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Three Dimension 3D Signal for Electroencephalographic (EEG)

N.Fuad[1,2]
[1]Department of Computer Engineering, Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Johore, MALAYSIA.
norfaiza@uthm.edu.my

R.Jailani[2],W.R.W.Omar[2], A.H.Jahidin[2], M.N.Taib[2]
[2]Faculty of Electrical Engineering, Universiti Teknologi MARA, 40450 Selangor, MALAYSIA

Abstract— **The present paper examined an experiment of brainwave signal electroencephalographic (EEG) analysis using signal processing and image processing for producing the EEG three dimension (3D) signal. EEG is a scientific tool for measuring brainwaves which give information about brain activity. The EEG signal has been collected from healthy subjects. The proposed method using signal processing for preprocessing stage are threshold, band pass filter and Short Time Fourier Transform (STFT). Threshold algorithm used to artefact removal for EEG raw signal. Band pass filter filtered raw signal into sub bands. STFT has been implemented to get EEG spectrogram. Image processing technique has been implemented to produce EEG 3D signal from EEG spectrogram such as color conversion, optimization, gradient and mesh algorithms. Color conversion has been used to convert from RedGreenBlue (RGB) to gray color and optimization are implemented to gray pixels image. Gradient and Mesh algorithm used to produce the 3D signal. The outcome shows that by implementing 3D signal for EEG , the relationship between three parameters (time, amplitude and power) for brainwave is more clearly.**

Keywords: Brainwave, Electroencephalographic (EEG), spectrogram, 3D signal.

I. INTRODUCTION

The brain cells are known as neurons and scientists estimated that a normal adult human brain consists of one hundred billion neurons and each neuron is connected to another two hundred fifty thousand other neuron. Human brain processes and sends information also it able to generate electrical power represented which is called waves [1-4].

Human brain is divided into two main regions which is right and left hemisphere. The left hemisphere is dominant in activities involving language, speech, arithmetic, and analysis whereas the right hemisphere is superior in perceiving, thinking, remembering, emoting and understanding [5-8]. Using both the right and the left brain will yield optimum balanced lifestyles resulting in happiness and good health [9].

The electroencephalogram (EEG) is one sum of different sinusoids with a fairly wide frequency spectrum which is divided into a different frequency bands named delta, theta, alpha and beta bands [10]. EEG spectral pattern is characterized by several spectral components which are spectral powers within internationally agreed frequency bands: delta-δ, theta-θ, alpha-α and beta-β. These spectral components represent EEG oscillations and are hypothesized to reflect cyclical variation in the excitability of neuronal assemblies [1, 11]. Beta is the highest frequency band with the lowest amplitude while Delta is the lowest frequency band having the highest amplitude.

TABLE 1: TYPES OF BRAINWAVE

	Frequency	Voltage	Condition
Beta	12-30 Hz	10 -20 uV	Activity, thinking
Alpha	8-12 Hz	50 uV	Relax, Closed Eye
Theta	3- 8 Hz	10 uV	Light sleep, emotional stress
Delta	0.2- 3 Hz	10 mV	Profound sleep

There are four types of brainwave, which are explained in table 1. Beta band for 10uV (low Beta) occurs when human are active, busy or anxious thinking and active concentration while high Beta occurs when thinking activity is low. Alpha band (50uV) occurs when human in relaxed/reflecting mode, closing the eyes and also associated with inhibition control, seemingly with the purpose of timing inhibitory activity in different locations across the brain. Maximum voltage for Theta band means than human is in light sleep and emotional stress. This band has been found during some continuous attention tasks and also especially in baby. Delta band (10mV) occurs for profound sleep mode in human activity [3].

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There are several toolboxes and software which can be used to produce the EEG topography. For instance, EEGLAB [12] has the Matlab embedded module and can be used to continuously process and event- related with MEG and EEG. The low resolution brain electromagnetic tomography or LORETA is used for EEG topography of Alzheimer patients [13]. The Brainstorm approach is used in [14] to display the scalp distribution of the signal of MEG and EEG.

Normally, time domain represents EEG signals. The time domain plot refers to a representation of time-amplitude signal. In the same time, frequency domain signal can leads to some additional information. The frequency component in signals can be produced using Fourier Transform (FT). For the analysis of EEG power density spectrum, artifact-free EEG epochs were re-referenced to a common average and were analyzed by a standard Fourier Transform (FT) algorithm [15]. The introduction of spectral characteristics and their calculation is based on the discrete Fourier Transform (FFT), and relies on estimates of the power spectral density via smoothed periodograms [16]. There have been a number of methods available recent years to produce time-frequency analysis and applied to image processing as two dimension (2D) data from EEG signal such as Short Time Fourier Transform(STFT) [17].

There are differences between 2D and 3D data especially in technology implementation such as baby scanning. 2D baby scanning displays 2 dimensions (height and width) and 3D scan displays 3 dimensions (height, width and depth) [18]. The image processing techniques used to analysis of 3D-surfaces of crystal [19] and brain-computer interface (BCI) [20] and 3D acoustic scattering used to assess the benefit of constant, linear and quadratic elements [21]. There are some method can implemented to produce 3D such as Matching pursuit, Wigner–Ville and Mesh.

Hence, this paper proposes the method of experiment to produce 3D signal for EEG. Then the results focus to one subject for right hemisphere or channel.

II. METHODOLOGY

A. *Subjects and Data Collection*

The data collections were perform at Biomedical Research and Development Laboratory for Human Potential, Faculty of Electrical Engineering, Universiti Teknologi MARA Malaysia. The samples were collected from healthy subjects. This study was approved by ethics committee from Universiti Teknologi MARA. The EEG data were collected using standarad Gold disk bipolar electrodes with 2-channel Fp1 and Fp2 and reference to earlobes A1, A2 and Fz. The electrode connections are in accordance to 10-20 International system with 256Hz sampling rate. The EEG signal was recorded for five minutes using g.MOBIlab, with wireless EEG equipment. The impedance was maintained below 5kΩ using Z-checker equipment. Figure 1 shows the experimental setup and five positions for experimental in different view which are the position for Fp1 (Frontal 1- (Attention), Fp2 (Frontal 2 - Judgment), A1 (Ear-clip reference point for left), A2 (Ear-clip reference point for right) and Fz (Centroid -Working memory). The data was processed using intelligent signal processing technique developed in SIMULINK and MATLAB.

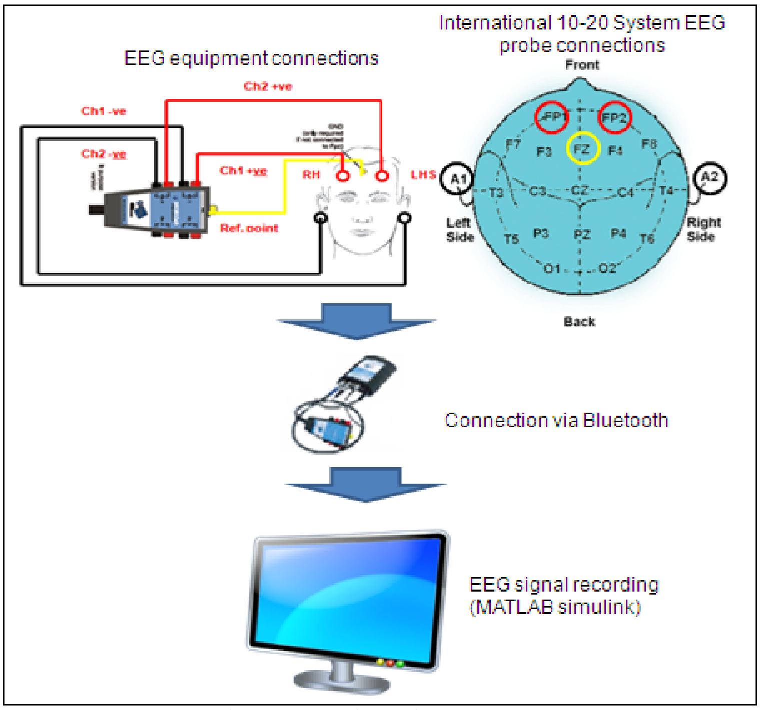

Figure 1. Experimental setup.

B. *Preprocessing*

After data collection, EEG raw data is processed separately sample by sample. EEG signal pre-processing includes artifact removal and band pass filter. Artifacts occur when the volunteers blink his or her eyes. This artifact were removed by means of a program designed using MATLAB tools by setting a threshold value. The threshold was set to eliminate data when the values are more than 100µV and less than -100µV. Meaning that only signal within -100µV to 100µV are meaningful and informatics. The band pass filter is designed using Hamming window with 50% overlapping for the frequency 0.5Hz to 30Hz which are delta (0.2- 3 Hz), theta (3-8 Hz), alpha (8-12 Hz) and beta (12-30 Hz) band. Figure 2 shows the flow diagram of preprocessing process.

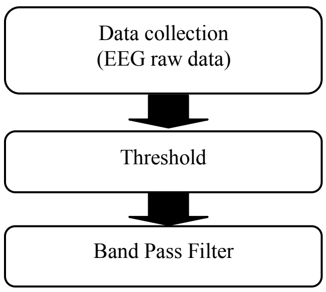

Figure 2. Flow diagram of preprocessing process

C. *Two dimension data (Spectrogram)*

The spectrogram image is produced using STFT with image size 436x342 pixels for both Fp1 and Fp2 channel. In spectrogram image, each frequency band is set. The Delta band is set from 0.5Hz to 4Hz, Theta band is set from 4Hz to 8Hz, Alpha band is set from 8Hz to 13Hz and Beta band is set from 13Hz to 30Hz. Most researcher using STFT [22,23] for classification of motor imagery EEG signals while other using Wigner-ville distribution [24,25] for detection of epileptic seizures in EEG recordings as time-frequency representation of EEG signals.

Therefore, STFT used to do time-frequency analysis (equation 1). STFT implemented to the EEG signal where, x(t) is the signal, w(t) is the window function, and * is the complex conjugate. The changes of signal that vary in time are performed by STFT. The STFT is to perform a FT on only a small section (window) of data at a time, thus mapping the signal into a two-dimensional function of frequency and time. The Fourier Transform (FT) will be multiplied with the window function to yield the STFT.

$$STFT_x^{(w)}(t,f) = \int_{-\infty}^{\infty} [x(t).(t-t').e^{-j2\pi ft}\, dt] \tag{1}$$

D. *Three dimension (3D)data/ signal*

Some methods using image processing technique has been implemented to produce EEG 3D signal from EEG spectrogram such as color conversion, optimization, gradient and mesh algorithms. The spectrogram is in RedGreenBlue (RGB) color. Color conversion has been used to convert from RGB spectrogram to gray scale spectrogram. Gray scale image consists of a data matrix (I) whose values represent intensities within some range which is 0 (black) and 255 (white). Gray scale are the most commonly used images within the context of image processing.

After conversion process, optimization technique named Optimization Options Reference (OOR) is implemented to gray scale pixels image.There are a lot of optimization options in MATLAB software function and for this experiment, DiffMaxChange (Maximum change in variables for finite differencing) option is used. From pixels value, we find the natural shape. This shape corresponds to the maximum of a certain energy function computed from the surface position and squared norm. Then we will find the height of the optimized surface at a finite number of points.

Gradient and Mesh algorithm used to resize the matrices (pixels value) into vectors. Two vector arguments replacing the first two matrix arguments, length(x) = n and length(y) = m where [m,n] = size(Z). A matrix X whose rows are copies of the vector x, and a matrix Y whose columns are copies of the vector y. The pair of matrices can evaluate used MATLAB's array mathematics features.

III. Results And Discussion

In this section, every result below is specific for EEG signal from one sample from Fp2 probe (right channel). From the results below, we can see the EEG signal in three different dimensions which are in one dimension (1D), two dimension (2D) and three dimension (3D) signals.

A. *Preprocessing*

In this section, results have been shown are from preprocessing process. Figure 3 shows an example of raw EEG signal for one sample from Fp2 which is maximum value is 180μV. The EEG data is filtered using band pass filter in time domain plot and shown in Figure 4 with 256 Hz frequency sampling. This can eliminate noise during capturing data for EEG. The artifacts occur in raw data when the volunteers blink his or her eyes and this artifact must be removed. The maximum value EEG data after filtering is 100μV.

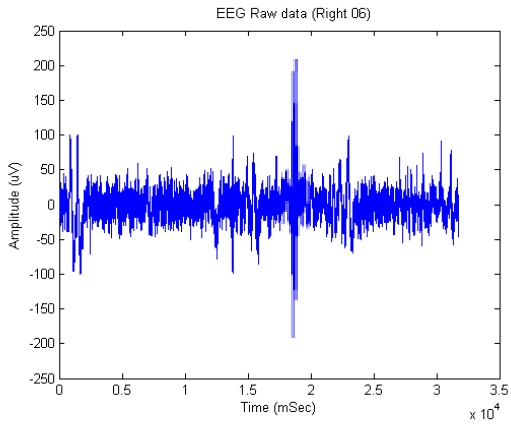

Figure 3. Raw EEG data in time domain one sample

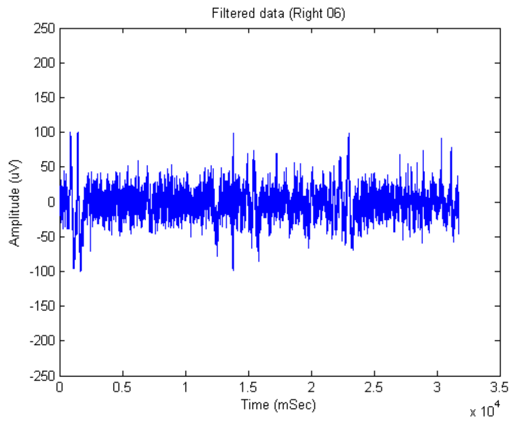

Figure 4. Filtered EEG data in time domain one sample

B. *Two dimension data (Spectrogram)*

This section shows result for two dimensions. Figure 5 shows spectrogram in time frequency domain. The spectrogram is generated by STFT. STFT used to analyze the amplitude value from filtered signal to color scheme and the explanation has mentioned previously.

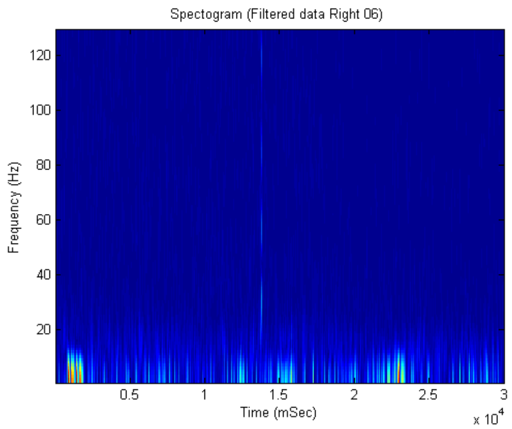

Figure 5 Spectrogram image one samples

C. Three dimension (3D)data/ signal

The RGB spectrogram in Figure 5 converted to gray scale spectrogram or image. Gray scale image is also called intensity image. The gray scale represents intensities within some range in pixel values which are 0 (black) to 255(white).

Figure 6 shows the pixels value of gray scale spectrogram and this pixel value will implement using optimization technique named Optimization Options Reference (OOR). This pixel values are refer to one part of spectrogram.

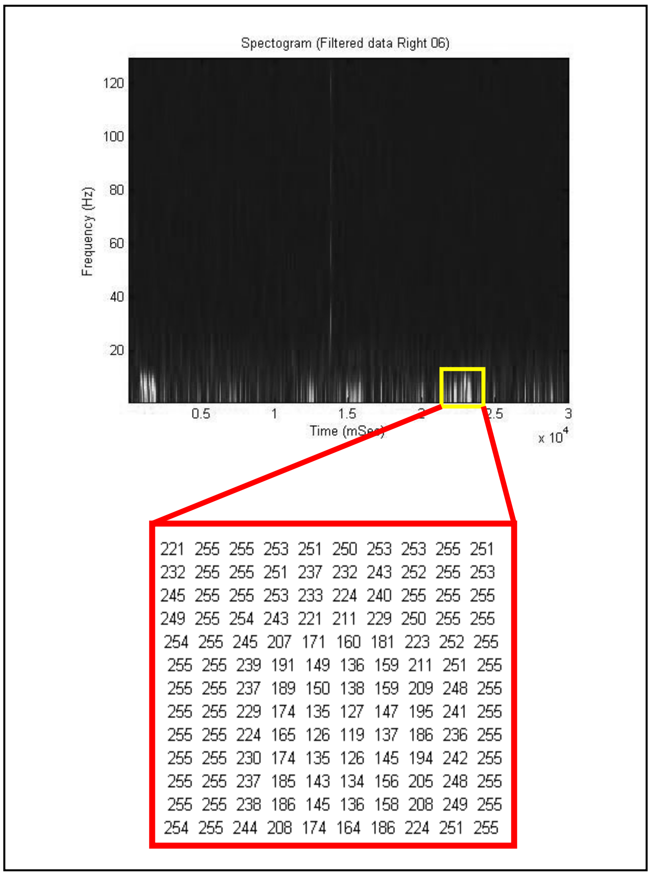

Figure 6. Pixel value for optimization for gray scale spectrogram

Figure 7 shows 3D signal for brain signal. The result in Figure 6 has been implemented using Mesh and Gradient to produce 3D signal for brain signal. This 3D signal shows maximum value is 1000 dB/Hz which is in circle.

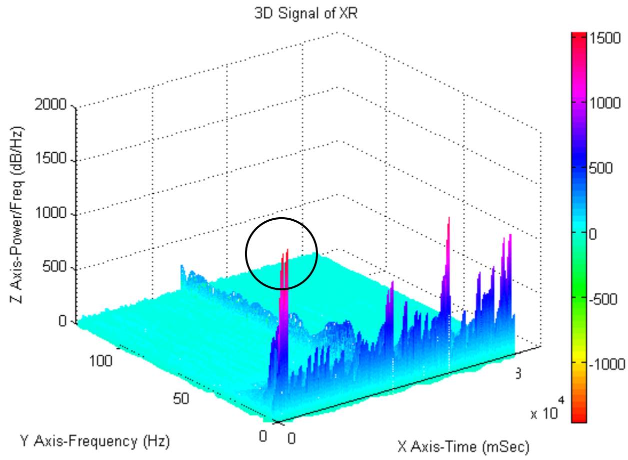

Figure 7. 3D signal for brain signal one samples

Through observation for 1D data for EEG in Figure 4, we can see the amplitude as a dependent parameter correspondent to the time as an independent parameter. However for 2D data in Figure 5, the frequency as a dependent parameter is corresponding to the time as an independent parameter is represented. Only two parameters relationship can be observed in 1D and 2D data.

For 3D data or signal in Figure 7, the relationships between three parameters (time, frequency and magnitude power) are clearly presented. Time and frequency are two dependent parameters correspond to power as an independent parameter. Besides that, Power Spectral Density (PSD) displayed clearly compared to the spectrogram in colour representation. The maximum of PSD value (in circle) and the spectral of power for each time and frequency also clearly presented. Therefore, we can get more information and this is become the advantages of EEG 3D data/signal compare to 1D and 2D data. All the advantages, we can highlight the significant of this technique.

IV. Conclusion

In this paper, we introduce methods to produce 2D and 3D data from 1D data/signal for EEG. Firstly, the raw EEG data in 1D must be preprocessing using signal processing methods. Then, we produce 2D data in spectrogram image through STFT. Some image processing methods has been implemented to produce 3D data from 2D data of EEG. The information and relationship between parameters in 3D data/signal has become the advantage and significant to the brainwave field research. From 3D data/signal, we can extract more features compared to one dimension (1D) and two dimensions (2D). This feature extraction will be done in next stage of experiment.

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