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Interpretation of Human Thought Using EEG Signals and LabVIEW

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***Abstract*—This document describes the analysis of Electroenchaplogram (EEG) or brain signals using computational tool (LabVIEW) to interpret human thought such as moving forward, backward, turn right, turn left and to stop. This study is conducted to assist the disable people to communicate with external environment. The EEG signals are captured using wireless EEG amplifier while the subject in relax conditioin. Then, the signals are analyzed in LabVIEW to reveal the features to describe human thought. The features will be applied by the state machine to control the movements. The extracted EEG features are the ratio of EEG power spectrum from 14 channels. The Read Biosignal and STFT Spectrogram Toolbox of LabVIEW are used to process the EEG raw data and to produce the EEG Power Spectrum. Then, the pattern of the EEG Power Spectrum are studied to provide the feature vectors for the state machine. The outcome of the study indicates that the movement or direction can be determined based on the extracted features of EEG signals in LabVIEW.**

Keywords—EEG, LabVIEW, power spectrum, human thought, direction, state machine

I. INTRODUCTION

Nowadays, Brain Computer Interface (BCI) technique has increased in popularity. BCI is a technique that enables interface between human brain and computer. Currently, BCI technique is implemented in various fields, such as robotics, communication, and mobility control. In year 2011, statistics shows that approximately 15% of the populations are disabled people, which is around 1 billion out of the total population of 7 billion people. Among the disabled people, some of them suffer difficulty in mobility. By analyzing brain signals acquired from the EEG device, disabled people can move freely by controlling the wheelchair using their thought. Brain signal is the recording of the electrical activity along the scalp. Different human thought will give different types of brain signal. There are six frequency bands of brain signals, which are the Alpha band, Beta band, Theta band, Delta band, Gamma band and Mu band [1-2]. The different types of brain signals can be used to study the human behavior. Throughout the project, brain signal will undergo signal conditioning and signal processing to provide the feature for the state machine to control the wheelchair. The combination of robotic wheelchair and EEG technology can help patients and disabled people to regain mobility, increases the quality of life and reduce expenses on the need of care giver [3]. Carlson and del R. Millan [4] had developed a control architecture of a wheelchairs using asynchronous motor-imagery using brain signals.

The pattern of neural activities can be used to study the cognitive or mental state of human. Brain signals contains a lot of features to describe human behaviors or traits and can be applied in many applications. For example, the change of EEG Alpha and Beta power were used to determine the type of human emotions while watching movies [2]. In addition, EEG signals were used to identify a person characteristic [5]. The mental workload and drowsiness level of aircraft pilots and car drivers can be assessed and determined from the analysis of the brain signals [6]. EEG signal can be used as a diagnosis tool as well. It can be used to detect the disease such as epilepsy [7]. Here, the LabVIEW was used to extract the EEG features that related to Epilepsy.

Researchers had introduced various methods to analyze brain signals. The famous method was nonparametric or spectral analysis of EEG signals to reveal the hidden features inside the signals. For example, Manoilov [8] had used power spectrum of EEG signals to measure the performance of the arithmetic mental taks. The Fourier transform technique was used to find the features for the Brain-Computer Interface application [9-10]. The spectral analysis of neural activity able to determine the control signal for the operation of the BCI system. However, the accuracy of the BCI system depends on the selection of the EEG features and must be free from any noises or artifacts factor. The major artifact to EEG signals come from eyes blinking or eyes movement (ocular artifact). Shah and Panse had developed the wavelet method using LabVIEW to eliminate ocular artifact from EEG signals [11-13]. The previous researches have shown that LabVIEW become effective tool to analyze EEG signals.

Hence, this study is conducted to achieve two objectives;. the first objective is to extract EEG features from the analysis of EEG signals to be applied in state machine to provide signal to motor controller to control the wheel chair. The second objective is to identify the direction based on the extracted features. The LabVIEW is used to analyze EEG signals and extract features for the state machine. Besides, the machine

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learning is also conducted. Human's learning process is based on experience, machine learning algorithm allow the machine to learn based on the training input and make prediction for the future data. If the data is sufficient, the system able to classify the input based on their features and it is even can make decision for us [14].

II. METHODOLOGY

The experiments for this study consists of several criterion as described below.

A. Subject Selection

10 subjects (6 males and 4 females) with age ranging from 20 – 30 years old are selected for this study.

B. Training Sessions

Prior to experiment, all the subjects are required to perceive the box picture in the computer screen while their brain signals are captured for the duration of 30 minutes.

C. Equipment setup

The EMOTIV EPOC EEG amplifier and electrodes are used to capture the EEG signals from the subject. The equipment are set-up as shown in Fig. 1 and Fig. 2 respectively.

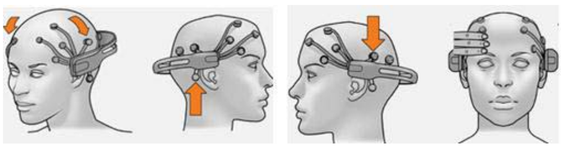

Fig. 1. The position of the EEG electrodes

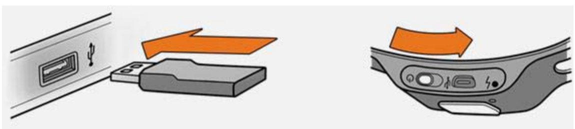

Fig. 2. EMOTIV EEG amplifier and dongle

The measurement position of the EEG amplifier is shown in Fig. 3. The diagram of the measurement location is displayed by EMOTIV software in the computer screen. All the position should be in green light before taking measurement. If any position has red light, the expriment should be stopped and conditions of the electrodes or amplifier need to be checked and verified. The EEG measurement location covers all the brain lobes except Cerebellum. The coverage brain lobes are Frontal, Parietal, Occipital and Temporal. There are a total of 14 measurement points.

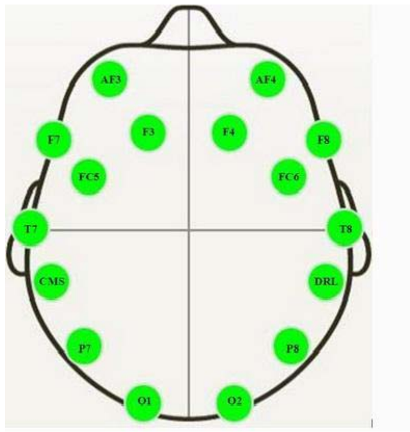

Fig. 3. EEG measurement position

The function of the brain lobes and their corresponding EMOTIV EEG measurement location is elucidated by Table I.

TABLE I. THE FUNCTIONS OF BRAIN LOBES AND MEASUREMENT POSITIONS

Lobe	**Function**	**EMOTIV EEG Positions / Channels**
Frontal	Emotions, Cognition	AF3, AF4, F3, F4, F7, F8, FC5, FC6
Parietal	Movement	P7, P8
Occipital	Sight, Vision	O1, O2
Temporal	Hearing	T7, T8

D. Measurement Protocol

The measurement protocol consists of 5 steps as illustrated in Table II. The subjects are instructed to be in relax condition and no movement are allowed during EEG measurement.

TABLE II. TYPE OF THINKING AND DURATION OF EEG

Steps	**Thinking types**	**Duration of EEG Recording**
1	Move forward	3 minutes
2	Move backward	3 minutes
3	Turn right	3 minutes
4	Turn left	3 minutes
5	Stop	3 minutes

E. Signal Processing

The raw data of EEG signals are sent to computer via Bluetooth and then saved as *.edf* file. Next, the data are transferred to LabVIEW for analyzing and identification of the EEG features. The spectral analysis of the EEG signals are conducted in LabVIEW to identify the EEG features for the types of thinking as described in Table II. The features vector is computed using the formula below.

$$Fv = (\Sigma r_n) / n \tag{1}$$

Fv is the feature vector, *r* is the ratio of the EEG power spectrum and *n* is the number of subjects.

III. RESULTS AND DISCUSSIONS

The LabVIEW coding is generated to read the recorded data from EEG amplifier in *.edf* file. To implement it, the Read Biosignal is selected in the LabVIEW Block Diagram as illustrated in Fig. 4. The While Loop is required to be placed outside the Read Biosignal block diagram to repeat the process until the termination button is pressed. The logical gate, OR gate is placed inside the loop to trigger the system to stop the process if there is an error in Read Biosignal or when End of File (EOF) is reached. The 50 ms timer is placed in the Block Diagram to avoid collapsion of the EEG data and will be starting after the While Loop finished. The indicator is placed in the Block Diagram to visualize the EEG data. Meanwhile, Fig. 5 displays the plot of the raw data of EEG signals from all channels.

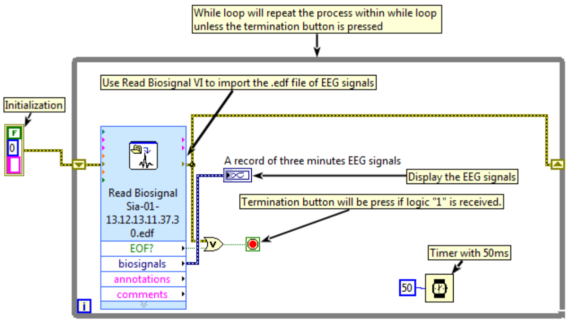

Fig. 4. LabVIEW block diagram to read EEG data

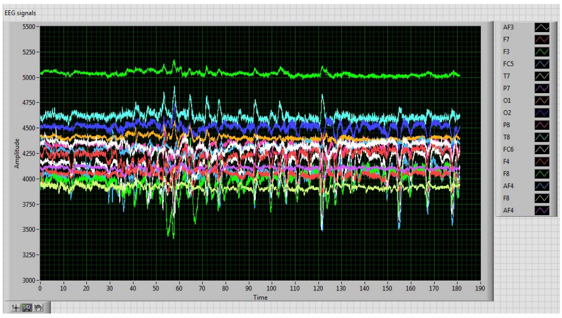

Fig. 5. LabVIEW front panel to display EEG signals from all channels

Next, the front panel to process the EEG data is constructed as shown in Fig. 6. Here, the front panel of LabVIEW consists of display panel of the EEG signals before and after filtering process, spectrogram of the EEG data, Power Spectral Density (PSD) of the EEG data, filter setting, EEG frequency bands (Delta, Theta, Alpha and Beta), and average power of the EEG frequency bands. For the filtering process, the *Hanning* window with FFT (Fast Fourier Transform) length of 1024 and 50% of window overlapping are selected. The front panel also displays the Mean Instantaneous Frequency (MIF). It is the central frequency of a signal that changing over time. It is computed from spectogram of the brain signals. The Power Spectral Density is calculated and plotted based on the range of the EEG frequency bands; from 0.5 Hz to 40 Hz. The plot of the EEG power spectrum is shown in Fig. 7. The plot confirms the behaviour or pattern of EEG Power Spectral Density for all frequency bands. Here, the Beta power is less than 5 $\mu V^2/Hz$. Meanwhile, Alpha power is between 5 $\mu V^2/Hz$ to 15 $\mu V^2/Hz$ with the peak frequency located at 10 Hz. Delta band has amplitude greater than 100 μ^2/Hz.

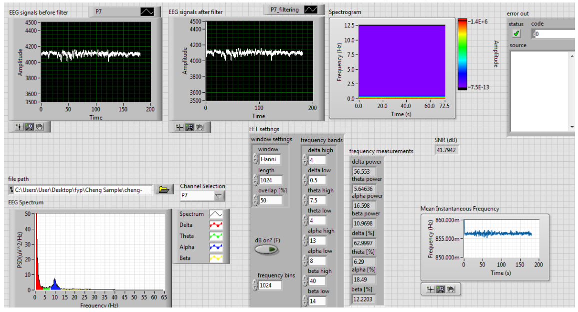

Fig. 6. LabVIEW front panel for signal processing

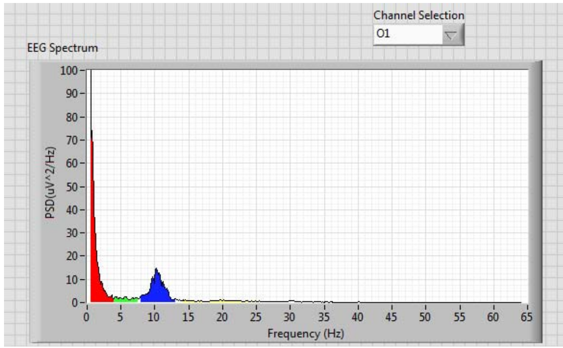

Fig. 7. LabVIEW plot of EEG power spectrum

The block diagram to run the LabVIEW front Panel to process the EEG data is elucidated by Fig. 8. Here, the LabVIEW block diagram shown in Fig. 4 is expanded to process the EEG signal by adding STFT (Short-Time Fourier Transform) to produce spectrogram image, waveform classical filter to filter the signals, FFT to produce EEG spectrum by converting the signal from time domain to frequency domain. The timer is expanded to 1000 ms for the while loop to complete executing the program.

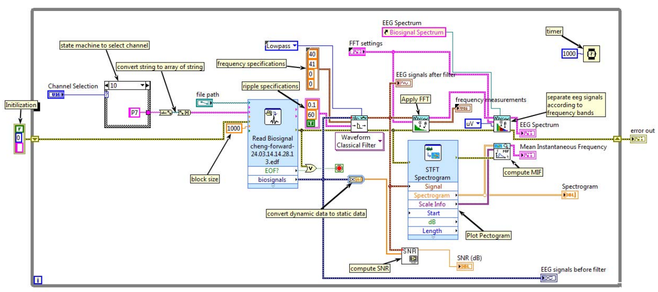

Fig. 8. LabVIEW block diagram for signal processing

Beside signal processing, LabVIEW block diagram is also constructed to perform statistical analysis of EEG data as illustrated in Fig. 9. The program will calculate the mean and standard deviation of the EEG power spectrum.

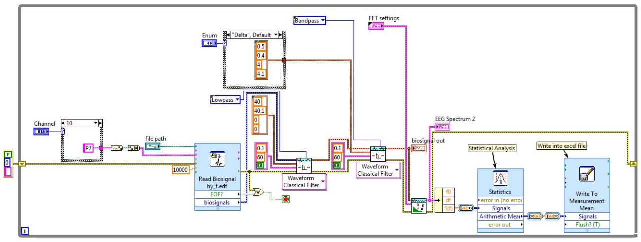

Fig. 9. LabVIEW block diagram for statistical analysis

The LabVIEW block diagram is constructed as shown in Fig. 10 to produce the features of all the EEG frequency bands using formula described in (1).

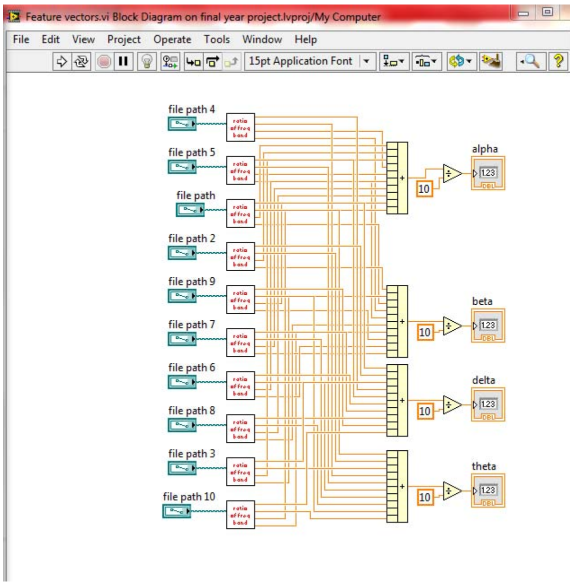

Fig. 10. LabVIEW block diagram to calculate EEG features

The features vector to represent human thought after analyzing the ratio of EEG power spectrum is tabulated as shown in Table III.

TABLE III. FEATURES OF HUMAN THOUGHT FROM 10 SUBJECTS

DIRECTION/ EEG BANDS	FORWARD	BACKWARD	LEFT	RIGHT	NEUTRAL
Delta band	0.9332	0.9286	0.9150	0.9257	0.9069
Theta band	0.0356	0.0366	0.0430	0.0400	0.0503
Alpha band	0.0212	0.0234	0.0251	0.0228	0.0254
Beta band	0.0099	0.0114	0.0170	0.0115	0.0174

Next, the LabVIEW front panel for state machine is developed based on the features shown in Table III. Both figures, Fig. 11 and Fig. 12 illustrate the LabVIEW front panel for implementating state machine. The forward direction is illustrated by Fig. 12. The direction of the state machine is only valid for the selected features that were obtained from the analysis of the EEG signals of the 10 subjects. Here, user can select the input signal by simply browsing the EEG signals from the recorded EEG signals and then select the EEG frequency bands. Next, the ratios and features of the EEG frequency bands in term of power spectrum are computed. The direction for the state machine will be determined based on the calculation of the feature vectors of EEG Power Spectrum. The lamp indicator is placed in this front panel to indicate the direction. The truth table of logical AND gate is applied to obtain the final direction based on the direction given by each EEG frequency bands. However, if one of the EEG frequency bands is differ from the directions of the other frequency bands, then the read incidator will turn on and 'stop' signal will be sent to state machine to stop the movement of the wheelchair as elucidated by Fig. 13.

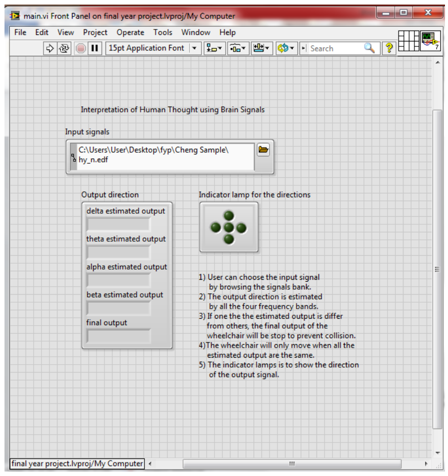

Fig. 11. LabVIEW front panel to determine the direction of state machine

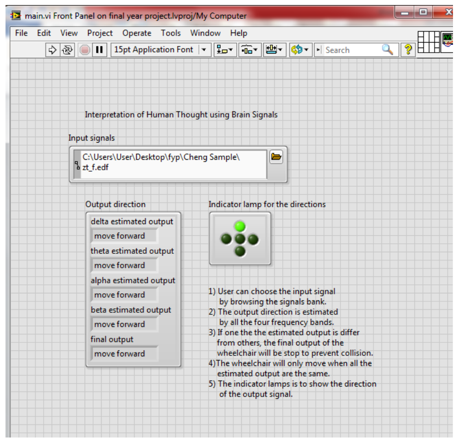

Fig. 12. LabVIEW front panel to indicate the forward direction for the state machine

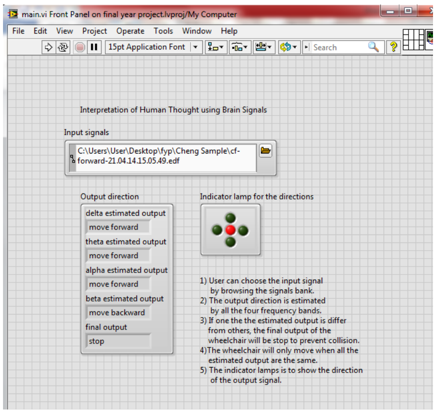

Fig. 13. LabVIEW front panel to indicate the stop direction for the state machine

The LabVIEW block diagram to produce the directions for the state machine is depicted by Fig. 14. The movement directions are determined using EEG features obtained from the calculation of the ratio of the EEG power spectrum of all EEG frequency bands.

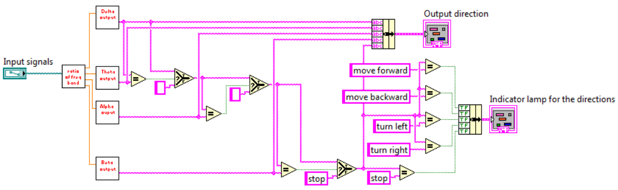

Fig. 14. LabVIEW block diagram to implement the stop direction for the state machine

As illustrated by Fig. 15, the accuracy for the forward, backward, left, right and neutral or stop directions is 70%, 30%, 20%, 20% and 50% respectively. The results of the study shows that only forward direction has high percentage of accuracy. There a lot of factors that might contribute to low accuracy of the directions such as the number of sample, the selection of EEG features and the noises from EEG amplifier and electrodes.

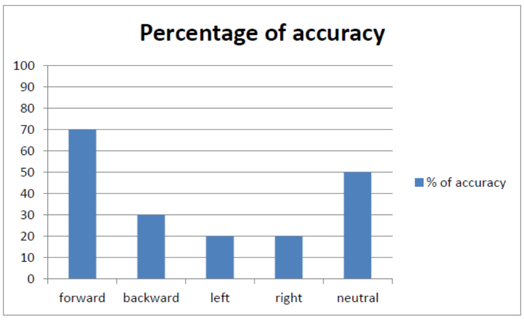

Fig. 15. The directions accuracy for the state machine

IV. CONCLUSIONS

The study succeeded to analyze the EEG signals using LabVIEW programming. The main objective of this study is to interpret human thought using brain signals and then to discover the reliable features for the state machine. These features will be used by the state machine to move the wheelchair of disabled or handicapped people. Even though, the accuracy of the direction for the state machine is low, the study succeeded to construct the LabVIEW block diagram to analyze EEG signals and come out with the features of human thought in term of moving forward, moving backward, turn to the right, turn to the left and to stop. The next study will be focusing on the accuracy factor of the directions.

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