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Interpretation of EEG thought signals for the control and movement using MATLAB

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Abstract - The human brain is an ocean of thoughts. It is estimated that there is a flow of about 10,000 signals per second. Each thought signal has a different specification. Thought signals are produced from the five sense organs that a human has, namely; eyes to see, ears to listen, skin to feel, tongue to taste and nose to smell. These sense organs have an ability to release a special kind of fluids or lipids called hormones. These hormones produce an electrical impulse in the neurons, based on their production quantity and their movement. These electrical impulses create thought signals. These thought signals are captured in the form of EEG (Electroencephalogram). In a human's daily busy life, he moves from one place to another for different works that he does. But, some couldn't do that because of their inability to move. The motto of this document is, to interpret human thought [1] signals like moving forward, backward, turn right, turn left and to stop. This research is conduct to aid the paralyzed to communicate with the external world. In brief, the procedure goes in the following way; the EEG signals are captured through the EEG Epoch amplifier [1] and is passed into the MATLAB for further programming. The signal is subjected to power spectrum analysis to extract the features of the raw signal. EEG power spectrum is found by finding STFT (Short time Fourier transform) of the raw signal. The obtained feature vectors are subjected to the state machine. The result of this research is a movement of direction based on the extracted features [1] of the EEG signal in MATLAB.

Keywords - EEG signals; electrical impulses; power spectrum; state machine; MATLAB; STFT

I. INTRODUCTION

Nowadays science and technology are taking more advanced steps in all fields. One of the best advancement in science and technology is the Brain and Computer Interface (BCI). In most of the research fields like robotics, Artificial Intelligence (AI), mobility command systems and in some communication techniques. As there is an approximate 11% increase in the rate of paralyzed people all over the world, this technique is acquiring its demand both technically and economically since it has most of its applications in mobility control. Inspecting data from EEG device [1] through BCI technique, paralyzed people can move easily by controlling their [1] warm chair or an exoskeleton in whatever direction they wanted, just by creating the movement thought in their brain. The below Fig. 1, illustrates the construction of a warm chair controlled by BCI. It takes commands from human thoughts, that is EEG signals and does processing in the embedded CPU.

Human brain produces thought signals at a frequency range of 0.5 to 500Hz. These frequencies are divided into six frequency bands of brain signals; they are Alpha, Beta, Theta, Delta, Gamma, and Mu bands. Alpha bands range from 8-12Hz, arising from synchronous and coherent electrical activity of thalamic pacemaker cells in humans. Beta bands range from 12.5-30Hz, arising from states associated with normal waking consciousness.

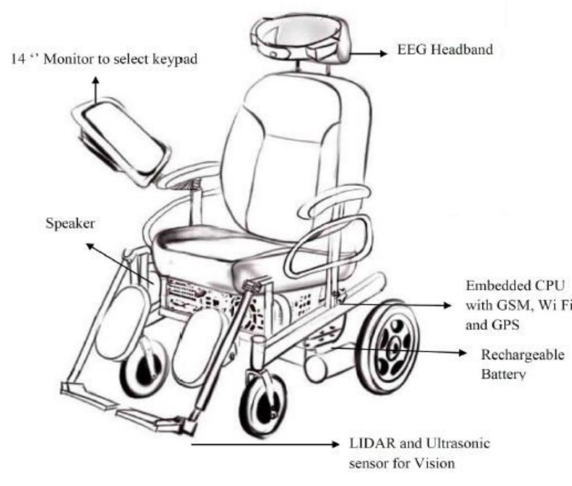

Fig. 1. Model of a warm chair controlled by EEG

Theta bands range from 4-7Hz, arising from fantasy and imaginary dream. Delta band ranges from 0.5-3Hz, arising from a deep, dreamless sleep. Gamma bands range from 30-100Hz, arising from motor functions and high mental

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activities. Mu band ranges repeat at a range of 7.5-12.5Hz, found over the motor cortex from ear to ear. All these bands combinedly are used to find human behaviour.

In the conventional scalp EEG, the recording is taken by positioning electrodes on the scalp area by applying a conducting gel or cream. This gel is used in a light erosion to reduce the impedance because of dead skin cells. Most of the EEG devices use electrodes, each of which is a connected impedance to a separate wire.

The whole paper deals with the brain signal, undergoing signal conditioning, which means that the analog form of the EEG signal is manipulated in such a way that it encounters the necessity of further stages for other to produce the feature for the state machine [1] for the movement of the warm-chair. The reason for combining the technology of warm-chair with EEG technology is, it can aid paralyzed and debilitated people retrieve their mobility and raise the graph of quality of life.

The most used method of analyzing the features of the analog EEG signal [9] is spectral-analysis. The power spectrum of the EEG signals used to produce the features of EEG. Another method to analyze the EEG signals is the Fourier transform analysis but the data acquired in this process must be free from all kinds of artifacts.

II. Methodology

A. Choosing the signals

Signals are taken from the cite called "*Physionet.org*". Where the subject's thoughts are pre recorded and stored in the form of .edf or .mat files.

B. Computation protocol

The below Table. 1. illustrates the operation protocol of for the subject to think the specified movement for a specified duration. Before this, the brain of the subject must be free from all types of distractions, so that there won't be any interference in the signal generated.

TABLE I. Computational Protocol of EEG Signals

Thinking types	Duration of EEG recording
Forward	4 minutes
Backwards	4 minutes
Right	4 minutes
Left	4 minutes
Stop	4 minutes

C. Apparatus Setup

The EEG - EPOCH has a total of 14 measurement points. The electrodes capture the electrical impulse produced inside the brain and retrieve the impulse as the EEG signal. The below Fig. illustrates the equipment's setup.

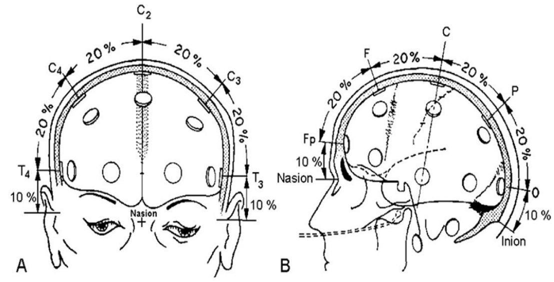

Fig. 2. Positioning an EEG -EPOCH on a subject's head

The 14 measurement points are divided as shown in Fig. 3, and they have their own specific signals generated at those points. Except for cerebellum, all other brain lobes are covered by EEG-EPOCH. The frontal lobe functions for 'Emotions and Cognition. It takes the positions AF3, AF4, F3, F4, F7, F8, FC5, FC6. Parietal lobe functions for movement purpose and takes positions P7, P8. Occipital lobe functions for sight or vision and positioned at O1, O2. Temporal lobe occupies T7, T8 positions and the sense of hearing is through this lobe.

The generated signal is collected from the EMOTIV EPOC EEG amplifier and stored into the computer in the form of .edf or .mat files through Bluetooth and taken into MATLAB for further evaluation.

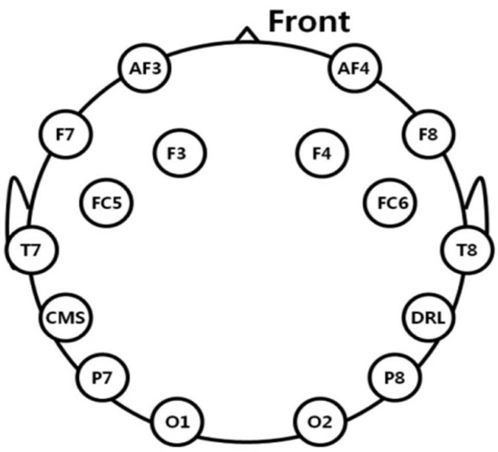

Fig. 3. Measurement positions of EEG

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D. Signal Processing

The main motive of signal processing in this procedure is to extract the features of the EEG signal. Initially, the EEG signal is loaded into the MATLAB, and the signal is normalized by subtracting the gain produced by the signal with the original value of the signal and later the subtracted value is divided by the base value of the signal.

val=load('Subject00_2_edfm.mat'); (1)
eeg=(val-Gain)/Base; (2)

This normalizes the original signal by removing any noise and artifacts present in it. Now for plotting the cure, we need to calculate the time of the curve with the provided sampling frequency and obtained signal.

time=(0:length(eeg)-1)/Fs; (3)
Fs=Sampling Frequency

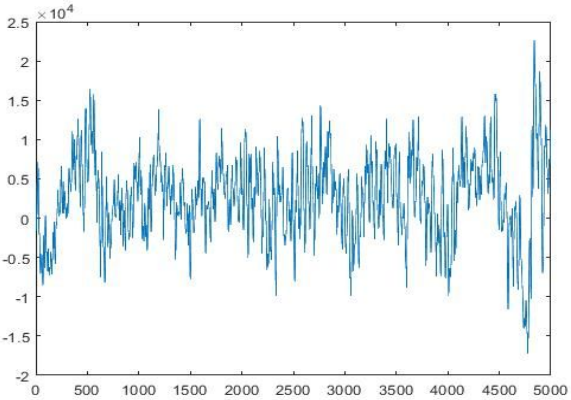

Fig. 4. Plot of Raw EEG signal

The above Fig. 3 illustrates the raw EEG signal from one of the thoughts extracted from the subjects chosen. For finding the features as of the EEG signals with the thoughts as shown in Table. 1, using spectral analysis in MATLAB. To compute the featured vectors we use the following formula.

$$Fv = (\sum r_n) / n \qquad (4)$$

From the above equation, *Fv* is the feature vector, power spectral ratio of the EEG signal is given as *r*, and n is the number of subjects involved in the experiment.

The power spectrum is used in this processes because it distributes the energy spectrum of a waveform among its different frequency components. So, after loading the EEG signal, the length of the signal is found. For filtering the signal, the window with Fast transform of length 1024 and 50% of window overlapping is used. Before finding the power spectral density the transformed signal is again normalized. Then Fast transforming this normalized signal and using the following formula, we compute the power spectral density.

$$PSD = (1-(Fs * N)) * (abs(fft))^2 \qquad (5)$$

Where PSD is the power spectral density and *Fs* is the sampling frequency of the signal and N is the length of the raw signal and the absolute value of the normalized *fft* (Fast Fourier Transform) [6] are used to compute. The power spectral density is plotted as shown in Fig. 5.

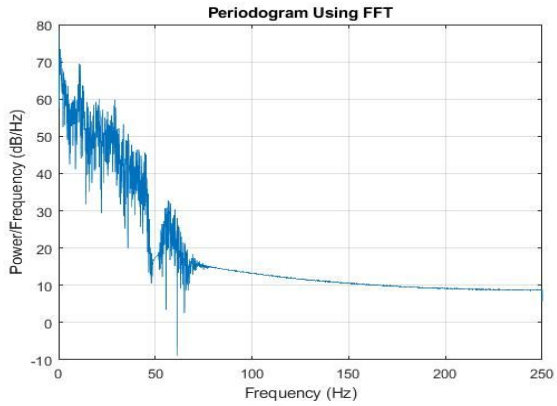

Fig. 5. Power spectral density of the raw signal

After finding the power spectrum of the input raw EEG data, STFT (Short Time Fourier Transform) [2] of the signal is done to produce the spectrogram image as shown in Fig. 6. Fast Fourier Transform[6] (FFT) is applied to change the signal from time domain to frequency domain.

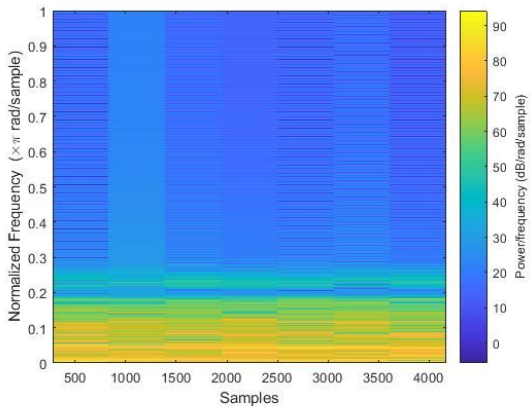

Fig. 6. Spectrogram of the extracted EEG features obtained by the STFT of the EEG data.

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The above spectrogram represents the plot between, Normalized frequency and samples. The samples here in the plot represents the extracted features of the raw EEG signal.

III. Results and Future Scope

A. Results

After the signal processing, the statistics of the signal is need to be done to find the mean and deviation of the signal. For that, a mean simulator is built in the Simulink as shown in Fig. 7.

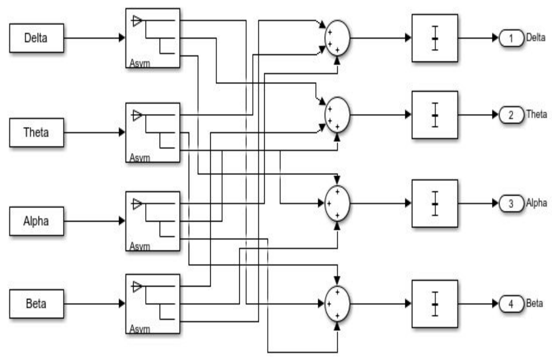

Fig. 7. Block diagram to calculate EEG features in Simulink

As per the code, the evaluation of the signals is done separately. Each signal is processed separately and sent into Simulink via assigned blocks. The mean and the features are calculated from the formula given equation (4). The mean calculation is done and is tabulated as shown in the following TABLE. II.

TABLE II. Extracted Features of Human Thought EEG Bands

Direction / EEG Band	Front	Back	Left	Right	Stop
Alpha	0.0252	0.0261	0.0272	0.0213	0.0277
Beta	0.008	0.0125	0.0162	0.0104	0.0169
Theta	0.0339	0.0351	0.0415	0.0396	0.0490
Delta	0.9212	0.9119	0.9130	0.9235	0.9055

The extracted features are sent through a state machine created using the values generated in Table.2. The state machine is coded in such a way that if the extracted features are in a mentioned range as shown in the above Table. 2, the direction is predicted.

For instance, if the generated signal produces a mean of '0.0252', the input signal is of the Alpha band and the state machine produces the output as 'Move Forward'. The generated output is shown in the command window of the MATLAB as depicted in the following Fig. 8.

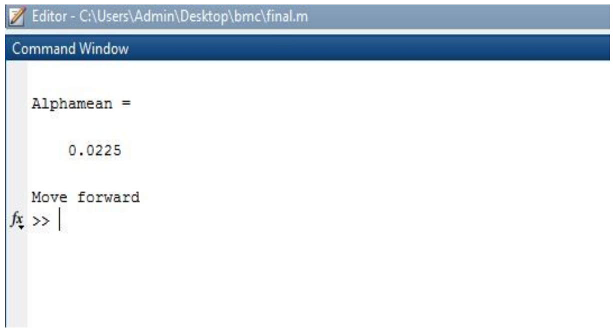

Fig. 8. Output of the State machine, depicting Move forward in Command window of the MATLAB.

B. Future scope

At present the software part is implemented, building the hardware is the main challenge for the idea. The same can be implemented in a more efficient way, using the concepts of data structures and algorithms. By converting this algorithm into data structures, the conversion of the algorithm into Embedded form becomes simple, which makes the hardware simple.

Conclusion

This research is all about generating an algorithm to control a warm chair using EEG signals produced from the human brain. The extracted EEG signals are first treated with power spectral density so as to distribute the energy spectrum of the waveform. Later the Short-time Fourier transform is applied on the signal to find the spectrogram of the signal which extracts the samples of the signal. Then the signal is sent to extract its features from the signal. The extracted features are further treated with a state machine such that the direction thought by the subject is extracted from the specified features of the signal.

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