

Analysis and processing EMG signals using Simulink

Gia Hoang Phan

Institute of Engineering and Technology, Thu Dau Mot University, Binh Duong Province, Vietnam,

phangiahoang@tdmu.edu.vn

Abstract: Many applications, such as brain-computer interfaces, sleep monitors and intelligent alarms, mood monitors, and other similar ones, use real-time analysis and processing of electroencephalography (EEG) data. This study was carried out using MATLAB Simulink to perform real-time analysis and processing of single and multi-channel EEG data by real-time classifying them into brain wave components: alpha, beta, delta, and theta, and real-time calculating the energy ratio of each brain wave component in real-time. We used basic blocks from the Simulink basic library and signal processing blocks from the DSP System Toolbox to construct our model. Our model has four main functions: plotting and pre-processing data, classification of brain wave components, calculation of energy ratios, and visualization of results. After connecting and configuring the settings of the blocks, we were able to finish our model. We then used single-channel EEG data to simulate the model and categorized the data in real-time into four different brain wave components: alpha, beta, delta, and theta. Through this research, we have developed a whole system for real-time analysis and processing of EEG signals, which may be utilized in various applications such as brain-computer interfaces, sleep monitors and intelligent alarms, emotion monitors, and so on.

Keywords: *EEG, electroencephalogram, brain wave component, Simulink, real-time, processing*

I. Introduction

I.1 Electroencephalography (EEG) and brain wave components

In our brain, the transmission of information between neurons is the source of our ideas, emotions and actions. Brain waves are produced by electrical impulses from nerve blocks that communicate with one another are coordinated with one another. When triggered or impulsed by other nerve cells, neurons in the cerebral cortex, cerebral hemispheres, and cells in the central nervous system structure can produce electricity. There are many synapses in the cerebral cortex, each generating the potential for excitement and inhibition once a synapse is formed. Combining cell potentials with synapse potentials will result in the production of the combined potential, which will be represented externally as potential brainwave oscillations.

Modern research has also shown that a live electric current powers every person. The source of electricity is the part of the brain where neurons are concentrated the greatest. Brain waves are produced by the brain's electrical activity and are split into five components: beta, alpha, theta, delta, and gamma. Our brain waves fluctuate in response to what we do and how we feel. For

example, the presence of slow brain waves (Delta waves) makes us feel weary, sluggish or slowed down.

I.2 Simulink and DSP System Toolbox

Simulink (Simulation and Link) is a MATLAB tool that allows users to simulate, analyze, and create natural systems for continuous, linear, or nonlinear objects, as well as logical event systems. It is a must-have for anybody who works with MATLAB (such as a manufacturing process)...

Construction of block diagram models from function module blocks is accomplished by "Clicking" and "Dropping" the blocks into the design window, followed by connecting the blocks and determining suitable parameters for each block. The last stage is running the model, evaluating the results, and making any necessary adjustments to get the desired outcomes. Simulink can communicate with MATLAB via several different blocks. The findings are returned to MATLAB in the Workspace area, where they may be further processed. MATLAB programs and mathematical expressions may also be put into the Simulink graphical model using the Simulink programming language. By simulating the system and seeing its timely reactions to different input signals, we may observe the system's timely responses to various input signals.

MATLAB and Simulink users may build, model, and evaluate signal processing systems using the DSP System Toolbox TM. It includes algorithms, applications, and scopes for signal processing systems design and simulation. Consequently, it is capable of simulating real-time digital signal processing systems for communications, radar, audio, medical equipment, the Internet of Things, and other uses.

DSP System Toolbox can design and analyze FIR, IIR, multi-rate, multistage, and responsive filters, among other types of filters. It can send signals from variables, data files, and network devices to build and test the system. Visualization and measurement of flowing signals are made possible by blocks such as Time Scope and Spectrum Analyzer. The DSP System Toolbox includes a system tool that facilitates the development of C and C++ code. Also included is the ability to model fixed-point data with bit accuracy and create HDL code using filters, FFT, IFFT, and other algorithms.

II. Methodology

II.1 Simulink blocks for EEG signal processing

We used basic blocks from the Simulink basic library and signal processing blocks from the DSP System Toolbox to construct our model. Our model has four main functions: plotting and pre-processing data, classification of brain wave components, calculation of energy ratios, and visualization of results.

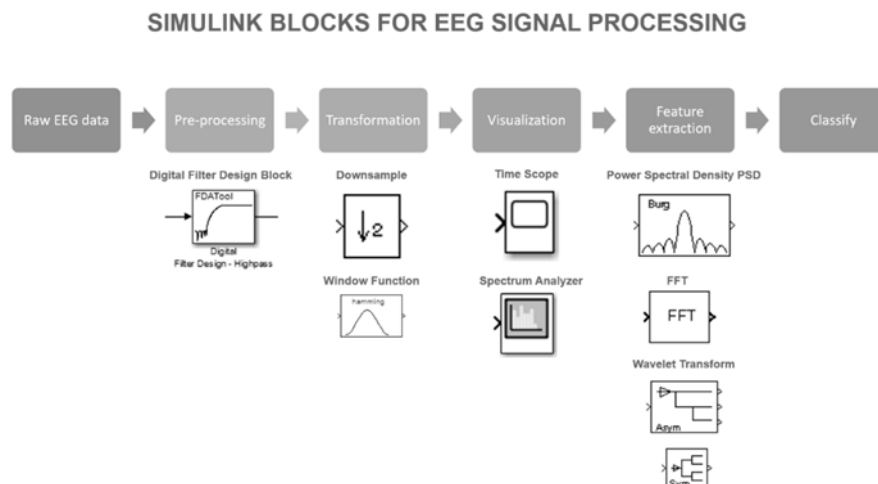


Figure 1:Processing EMG signals using Simulink

Pre-processing blocks.

Digital Filter Design Block.

It is possible to build and evaluate FIR, IIR, multi-rate, multi-stage, and responsive filters using the Digital Filter Design block. The Digital Filter Design block is used to design and execute digital filters. Aside from that, you may filter single or multichannel signals using filters that have been created by the tool. Specifically, the Digital Filter Design block is intended to simulate the digital behavior of your filter on floating-point systems such as personal computers or digital signal processors (DSP).

Transformation blocks.

Up Sample/ Down Sample Block.

Sample blocks that are used to resample input at greater rates by adding zeros or resample input at lower rates by removing samples are called Up/Down sample blocks.

Window Function Block.

It is necessary to utilize the Window Function block to calculate and apply the window to the input signal. Before anything else, the block generates a window vector by sampling a window given by the Window type argument. You may choose the proper window type once you have determined the filter's specific needs. For example, Rectangular, Barlett, Hann, Hamming, Blackman, and so on are defined by two basic parameters: size and shape. In addition, peak approximation error and the width of the main lobe are also measured.

Feature-extraction blocks.

PSD (Power Spectral Density) Block.

The PSD block will calculate the PSD power spectrum by different methods, including: Burg, Cov AR, Mcov AR, Yule AR

IFFT/FFT ((Inverse) Fast Fourier Transform) Block.

The FFT block performs a fast Fourier transform (FFT) over the first dimension of the input array N-D, which is the unit of measurement. The FFT implementation used in this block is one

of two potential options. Choose between deploying using the FFTW library or deploying using the Radix-2 algorithms, depending on your needs.

DWT (Discrete Wavelet Transform) Block.

It is possible to divide signals into subbands with narrower bandwidths and slower sample rates using the discrete wavelet transform (DWT) of the input signals. To get the results at the output, we may choose between wavelet families (Haar, Daubechies, Symlets, and so on) and the sequence in which the wavelet transform is performed.

Analyzer, visualization, calculation blocks.

Time Scope/ Scope Block.

The Time Scope Block and the Scope Block are used to show and evaluate signals produced during simulations and record signal data to MATLAB for further analysis. They all show time-domain signals and perform the same functions, although they have a different default configuration than one another. When it comes to discrete-time processing, the Time Scope is most often employed, and the Scope is optimized for broad time-domain simulation.

Spectrum Analyzer Block.

Spectrum Analyzer block displays frequency spectrum of signals. It can be used in models running in different simulation modes: Normal, Accelerator, Rapid Accelerator, and External simulation mode.

II.2 Build Simulink block diagram model

Following the selection of suitable blocks, we linked these blocks together and calculated the required parameters for each connected block. Thus, the following four primary functions of our model are implemented as four block-groups of sequential operation to real-time process the EEG data into our result: plotting and pre-processing data, brain wave components identification and classification, energy ratio calculation, and visualization of the resulting data.

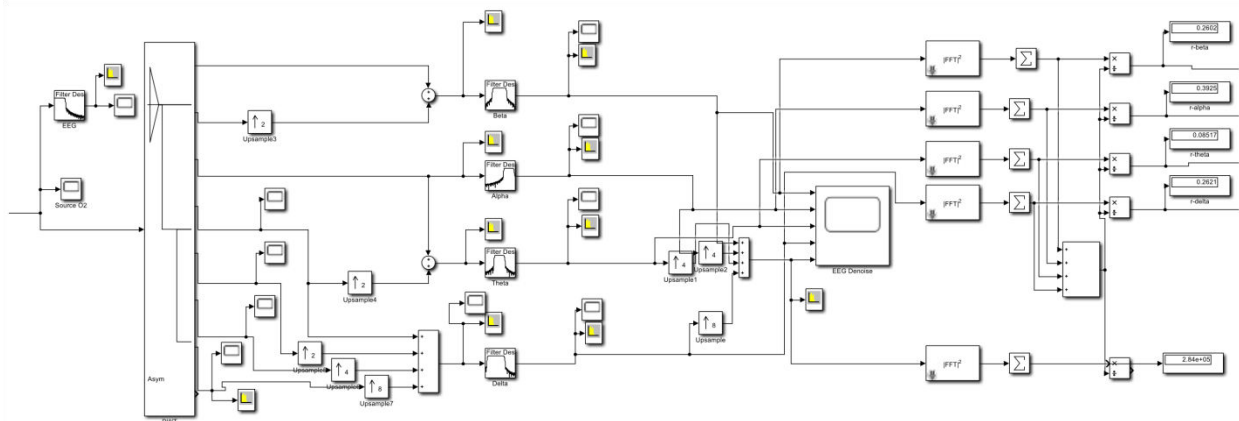


Figure 2:Real-time EEG signal processing using Simulink block diagram model

III. Results

After connecting and configuring the settings of the blocks, we were able to finish our model. Real-time classification of EEG data into four brain wave components: Alpha, Beta, Delta, and

Theta was performed while simulating the model with single-channel EEG data. The energy ratio of each brain wave component was determined while simulating the model with single-channel EEG data.

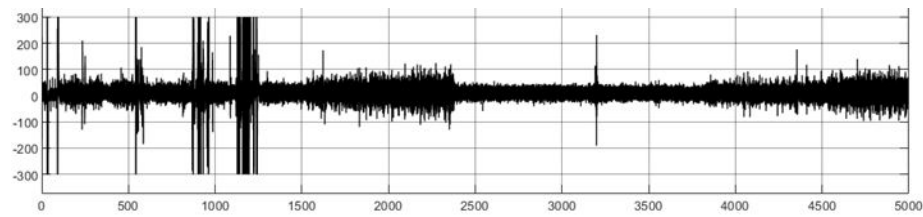


Figure 3:Input single-channel EEG data

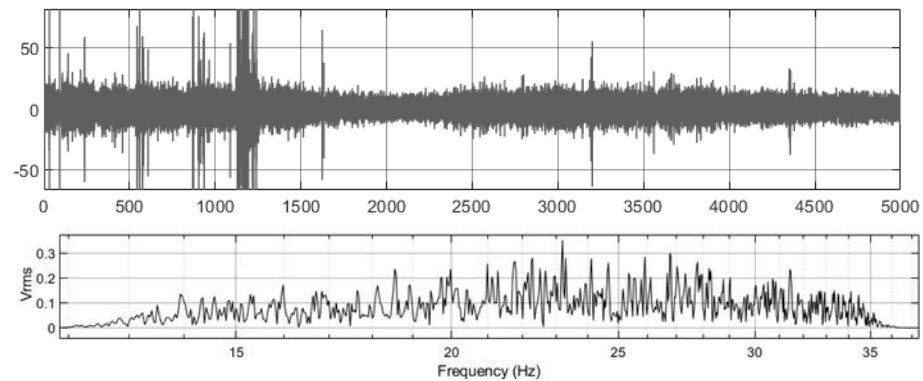


Figure 4:Beta wave component and frequency spectrum

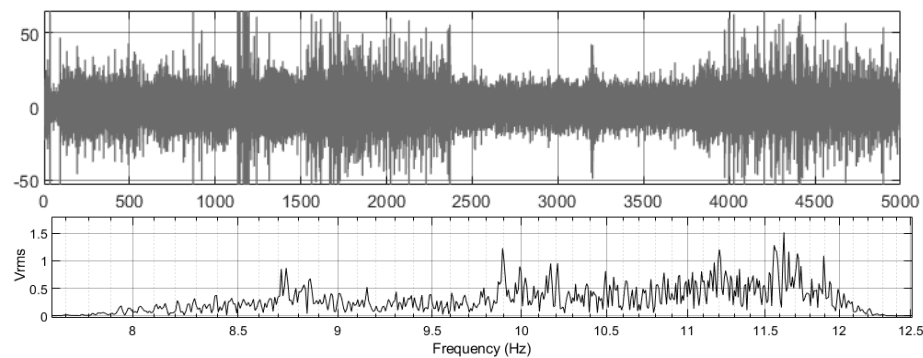


Figure 5:Alpha wave component and frequency spectrum

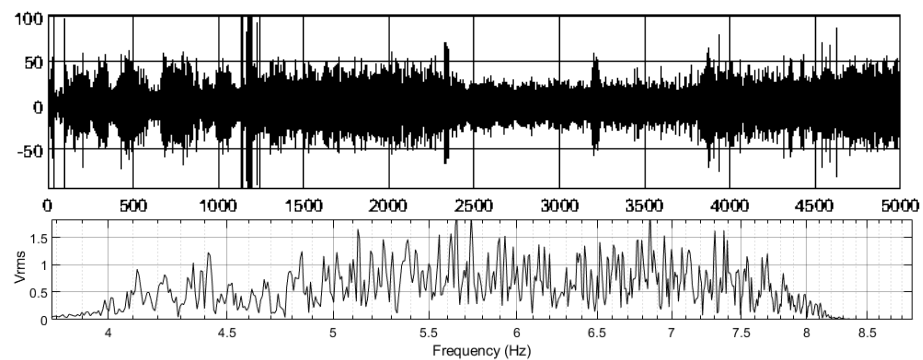


Figure 6:Theta wave component and frequency spectrum

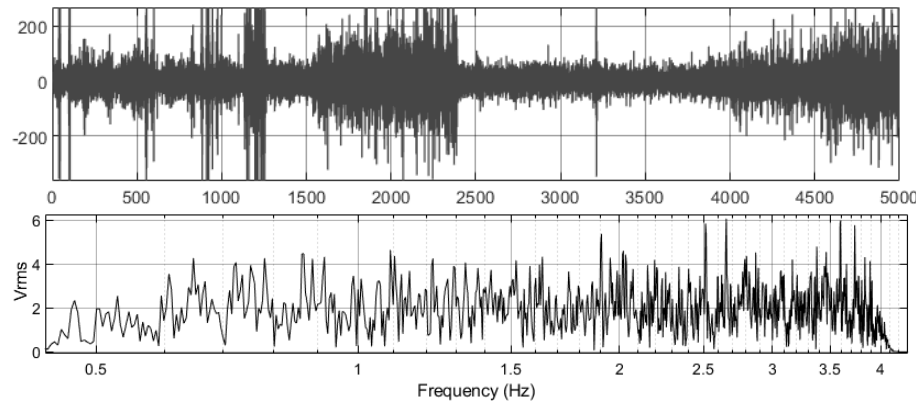


Figure 7:Delta wave component and frequency spectrum

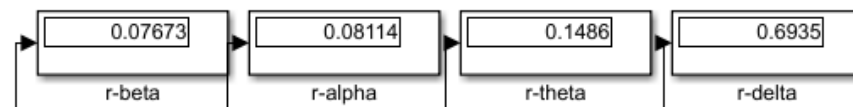


Figure 8:Energy ratio of each brain wave component

IV. Conclusion and Discussion

Through this research, we have developed a whole system for real-time analysis and processing of EEG signals, which may be utilized in various applications such as brain-computer interfaces, sleep monitors and intelligent alarms, emotion monitors, and so on.

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