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Prediction of Disorder of Brain using EEG Signal Processing in MATLAB GUI Platform

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***Abstract*— Electroencephalography (EEG) records electrical activity of the brain. In this paper, a user-friendly platform using MATLAB with GUI (Graphical User Interface) is designed for analyzing EEG data and spotting patterns in it for fast diagnosis purposes. At first the noise is omitted by using a Butterworth low pass and FIR bandpass filter respectively and then explored to determine power spectral density. Several parameters (mean, variance, skewness and kurtosis) are extracted from the diagrams of power spectral density and contour of the peaks. It is seen that mean is high and skewness and kurtosis are low for affected brain. The relationship can be more useful to find out the presence of any disorder in brain.**

Keywords— EEG signal; MATLAB with GUI; Butterworth filter; Bandpass filter; PSD; Spectral diagram; Mean; Variance; Skewness; Kurtosis

I. INTRODUCTION

Human brain processes information of different activities of the body. This part encloses billions of neurons that change the flow of electrical currents across the membranes throughout the processing. Some electrodes attached to the surface of the scalp records the potential difference between the electrodes which is called electroencephalography (EEG). Several works has been done to remove noise from EEG signal to increase accuracy in the detection of brain disorder. Many techniques have been developed for helping in the diagnosis of such disorder. VO-NGOC et al. [1] developed a procedure to calculate correlation functions for the EEG signal. Power spectral analysis of EEG has been done to detect epilepsy or disorder of human brain using different techniques such as Welch method, SVM, wavelet transform [2-4]. Some other techniques like empirical mode decomposition (EMD), empirical wavelet transform (EWT) are also proposed to detect epileptic seizure accurately [5-6]. In the progress of signal analysis, Li et al. [7] proposed an adaptive and localized time-frequency representation in EEG signals by means of multiscale radial basis functions (MRBF) and a modified particle swarm optimization (MPSO) to improve both time and frequency resolution simultaneously. Another researcher named Handojoseno et al. [8] analyzed univariate and multivariate EEG features by both Fourier and wavelet analysis in the confirmation and prediction of FOG (Freezing of Gait). Cetin et al. [9] proposed a Matlab-based GUI system based on artificial neural network (ANN) to detect normal and epileptic EEG signals. Autoregressive model algorithms are used to calculate coefficients such as epoch number, learning rate etc. Only classifier performances are emphasized from the analysis of EEG signal. But there is no information about the condition of a patient.

In this work, a GUI (Graphical User Interface) platform using MATLAB is developed to identify the presence of disorder in brain within short time and gives a clear comparison between affected and normal brain. Artifact due to EOG (Electro-Oculogram) gets mixed up with EEG signal that is removed by using bandpass filter. From spectral plot and statistical parameters (mean, variance, skewness and kurtosis), the status of brain is predicted.

II. METHODOLOGY

The overall methodology for predicting brain disorder consists of EEG data collection from a database for 10 subjects, design of a graphical user interfacing platform through MATLAB tool, and the processing and analyzing those data in the designed platform finally.

A. *Collection of EEG Data*

To carry out the analysis, ten subjects are considered where five subjects have unaffected brain and other five have affected brain. Data of these subjects are collected from a database which is publicly made available by Dr. Ralph Andrzejak [10]. The sampling rate is 173.61 Hz with 4097 samples in total and the duration of each signal is 23.6 seconds.

B. *Design of a GUI platform in MATLAB*

A GUI platform in MATLAB tool is designed so that the platform acts as an EEG signal monitor. The designed platform has different types of buttons such as EEG Signal, Filtered Signal, PSD, the contour peaks and statistical parameters of the signal in order to analyze the signal by any person without having the knowledge of programming. When these buttons are pressed then they will be activated to complete their corresponding functions. The button named EEG Signal load the original EEG signal. As the original signal is noisy, Filtered Signal removes the noise to make the analysis more effective with increased accuracy.

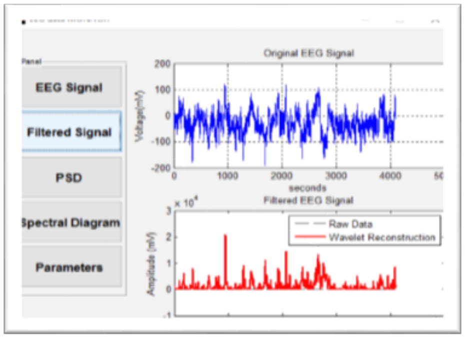

Fig. 1. Designed GUI platform to process EEG signal.

Fig.1 represents the designed GUI platform for processing EEG signal. For normal brain activity of subject 2, the original and filtered EEG signals are displayed.

C. Processing and Analyzing EEG signal

For the purpose of analysis, the collected data is stored in a Microsoft Excel which is saved as .xls file. Then the stored data is loaded in the designed GUI platform using MATLAB tool for processing and extracting some features.

1) Filtering of EEG signal: The signal is filtered to extract some features in frequency domain or remove undesirable artefacts like EOG, EMG etc. Finite impulse response (FIR) filters are suitable for biomedical signal processing because these filters give output which is proportional to input. At first, butterworth lowpass filter with order 10 at cutoff frequency 0.1 Hz is used to remove the EOG artefact from noisy signal. Then the signal is again filtered using 9^{th} order FIR Bandpass filter to improve the baseline having frequency between 1 Hz and 500 Hz. As the filtered EEG signal, x(t) is high ephemeral, wavelet reconstruction method is applied for noise reduction.

The continuous wavelet transform (CWT) provides a time-frequency transform of a temporal signal, $x(t)$, and a basis function or a set of wavelets, $\psi_{a,b}(t)$ to represent the original signal [11]. The CWT is defined as:

$$C(a,b) = \frac{1}{\sqrt{a}} \int x(t) \psi_{a,b}(t) dt \tag{1}$$

where, C(a,b) represents the CWT coefficients at scale a and temporal location b. After wavelet reconstruction, $x_j(n)$ signal is obtained.

2) Estimation of power spectral density: The PSD describes about the distribution of power of signal depending on frequency.

Welch's method is used to estimate power spectra, P_w

$$P_{w(f,N)} = \frac{1}{K} \sum_{i=1}^{K} \frac{1}{L} \left[\sum_{j=0}^{L-1} w(n) x_j(n) e^{-j2\pi n} \right] \tag{2}$$

where, K is number of segments and L is the length of segment. The signal is segmented and weighted by window w(n) with length of L. The window overlapping is used to obtain better undistorted results [12].

3) Statistical Features Extraction: Then signals are further processed to extract different statistical features (mean, variance, skewness, kurtosis) to come to a decision about the condition of subjects.

a) Mean: The mean μ_n represents the average value of all samples of the EEG signal in the analysis.

$$\mu_n = \frac{1}{N} \sum_{n=1}^{N-1} x_n \tag{3}$$

b) Variance: Variance specifies the degree of statistical dispersion of the observations from the mean value.

$$V = \sum_{i=1}^{N} \frac{(x_i - \bar{x})^2}{N-1} \tag{4}$$

where, $\bar{x}$ is average value of the signal.

c) Skewness: The degree of reflection of asymmetry in the histogram of instantaneous power is termed as skewness. The skewness is defined for a signal as,

$$Skew[X] = E\left[\left(\frac{X-\mu}{\sigma}\right)^3 \right] = \frac{E[X^3] - 3\mu\sigma^2 - \mu^3}{\sigma^3} \tag{5}$$

where, μ and σ are the mean and standard deviation respectively. E denotes statistical expectation [13]. If the histogram is symmetrical, the skewness is zero. If the left hand tail is longer, the skewness will be negative. If the right hand tail is longer, the skewness will be positive.

d) Kurtosis: Kurtosis is a measure for the degree of flatness or peakedness in the variable distribution [14].

$$Kurt[X] = \frac{E\left[(X-\mu)^3\right]}{E\left[(X-\mu)^2\right]^2} \tag{6}$$

High kurtosis tends to have a peak near mean and decline rather rapidly. Low kurtosis tends to have a flat top near the mean rather than a sharp peak with heavy tails. The standard normal curve of instantaneous power has zero kurtosis.

III. Results and Discussion

The GUI platform is designed, and different buttons are included to perform different operations. PSD is a button that plots the power spectral density with the variation of frequency to get the distribution of power for each subject. The power spectral density of subject 2 having normal brain activity has been shown in fig. 2.

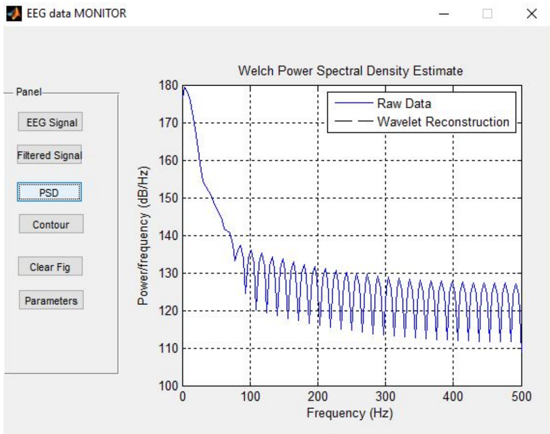

Fig.2. PSD for normal brain activity of S2 in MATLAB GUI.

It is seen that, with the increase of frequency, PSD decreases sharply for normal brain activity.

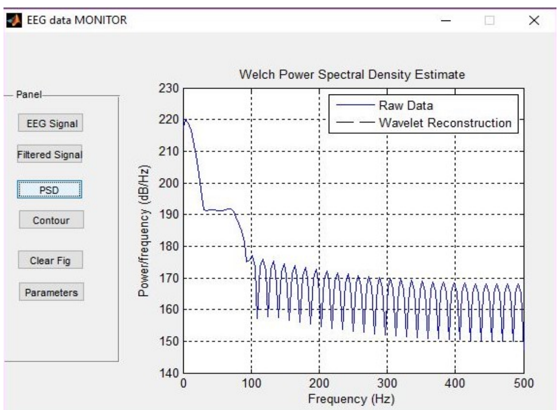

Fig. 3. PSD of S1 having affected brain in MATLAB GUI.

Fig. 3 demonstrates the power spectral density of affected brain for subject 1. It is observed that, with the increase of frequency, PSD decreases slowly for brain having disorder.

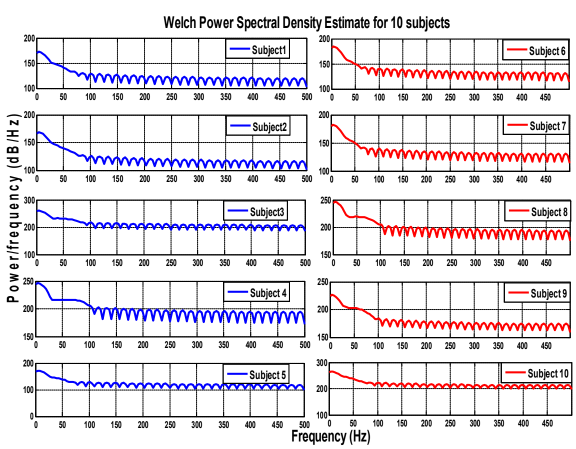

Fig. 4. Power spectral density for ten subjects in MATLAB GUI.

Fig. 4 shows power spectral densities of 10 subjects with respect to frequency. The left column is the PSD of the EEG signals of subjects with non- affected brain. The right column represents the subjects having affected brain. These analyzed diagrams give the clear comparison between normal brain and affected brain. Those subjects with brain disorder have higher PSDs than non- affected subjects. When the Contour button is clicked then patterns for different subjects are obtained. If there is any disorder in brain then the pattern will not be continuous. For the subject having normal brain activity the peaks of contours will be same.

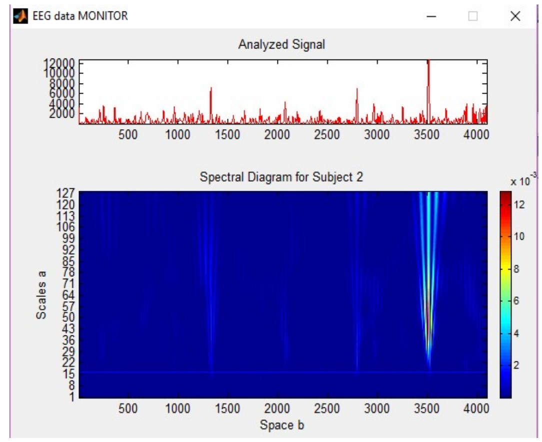

Fig. 5. Spectral diagram of normal brain activity in MATLAB GUI.

The filtered EEG signal and spectral diagram for normal brain activity of subject 2 has been represented in fig. 5. The more density of blue color indicates the less disorder in brain activity.

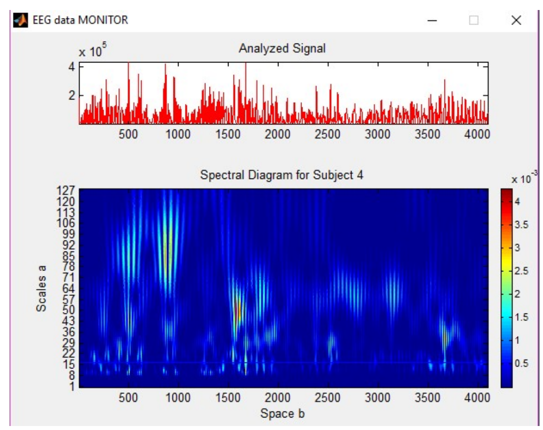

Fig. 6. Spectral diagram of affected brain activity in MATLAB GUI.

Fig. 6 illustrates the filtered signal and spectral diagram of affected brain. In the range of space between 3500-4000, higher peak is obtained and red color appears in the same region which represents the disorder of brain. These spectral diagrams represent the distinct comparison between normal brain and affected brain. Finally the Parameters button is pressed to extract different statistical features (mean, variance, kurtosis, and skewness) for different subjects as shown in fig. 7. Mean, variance, skewness, and kurtosis are the effective statistical features which are able to describe variation of instantaneous power of independent frequency components changed over time.

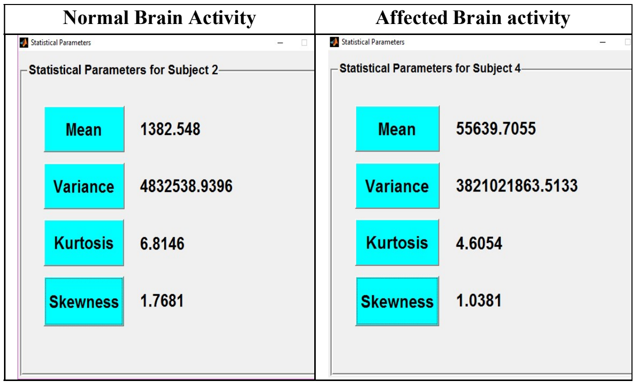

Fig. 7. Statistical parameters of normal and affected brain for S2 and S4.

TABLE I. ANALYZED RESULTS OF EEG SIGNALS

Subjects	**Statistical Parameters**				
	Mean	***Variance***	***Kurtosis***	***Skewness***	***Status***
S1	732.25109	958423.86	6.28277	1.61845	Sound
S2	1382.548	4832538.9	6.8146	1.7681	Sound
S3	760.55799	1230025	6.10753	1.62294	Sound
S4	55639.7055	38210218	4.60547	1.03812	Affected
S5	164416.766	65245479	5.18188	1.77365	Affected
S6	1399.5519	4531829.9	6.83904	1.83543	Sound
S7	637.11056	1116823.5	6.14460	1.74440	Sound
S8	53541.8292	50840025	4.76716	1.27448	Affected
S9	118857.514	18337943	5.08950	1.23617	Affected
S10	17169.990	84669042	5.05027	1.56911	Affected

The analysis of EEG signals for 10 subjects has been shown in the TABLE I. It demonstrates that among different subjects, values of mean, skewness and kurtosis distinguishes between normal and affected brains. The condition of subject is normal when skewness and kurtosis become high along with the mean becomes low. With the decrease of skewness and kurtosis, the disorder of brain increases. The mean value becomes larger for affected brains and turns poor for sound brains. The result provided by the database was that 5 subjects were in normal condition and other 5 subjects were affected by brain disorder. The result found from the designed GUI platform is almost same.

IV. CONCLUSION

A user-friendly platform in GUI platform is designed successfully which is effective for physicians along with researchers for further analysis. Power spectral density and spectral diagram has been obtained along with the extraction of statistical parameters (mean, variance, skewness and kurtosis) in MATLAB GUI within a single click. The results of this work matches with the result provided by the collected database. The platform helps to reduce time consuming calculation. In signal processing, mean is not very useful, since it gives only a compromise value between the two peaks. Further rigorous statistical analysis could be done to ascertain the conditions of brain among different subjects by placing electrodes directly on human body. Similar approach can be explored further for finding syndromes of several neurological disorders.

REFERENCES

[1] B. Vo-Ngoc, K. Furuta, J. M. Langlois, and J. G. Paquet, "A Possible Procedure to Calculate Correlation Functions for the EEG," *IEEE Trans. on Biomed. Eng*., vol. BME-17, pp. 265-267, 1970.

[2] M. Awais, N. Badruddin, and M. Drieberg, "Driver drowsiness detection using EEG power spectrum analysis," in *2014 IEEE Region 10 Symp.*, 2014, pp. 244-247.

[3] H. Meng, L. Jiaojie, L. Guang, T. Xiaowei, and D. Qiuping, "Classification of Normal and Hypoxia EEG Based on Approximate Entropy and Welch Power-Spectral-Density," in *The 2006 IEEE Int. Joint Conf. on Neural Network Proc.*, 2006, pp. 3218-3222.

[4] Z. Zhang and K. K. Parhi, "Low-Complexity Seizure Prediction From iEEG/sEEG Using Spectral Power and Ratios of Spectral Power," *IEEE Trans. Biomed. Circuits Syst.,* vol. 10, pp. 693-706, 2016.

[5] V. Bajaj and R. B. Pachori, "Epileptic seizure detection based on the instantaneous area of analytic intrinsic mode functions of EEG signals," *Biomed. Eng. Lett.,* vol. 3, pp. 17-21, March 01 2013.

[6] B. A and R. B. Pachori, "A multivariate approach for patient specific EEG seizure detection using empirical wavelet transform," *IEEE Trans. Biomed. Eng.,* vol. PP, pp. 1-13, 2017.

[7] Y. Li, X. Wang, L. Luo, K. Li, X. Yang, and Q. Guo, "Epileptic Seizure Classification of EEGs using Time-Frequency Analysis based Multiscale Radial Basis Functions," *IEEE J. Biomed. Health Inform.,* vol. PP, no. 99, pp. 1-12, 2017.

[8] A. M. A. Handojoseno, J. M. Shine, T. N. Nguyen, Y. Tran, S. J. G. Lewis, and H. T. Nguyen, "Analysis and Prediction of the Freezing of Gait Using EEG Brain Dynamics," *IEEE Trans. Neural Syst. Rehabil. Eng.,* vol. 23, pp. 887-896, 2015.

[9] G. Dogali and M. R. Bozkurt, "The detection of normal and epileptic EEG signals using ANN methods with Matlab-based GUI," *Int. J. Comput. Appl.,* vol. 114, pp. 45-50, 2015.

[10] R. G. Andrzejak, K. Lehnertz, F. Mormann, C. Rieke, P. David, and C. E. Elger, "Indications of nonlinear deterministic and finite-dimensional structures in time series of brain electrical activity: Dependence on recording region and brain state," *Physical Rev. E,* vol. 64, pp. 061907, 2001.

[11] A Diery, D Rowlands, T Cutmore, DA James, "Wavelet Analysis of Atrial Electrical Activity," *WSEAS Trans. Syst.*, vol. 3, no.10, pp. 3189-3192, 2004.

[12] P. Welch, "The use of fast Fourier transform for the estimation of power spectra: a method based on time averaging over short, modified periodograms," *IEEE Transactions on audio and electroacoustics,* vol. 15, no. 2, pp. 70-73, 1967.

[13] M. Dyson, F. Sepulveda, and J. Q. Gan, "Localisation of cognitive tasks used in EEG-based BCIs," *Clinical Neurophysiology,* vol. 121, pp. 1481-1493, 2010.

[14] T. Liu, J. Shi, D. Zhao, and J. Yang, "The relationship between EEG band power, cognitive processing and intelligence in school-age children," *Psychology Sci.,* vol. 50, pp. 259, 2008.