Wavelet Domain Extraction of Features from single channel Sleep EEG

Vijayakumar Gurrala, Padmasai Yarlagadda, Padmaraju Koppireddi

Abstract--- ***Sleep is just as important as diet and exercise. Humans spend about a third of their lives asleep. In the large data sets like Sleep Electroencephalogram (Sleep EEG), to do analysis it becomes tedious and time taken. Instead of considering the whole data, considering a few critical features from the signal makes the analysis simpler and the memory requirements are also less, since the analysis could be carried out on digital platform. A feature is a distinguishable sectional property obtained from a portion. Feature extraction depicts the number of feature to be extracted from the signal. Thus the feature extraction plays a pivotal role in the analysis of Sleep EEG. In this work we discussed the decomposition of Sleep EEG signal into required frequency bands and adopted feature extraction techniques of wavelet decomposition method to extract features from Sleep EEG signal by considering single channel EEG.***

Key words: Sleep EEG, Features, Feature Extraction, Wavelet decomposition, CEEMD-AN.

INTRODUCTION

The records of the electrical activity of brain termed as Electroencephalogram (EEG).These recordings are done on the scalp by placing electrodes in different special locations on the scalp. The analysis of EEG leads to determine the state of brain, dysfunction of brain detection of epilepsy or seizures, sleep disorders etc. Humans spend about a third of their lives asleep. The lack of sleep hampers the performance of an individual. Nowadays research is going on the sleep disorders. The diagnosis of sleep disorders done by analyzing the majorly the EEG signal.

Since the recording of Sleep EEG took for several hours, the printed data requires many papers and even the amount of data required to process on digital means is also large. The reduction of data may lead to loss of information. In such cases the concept of features solves the issue [1]. Instead of considering the whole recorded data, extract the required features which subsequently serves the purpose of diagnosis of sleep disorders [2]. In this work we presented methods to decompose the EEG data into several frequency bands and the extraction of features from the frequency bands.

METHODOLOGY: As long as the brain is functioning, the spontaneous activity is continuous. The frequency range for EEG signal is 0 Hz to 50 Hz. According to the activity of brain, the frequency range is sub divided into 5 bands. They are Delta, Theta, Alpha, Beta, and Gamma. Each frequency band constitutes state of brain. The dominance of these bands represents the stages of sleep in Sleep EEG [3,4]. The work flow of determining bands and extraction of features from Sleep EEG is depicted in Fig.1.Any biological signal is contaminated with an unwanted signal called as artifact. Hence the first step in processing of bio medical signals is artifact removal or preprocessing [5]. In preprocessing acquired data is processed for artifact removal and converted into suitable form for the digital processing.

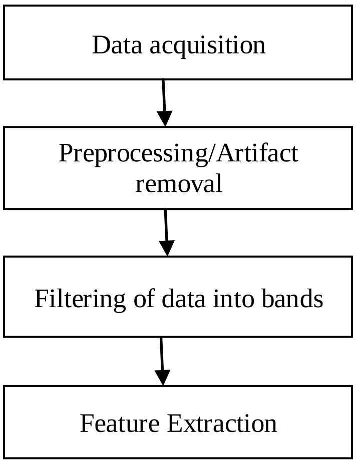

Fig.1.Block diagram of Feature Extraction from Sleep EEG.

The data is acquired by placing electrodes on scalp at different locations called as channels, given10-20 systems. In this work we consider online Sleep EEG database extracted from one channel. However online database is artifact free, we consider Complete Ensemble Empirical Decomposition with Adaptive Noise [6] method to remove artifacts from Sleep EEG data. There is no unique mathematical model for EEG dynamics to integrate the properties of EEG due to its non -stationary nature. But still it can be achieved by statistical concepts. Hence whatever the features we considered, they should give information about the state of brain. In this connection the features are categorized as spatial, spectral and temporal. Spatial features describe spatial location that the relevant signal comes from i.e. specific channel. Specific channel determines signal originating from specific areas of the brain. In this work we consider Fpz-Cz channel data. Spectral(frequency) features describes the power variation in frequency bands.

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Temporal(time) features describe the relevant signal variation with time. Temporal features of Mean(M), Variancr(V) Standard Deviation(SD) and Root Mean Square (RMS) are derived from the Wavelet Decomposition method[4. In this method it uses long time windows for low frequency information and short time windows for high frequency information. Thus Wavelet decomposition gives fine low frequency resolution of the EEG signal [7,8]. The decomposition is shown in the Fig.2.

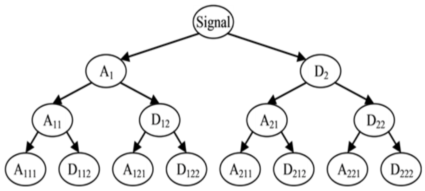

Fig.2.Signal decomposition using wavelets.

The wavelet coefficients can be computed by mother wavelet $\varphi_{s,t}(x)$ as shown in equation(I).where s, $\tau \in$ R, s>0, and R is the wavelet space, while s and τ are the scaling factor and shifting factor respectively.

$$\varphi_{s,t}(x) = \frac{1}{\sqrt{x}}\,\varphi\left(\frac{t-\tau}{s}\right) \qquad \text{(I)}$$

The decomposition is computed by filtering the discrete signal repeatedly up to a predetermined level N. The filter consist of a low pass filter to obtain the approximation coefficient (CA) and high pass filter to obtain the detailed coefficient (CD). After each level of filter, the signal is down sampled by half the sampling frequency in the previous level N-1 since the frequency element is reduced by half. The features are determined from the signal by the equations (II), (III) and (IV).

$$\text{Mean } \mu = \frac{1}{N}\sum_{i=0}^{N-1} x_i \qquad \text{(II)}$$

$$\text{Variance } \sigma^2 = \frac{1}{N-1}\sum_{i=0}^{N-1}(x_i - \mu)^2 \qquad \text{(III)}$$

$$\text{RMS } x_{rms} = \sqrt{\frac{1}{N}(x_1^2 + x_2^2 + \dots + x_n^2)} \qquad \text{(IV)}$$

RESULTS AND DISCUSSIONS: In this work we have discussed the major steps involved in the sleep stage classification by using EEG signal analysis process namely decomposition of the signal into sub bands and feature extraction. The input signal that we have considered is taken from the Physiobank ATM database [9]. It is a sleep EEG signal sampled with a frequency of 100 hertz with 1000 samples per signal which means a sampling interval of 0.01 seconds and lasts for 10 seconds.Fig.3.a and Fig.3.b.shows the considered Sleep EEG signal's and the artifact free signal after processing through the CEEMDAN process.

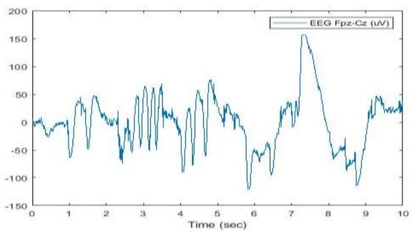

Fig.3.a.Considered Sleep EEG signal (Fpz-Cz channel only).

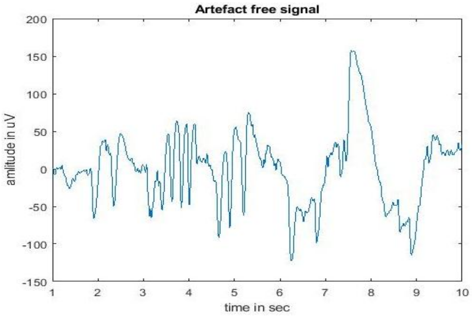

Fig.3.b.Artefact free Sleep EEG signal (CEEMDAN output).

This signal fed to wavelet decomposition and it decomposes the signal into required bands of Delta, Theta, Alpha, Beta, and Gamma.Fig.4.a.shows the signal decomposition in terms of number of samples and Fig.4.b.shows the signal decomposition in terms of its various frequency bands.

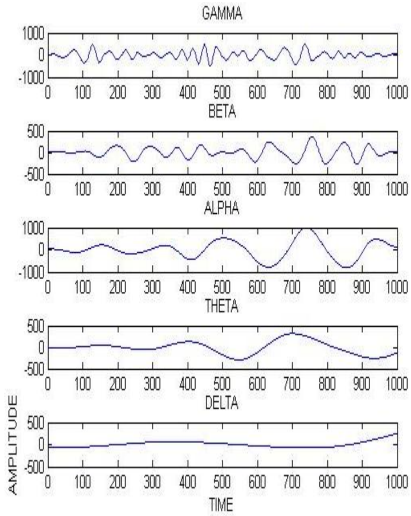

Fig.4.a.Signal decomposition in terms of number of samples.

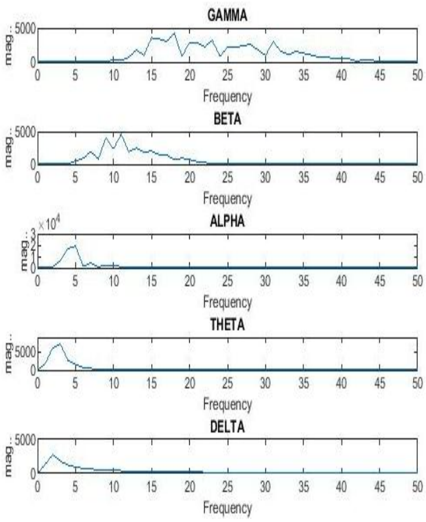

Fig.4.b.Signal decomposition in terms of frequency bands.

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For each frequency sub band the features were obtained and listed in Table.1 and Table.2.

Table.1.Extracted Temporal Features from Sleep EEG considering single channel EEG.

Subband signal	Max	Min	M	V	SD	RMS
Delta	22.540	-6.64	0.526	38.312	6.189	38.589
Theta	29.615	-27.39	-1.27	204.38	14.29	206.01
Alpha	92.828	-76.67	0.559	1.45e3	38.11	1.45e3
Beta	34.611	-25.95	0.034	143.98	11.99	143.98
Gamma	47.018	-46.85	0.031	268.21	16.37	268.21

Table.2.Extracted Spectral Features from Sleep EEG considering single channel EEG.

Sub band signal	Max	Mean	Frequency at which Max occurs
Delta	2.7854e+03	59.2051	2
Theta	7.2069e+03	56.6300	3
Alpha	1.9196e+04	123.0653	5
Beta	4.6129e+03	61.7569	11
Gamma	4.2280e+03	119.1032	18

CONCLUSIONS: In this work, we have implemented wavelet method for the extraction of features in Sleep EEG signal. As mentioned, accurate analysis of these features is important for applications such as disease analysis and brain-computer analysis. The features such as Mean, Standard Deviation (SD) and Root Mean Square (RMS) can be extracted efficiently using Discrete Wavelet Transform (DWT) method due to its high Signal to Noise Ratio (SNR). The extracted features can further be used to generate the classification algorithm for the diagnosis of various sleep disorders. The unique features will cover different EEG characteristics like amplitudes, frequencies, spatial distribution, wave morphology so that we can estimate behavioral and physiological states and even it can be helpful for authentication reasoning problems.

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