifestyle can be provided for individuals, hence making them more productive.

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