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Analysis of EEG Signal from Right and Left Hand Writing Movements

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Abstract—**This paper studies on the characteristics of electroencephalogram (EEG) which generated from writing using right and left hand. The EEG signals were recorded from 4 channels, C3, C4, P3 and P4 and processed using band pass filter (8-30Hz). Two method of analysis were performed; Fast Fourier transform and power spectral density. The results showed that Power Spectral Density can be used to distinguish right and left hand writing movements from EEG signals.**

Keywords-component; Electroencephalogram; writing, Fast Fourier Transform, Power Spectral Density

I. INTRODUCTION

Electroencephalogram (EEG) is used in Brain Computer Interface (BCI) to convert mere reflections of central nervous system (CNS) activity into messages that act on the world [1]. BCI has been used to control instruments using signal from human or animal brain which is recorded either invasively or noninvasively [2, 3]. It is a communication system that allows interaction between human and external devices.

There are 4 main components of brain; cerebrum, cerebellum, the brain stem and the thalamus [4]. The largest part of the brain is cerebrum. Its function is to give us information on what happen around us and how to respond with it. It is divided into two modules that is right and left hemisphere as shown in Figure 1. Muscles of our right body are controlled by the left hemisphere and the left body muscles are controlled by the right hemisphere.

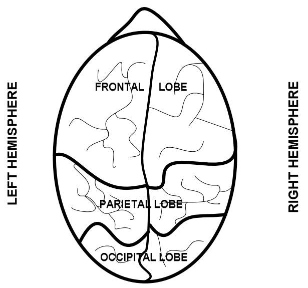


Figure 1: Location of right and left hemisphere in cerebrum of brain

Numerous investigations have studied EEG signals from right and left hand movements. Zhang et al [5] extracted features of EEG signal obtained from imagined right and hand movements using power spectral entropy. Cincotti et al [6] studied EEG signals from imagined right and left finger movements. However, none of the researchers investigates the EEG signal characteristics obtained from right and left hand writing movements.

This paper discusses the analysis of EEG signals generated from right and left handed writing activities. Fast Fourier Transform and Power Spectral Density were used to distinguish between the left and right hand writing movements.

II. BACKGROUND THEORY

EEG signal has unique pattern which can be revealed from Fourier Transform analysis. This signal can be recorded by placing multiple electrodes on the cortex, under the skull or certain locations on the scalp. Applying Fourier transform on the signal allows the frequency content to be extracted. There are 5 major brain wave types can be identified; delta (0.5-4Hz), theta (4 – 7.5Hz), Alpha (8 -13 Hz), Beta (14 – 26Hz) and Gamma (above 30Hz, mainly up to 45Hz) [7].

Fast Fourier Transforms (FFTs) is an algorithm that will compute discrete Fourier transform (DFT) and it's inverse. Equation (1) above is the equation defined the DFT of an N-length. To examine the frequency of the signal generated, frequency analysis done due to the types of EEG signal in time domain [8].

$$X(k) = \sum_{n=0}^{N-1} x[n]\exp\left(-\frac{j2\pi kn}{N}\right) = \sum_{n=0}^{N-1} x[n]W_N^{kn} \quad \text{--(1)}$$

X[k] is evaluated for $0 \le k \le (N-1)$

W_N^{kn} is a periodic functions with a limited number of distinct values.

A. Power Spectral Density(PSD)

Power spectral density has been used to investigate the EEG signal power for various cases. These includes in the study of human brain changes after consuming alcohol [9] and validation of neural mass model [10]. The power spectral density (PSD) indicates how the sequence's power or energy is distributed in the frequency domain, and is widely-used to measure the random signals and noise.

The general PSD equation is given by Equation (2),

$$Pxx(X) = \sum_{m=-\infty}^{\infty} \text{Øxx[m]exp}\,(-\text{jXm}) \quad \text{-----(2)}$$

$Pxx(X)$ is related to the spectral power distribution of a digital sequence [6].

Power spectral density function (PSD) shows the strength of the variations energy as a function of frequency. PSD shows at which frequency variations are strong and at which frequency variations are weak.

III. METHODS

A. EEG Recording

The EEG datasets used in this study was collected from right and left-handed subjects. Four channels have been used to record EEG data that is C3, C4, P3 and P4. However, in this study, EEG obtained from C3 and C4 channels was used since these channels associate with activities produced from right and left hands.

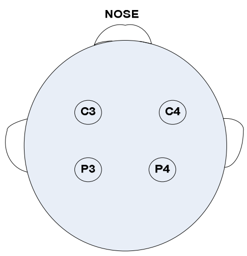


Figure 2: Location of electrode placements.

In EEG recording stage, subjects were asked to write a passage for 3 trials. In each trial, EEG was recorded in 120 seconds as shown in Table 1. Before a new trial was conducted, the subjects were asked to relax in 20s and then focus on the task.

TABLE I. TIME SEQUENCE OF ONE TRIAL OF WRITING ACTIVITY

20s	**10s**	**90s**
Relax	Start writing	Writing the passage

B. Data pre-processing

The recorded EEG signals consist of artifacts which interfere with the embedded information and need to be removed. Mehrdad Fatourechi et al [11] has reported that this artifacts are eye movements, known as electrooculogram (EOG) and muscle movements, known as electromyogram (EMG) in the context of BCI systems. In order to remove the artifacts, a band-pass filter with frequency of 8-30Hz was used. EOG and EMG has a wide frequency range with EOG has frequency below 4Hz meanwhile EMG with frequency higher than 20Hz – 300Hz [11, 12].

C. Frequency Analysis

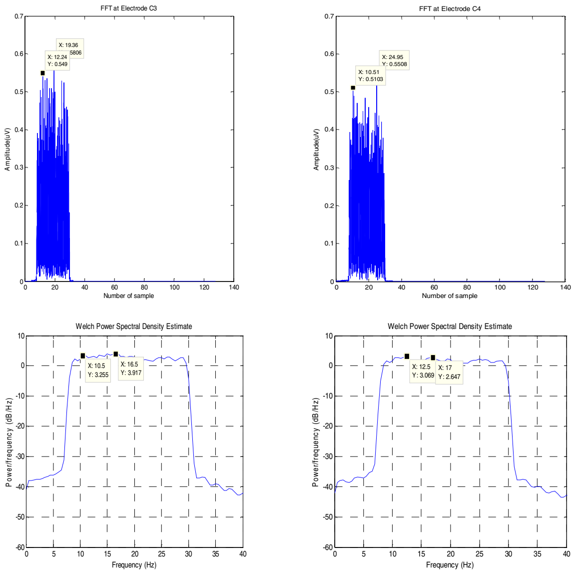
The EEG signals from the left and right handed subjects were first analysed using Fast Fourier Transform. After frequency analysis, power spectral density (PSD) was then computed. Here, Welch's method was used to calculate the power spectral density. Welch's method has been used by Meng Hu et al to classify normal and hypoxia EEG since it enables the basic information of how power distributes as a functions of frequency to be revealed [13].

IV. RESULTS AND DISCUSSIONS

Frequency spectrum and power spectral density of EEG signals obtained from the right handed and left handed writers are shown in Figure 3 to Figure 6. It is obvious that there are different pattern of frequency spectrum produced from right and left handed writers. This shows that electrode C3 and C4 are suitable electrode placement to clearly differentiate EEG signals obtained from right and left- handed writers.

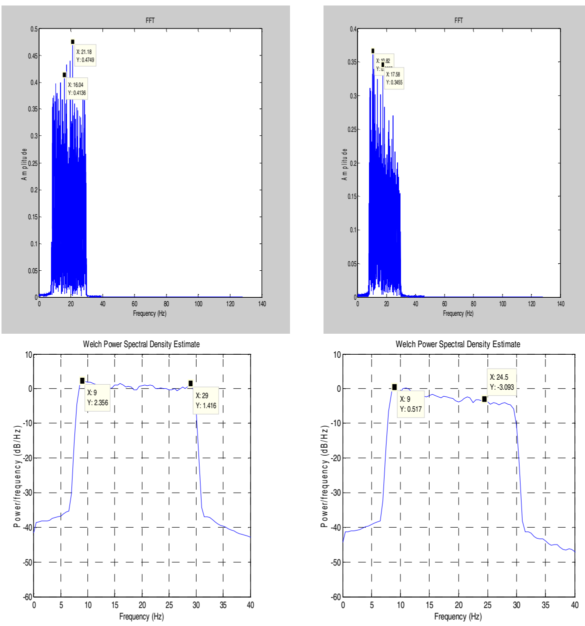
Figure 3 and Figure 4 show the frequency spectrum of EEG signal from male and female subjects that perform writing using right hand. From the frequency spectrum, it can be seen that writing activities are more apparent from EEG signals recorded at electrode C3 compared to C4. The PSD results also give the same indication where the maximum PSD at electrode C3 for right handed subject is more (3.917 db/Hz) than that obtained at electrode C4 (2.647 db/Hz).

Meanwhile, the frequency spectrum of EEG signals from left hand writing movements obtained at electrode C3 in figure 5 and Figure 6 is similar to that obtained at electrode C4. However, the maximum PSD of EEG recorded at electrode C3 is more than that obtained at electrode C4, which clearly shows that C4 gives more indication of left hand writing movements.



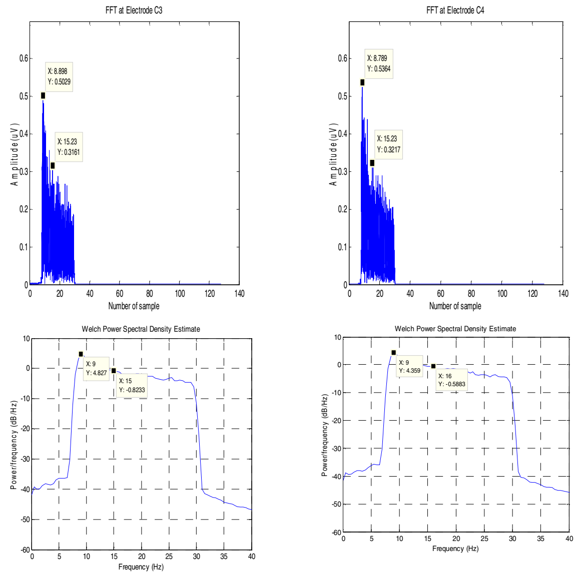
(a) (b)

Figure 3:Frequency spectrum and power specral density of EEG signal obtained from right handed male writer at (a) C3 and (b) C4



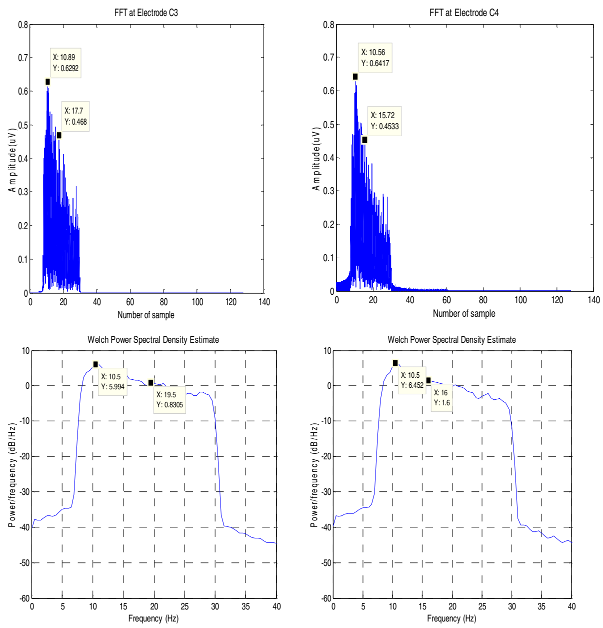
(a) (b)

Figure 4 : Frequency spectrum and power spectral density of EEG signal obtained from right handed female writer at electrode (a) C3 and (b) C4



(a) (b)

Figure 5: Frequency spectrum and power spectral density of EEG signal obtained from left handed male writer at electrode (a) C3 and (b) C4



(a) (b)

Figure 6: Frequency spectrum and power spectral density of EEG signal obtained from leftt handed female writer at electrode (a) C3 and (b) C4.

The detail maximum power (db/Hz) of EEG signal at each electrode for right and left handed writers is shown in Table II and Table III.

TABLE II. THE MAXIMUM POWER (DB/HZ) OF EEG FROM RIGHT-HANDED WRITING ACTIVITY

Subject	Max.Power at Electrode C3(db/Hz)	Max.Power at Electrode C4(db/Hz)
1	3.917	2.647
2	1.416	-3.093
Average	2.6665	-0.223

TABLE III. THE MAXIMUM POWER (DB/HZ) OF EEG FROM RIGHT-HANDED WRITING ACTIVITY

Subject	Max.Power at Electrode C3 (db/Hz)	Max.Power at Electrode C4 (db/Hz)
3	-0.8233	-0.5883
4	0.8305	1.6
Average	0.0036	0.50585

Figure 7 and Figure 8 show the dominant electrode placement for left and right handed writer based on the power spectral density plot. It is obvious that for right-handed writer, the power of EEG signal from electrode C3 is more than that produced from electrode C4. Meanwhile for left-handed writer, the EEG signal power spectral density is larger than that obtained from electrode C3.This is because for right-handed person, the EEG signal is activated at left-hemisphere in the brain meanwhile for left-handed person, the signal is activated at right-hemisphere in the brain.

The results obtained from this study are in agreement with that reported by Zhang et al [5]. They have found that power spectral entropy of EEG signal from imagined right hand is dominant at channel C3 [5]. Thus, channel C3 and C4 can be used to record EEG signals for imagined right and left hand movements. Since this method is suitable for imagined movement, it is also good for actual hand movement either for right and left-handed writer.

In another study, Yang has discovered that there are some differences between the EEG waveforms from the two sides of brain, left and right [6]. They found that EEG waveform from C4 location was more suppressed than that from C3 when movements from left hand were imagined [6]. This means that the left and right hand movements may produce different characteristics of EEG signals.

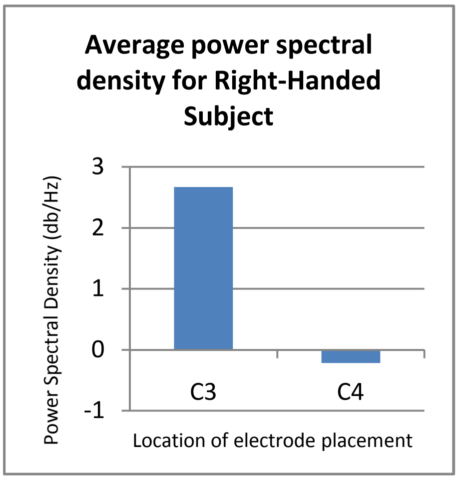


Figure 7: Average power spectral density for right-handed subject.

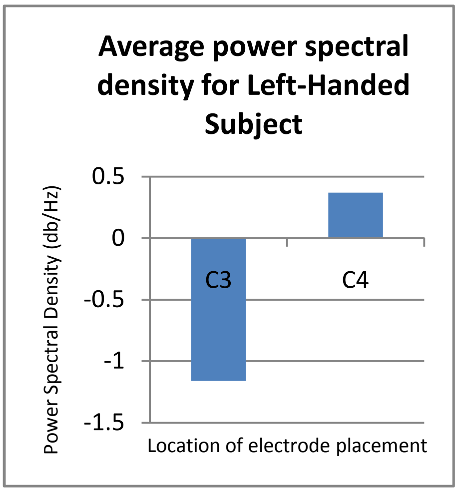


Figure 8: Average power spectral density for left-handed subject.

V. CONCLUSION

EEG signal from right-handed and left-handed writing have been analysed using frequency analysis and power spectral density are discussed in this paper. Four electrodes were used to acquire the EEG signals, however only EEG signals from electrode C3 and C4 were analysed. It was found that the power spectral density of EEG signal from right-handed and left-handed writing is different. EEG signal obtained from right handed writing produced higher power spectral density (PSD) in the signal is recorded at electrode C3. For left-handed writing, the suitable electrode placement is C4.

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