ISSN(Online) : 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 4, April 2016

Real Time System to Detect Human Stress Using EEG Signals

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ABSTRACT*:* EEG (Electroencephalogram) signal is a neuro-signal which is generated due the different electrical activities in the brain. Different types of electrical activities correspond to different states of the brain. These signals can be captured and processed to get the useful information that can be used in early detection of some mental diseases. Raw EEG signals are captured by using Neurosky Mindwave EEG headset and sent to an android application via Bluetooth. The application generates a CSV file which is exported to MATLAB for further processing. FFT is used to convert the signal from time domain to frequency domain and Butterworth filter is used to extract various frequency bands like alpha, beta, delta and theta. For each of these frequency bands, Relative Energy Ratio (RER) in terms of Energy Spectral Density is calculated which indicates the dominant frequency band and the corresponding stress level.

KEYWORDS*:* EEG, Neurosky Mindwave, Energy Spectral Density, Relative Energy Ratio, Spectral Centroid

I. INTRODUCTION

Stress is generally defined as response of a person to the surrounding conditions or pressures. Stress is an integral part of modern life style. If ignored, stress can lead to chronic mental illness and diseases. Hence it is important to detect stress at an early stage and take appropriate measures. Mental stress can be cured through counselling and therapy. But it requires active participation of the person seeking counselling. This may not be possible in some cases when a stressed person is not able to express himself frankly, which makes the job of a counsellor difficult. This problem can be solved by recording and analyzing EEG signals.

EEG signals are nothing but voltage levels generated by neurons inside the human brain during mental or physical activities. These signals are captured using equipments with multiple electrodes usually available in hospitals. Electrodes are placed at different positions on the scalp, using some standard techniques, to capture the signal.

The aim of this experiment is to develop a portable, inexpensive and easy to use real time system for capturing and analyzing EEG signals to detect stress level. Section 1 gives an introduction on how EEG signals can be used in detection of stress. Section 2 contains literature survey. Section 3 contains the implemented system for stress detection. Section 4 is the results section illustrating the screenshots and other information and Section 5 includes conclusion. Section 6 includes future scope.

II. LITERATURE SURVEY

Rather than implementing the questionnaires based method such as Cohen's Perceived Stress Scale, Stress Response Inventory and Hamilton Depression Rating Scale to detect the level of stress, use of feature extraction techniques to extract required features from EEG signals also offers a good alternative. For example, Fast Fourier Transform (FFT), Discrete Wavelet Transform (DWT), Discrete Cosign Transform (DCT) etc. can be used for feature extraction before classifying the data. Sulaiman et al. [8] proposed a combination of EEG Asymmetry and Spectral Centroids techniques to detect unique pattern of human stress. Spectral Centroids technique was widely used in speech and audio recognition

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because of its robustness to recognize the dominant frequency [9-11]. Poulus et al. [12] used EEG spectral power and mean frequency of Alpha band as a feature to NN (Neural Network) in order to identify person's characteristic. Also, k-NN classifier was used to detect and classify human personality and characteristics from the EEG signal pattern when listening to music [13-16].

III. METHODOLOGY

Methodology of the implemented system is illustrated in Figure 1. It shows the flow of operation of the system. The first phase shows the data collection process. The data is gathered using an android application. This data is then exported to MATLAB environment for further processing and analysis.

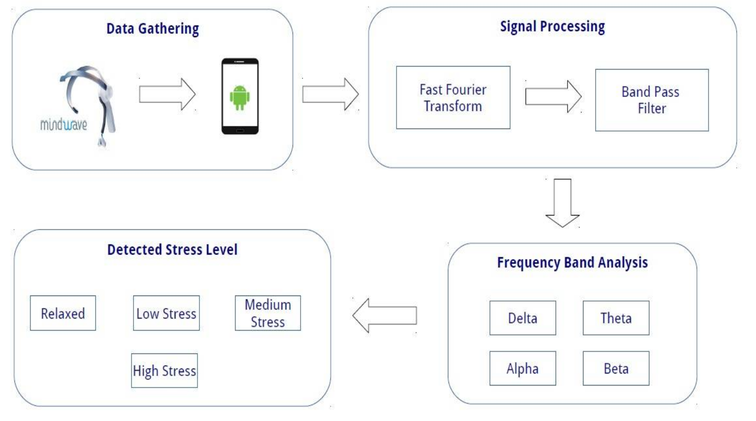

Figure 1: Methodology of the Stress Analyzer system

A. Data Gathering

The Neurosky Mindwave [2] is a consumer grade single electrode EEG headset. It communicates with computer or smart phones via Bluetooth using ThinkGear communication protocol. The data consists of raw EEG values in microvolts. Sampling rate of this device is 512 Hz. In this experiment, EEG headset captures data and sends it to an Android application, which is then stored in a CSV file. This file can be shared via email, Bluetooth and WI-FI direct. For the development of android application, ThinkGear API was used. Data was collected from various subjects while performing different tasks like counting numbers in reverse manner, listening to instrumental music etc.

B. Signal Processing

The CSV file generated by Android application is exported to MATLAB environment for further processing.

1) *FFT*: A Fast Fourier Transform converts a signal from its original domain (in this case, time) to a representation in frequency domain. FFT is calculated as follows:

$$X_k = \sum_{n=0}^{N-1} x_n e^{-i2\pi k \frac{n}{N}} \qquad k = 0, \ldots, N-1.$$

Power spectrum is generated by calculating square of FFT.
Figure 2 shows the process of converting a signal from time domain to frequency domain. Frequency domain is needed because, it is possible to mathematically represent the signal when it is in frequency domain. This mathematical representation is necessary for processing the signal.

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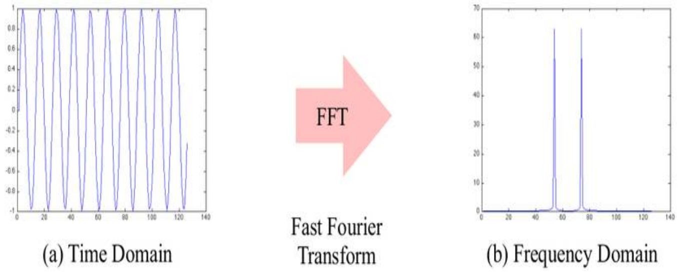

Figure 2: Fast Fourier Transform

2) Butterworth Bandpass Filter: Butterworth filter is a type of signal processing filter designed to have as flat a frequency response as possible in the passband. It is used to extract different frequency bands such as Delta, Theta, Alpha, Beta and Gamma. The following function is used to design and implement Butterworth filter in MATLAB*:*

[b a] = butter(n, [f1 f2], ”bandpass”)
Data_out = filter(b ,a, Data_in)
where,

[b, a] = filter coefficients
n = order of the filter(n=1)
[f1 f2] = frequency range
Data_in = power spectrum

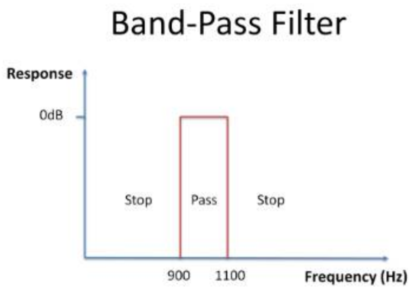

Figure 3: Bandpass filter

C. Relative Energy Ratio(RER)

Energy Spectral Density (ESD) is calculated by dividing the area of the power spectrum by frequency range. ESD is selected for feature calculation because it covers overall energy distribution for each frequency band [1].

RER is used to observe the changes in EEG frequency bands. RER is calculated for each frequency band as follows:

Total power = $ESD_\alpha + ESD_\beta + ESD_\theta + ESD_\delta + ESD_\gamma$

RERα = $\log_{10}$ (ESDα/Total Power)

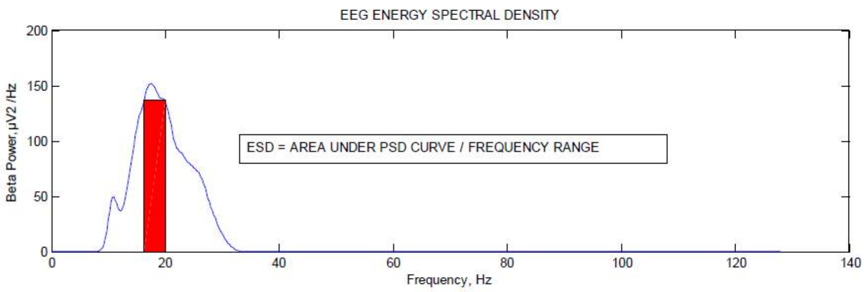

Figure 4 : Energy Spectral Density

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D. Stress Level

The frequency band with the highest value of RER is considered to be dominant. The following table shows different stress levels corresponding to different frequency bands:

Table 1 : Frequency bands

Dominant frequency band	Frequency range(Hz)	Stress level
alpha	8 -12	Relaxed
Low beta	12-15	Relaxed
Medium beta	16-20	Low
High beta	21-30	Medium
gamma	31-100	High

IV. RESULTS

This section includes screen shots of dekstop application developed in MATLAB and android application that is used to acquire EEG signals from NeuroSky MindWave and send the data to another machine for further processing. Figure 5 shows the screenshot of android application.

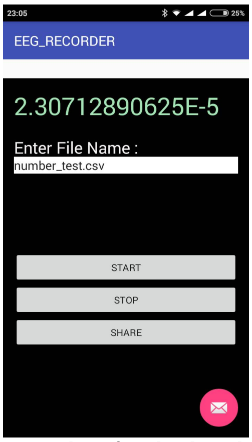

Figure 5: Screenshot of Android Application

Figures 6 shows the graph of the raw signal that has been received from the android applicatioin.

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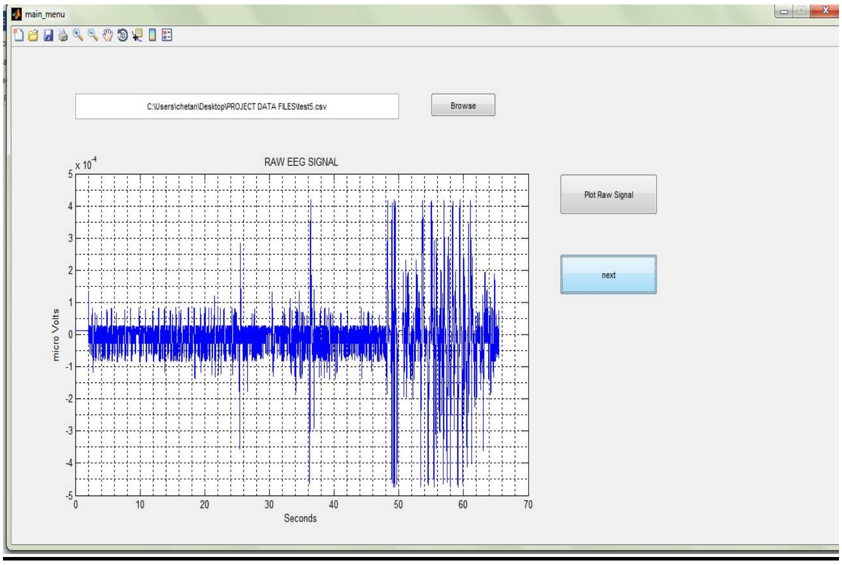

Figure 6: Graph of Raw EEG signal

Figure 7 shows the graph of the signal after taking Fourier transform of the raw EEG signal. This coverts the original signal that is in time domain to frequency domain.

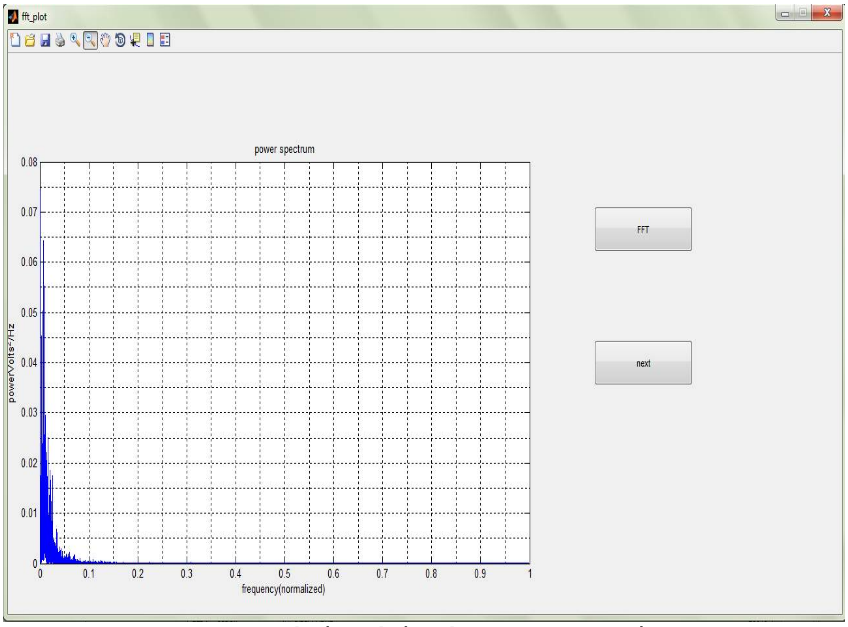

Figure 7: Graph of signal after taking its Fourier Transform

Once the signal in frequency domain is obtained, the signal is then split into various bands such as delta, theta, alpha, low beta, medium beta, high beta, gamma which is shown in Figure 8.

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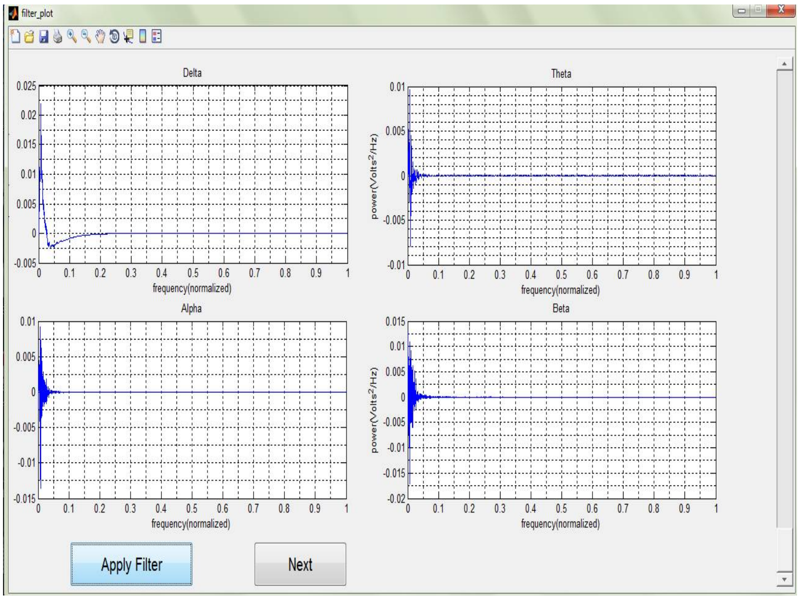
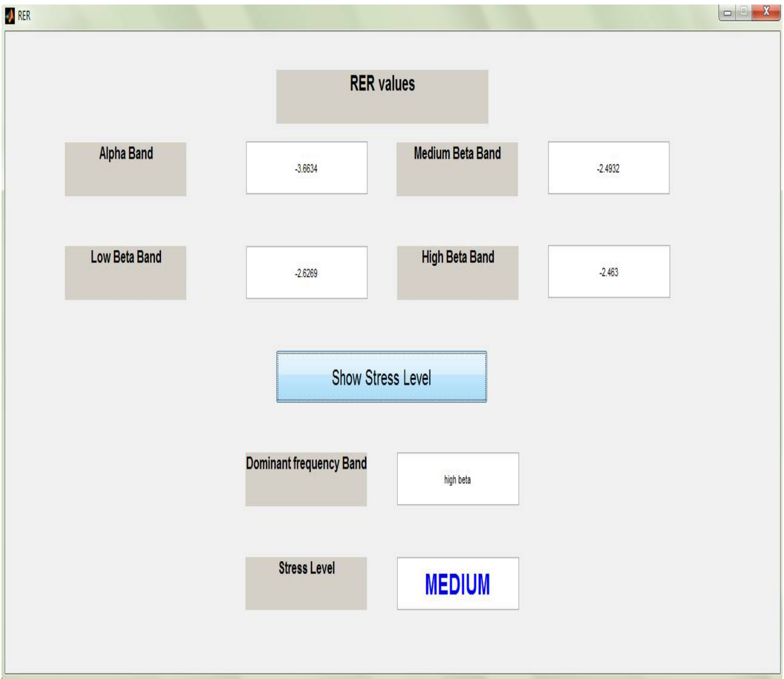


Figure 8: Splitting of Various frequency bands

Figure 9: Calculation of RER and identifying stress level

Further, RER in terms of ESD is calculated for each frequency band and the dominant frequency band is determined and stress level is identified accordingly. This is shown in Figure 9.



The calculated RER for various scenarios and the identified stress levels can be seen in Table 2.

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Table 2**: RER values and corresponding stress levels for various scenarios**

SUBJECT	ACTIVITY	RER(α)	RER(β_{low})	RER(β_{medium})	RER(β_{high})	STRESS LEVEL
1	Closed Eyes	-3.571	-3.8417	-5.7607	-4.6889	RELAXED
2	Listening Instrumental Melody Music	-1.4077	-1.3949	-1.3888	-1.3948	LOW
3	Reverse Number Counting	-3.0944	-3.2657	-2.9189	-2.8661	MEDIUM
4	Multitasking	-3.6634	-2.6269	-2.4932	-2.463	MEDIUM
5	Normal Activity	-1.0383	-1.0288	-1.0302	-1.0443	RELAXED
6	Subjects Before Exam	-3.164	-3.2736	-3.3755	-2.2937	MEDIUM
7	Subjects After Exam	-1.7849	-1.7165	-1.736	-1.7519	RELAXED
8	Sleep state	-1.0882	-1.0817	-1.0834	-1.0926	RELAXED

V. CONCLUSION

The paper shows the methodology of the Stress Analyzer system. It shows the simplicity of the system. It can be concluded from the paper that a portable and affordable alternative to the traditional bulky and expensive EEG analysis system can be developed. The system thus can be used as a personal health care system.

VI. FUTURE SCOPE

Future work aims to use other feature extraction techniques such as Discrete Wavelet Transform (DWT) [4], Discrete Cosine Transform (DCT), etc. and classification algorithms such as KNN, LDA, SVM, etc. which can increase the accuracy of the output. Automation of the system can make it more user friendly, which can be achieved by computing the analysis of the EEG signal on cloud and getting the results back on android application.

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