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FREQUENCY BAND SEPARATION FOR EPILEPSY DETECTION USING EEG

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Abstract: Epilepsy Detection using EEG requires feature extraction from the acquired signal in specific frequency range of delta, theta, alpha, beta, and gamma. Though some researchers have mentioned the use of DWT decomposition to obtain these bands, the method given is inadequate to achieve these. This paper explicitly describes the method of up-sampling and recombining of several decomposed subbands to achieve the required frequencies.

1. INTRODUCTION

EEG is a non-invasive medical technique useful for the diagnosis of number of brain disorders. Approximately 1% of the world's population suffers from epileptic disorder, a disorder of the normal brain characterized by excessive neuronal activity in the brain [1]. Epileptic seizures are manifestations of epilepsy and are the result of sudden, usually brief, excessive electrical discharges in a group of neurons and that different parts of the brain can be the site of such discharges. The clinical manifestations of seizures therefore vary and depend on where in the brain the disturbance first starts and how far it spreads. They may be localized in certain area of the brain called partial seizures, which can be seen only in a few channels of the EEG recording, or may be involved the whole brain area called generalized seizures, which can be seen in every channel of the EEG recordings.

Over past two decades EEG signal representations based on a Fourier transform has been a common approach. EEG spectrum contains some characteristic waveforms that fall primarily within four frequency bands - delta (0-4 Hz), theta (4-8 Hz), alpha (8-12 Hz), and beta (12-30 Hz). This method has proved quite beneficial for various EEG characterizations, but the disadvantage lies in the fact that fast Fourier transforms (FFT), suffers from large noise sensitivity [2]. Soft-computing methods have been proposed then in the literature for the detection of the epileptic activity in EEG signal [3,4]. Also included is an overview of detection techniques [5]. Methods not so frequently used are template matching and generally used time domain, frequency domain and time-frequency domain methods [6].

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2. PROBLEM DEFINITION

In 1980 a powerful method called the discrete wavelet transforms (DWT) was introduced. Since early days work done for frequency subband separation of EEG signal for epilepsy detection is based only on decomposition of the signal to certain levels. This is followed by feature extraction from these subbands. However the decomposition of each subband does not generally include that peculiar frequency range as defined in Delta, Theta, Alpha, Beta, Gamma subbands. To get this frequency band is still a challenge for the researchers. A passing reference about the technique is made by Shantha Selva Kumari et al [7]; however, the methodology for obtaining the signal in this band is not given explicitly. Only decomposition method is described, which alone is not capable of the getting the required frequency band.

3. PROPOSED WORK

The goal of this present work is to find out the frequency range of each subband after decomposition using discrete wavelet transform to certain levels and then recombining frequencies falling in the range of each subband using inverse discrete wavelet transform. These subbands can further be used to extract features from EEG signals accurately for various applications like brain machine interfacing or designing expert systems for diagnosing epileptic activity efficiently.

4. METHODOLOGY

The EEG data used in the work is available at the Department of Epileptology, University of Bonn [8]. The complete data set consists of five sets (A-E), each containing 100 single channel EEG signals. These segments of EEG signals were cut out from continuous multi-channel EEG recordings and that too after taken care for artifacts like muscle activity or eye movements. Each signal segment is of 23.6 s duration containing 4096 samples. Sets A and B have EEG segments taken from surface EEG recordings that were carried out on five healthy volunteers using a standardised 10-20 electrode placement system.

SET A is of healthy volunteers relaxed in an awake-state with eyes open and SET B with eyes closed. Sets C and D contained only activity measured during seizure free intervals, Set E only contained seizure activity. The signal recordings were done by the 128-channel amplifier system, using an average common reference. The data were digitized at 173.61 samples per second using 12 bit resolution. Bandpass filter settings were 0.53-40 Hz (12dB/oct). In this work, we used two dataset (A and E) of the complete dataset.

Wavelet transform can be defined as a spectral estimation technique in which any general function can be expressed as a sum of an infinite series of wavelets. The decomposition of the signal results in a set of coefficients called wavelet coefficients. The decomposition is done by low pass and high pass filter in time domain. DWT successfully analyses the multi-resolution signal at different frequency bands, by decomposing the signal into approximation and detail information. Here Data is first pre-processed by removing dc component from the signal thereby achieving different levels of decomposition for Daubechies order-2 wavelet with a sampling frequency of 173.6 Hz on each signal of 4096 samples. Figure 1 shows the decomposition of the EEG signal x(n) at Nyquist frequency which is the maximum useful frequency i.e. half of sampling frequency 86.8 Hz. Signal is subjected to six level decomposition where each stage of this scheme consists of two digital filters.

The first filter, $h[n]$ is the high pass filter or it is the discrete mother wavelet and the second, g[n] is low-pass filter. After the first level of decomposition, the EEG signal (0-86.81Hz), is decomposed into its lower resolution components, CA1 (0-43.4) Hz and higher resolution components, CD1 (43.4-86.81 Hz).

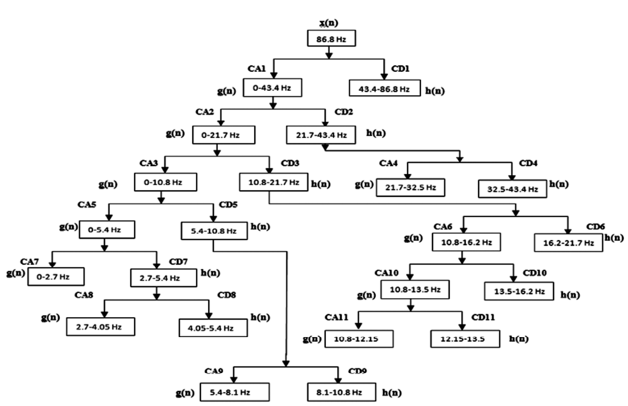

Figure 1: Decomposition of Signal into its Approximation and Detail Coefficients

Likewise six level of decomposition is done The approximation and detail coefficients are shown in diagram by CA_i and CD_i where i is 1,2,3.... at each level of decomposition. The data after decomposition to various levels has approximation and detail coefficients at each level of different frequency resolution. These frequencies are to be then recombined in order to achieve subbands delta, theta, alpha, beta, gamma at their perspective frequencies. The delta band is of frequency range 0-4 Hz so lower resolution components i.e. approximation coefficients CA7 (0-2.7 Hz) and CA8 (2.7- 4.05 Hz) are to be recombined. But the problem arises when the number of samples of CA7 and CA8 mismatch. CA7 has 128 samples while CA8 has 64 samples. For this up-sampling of CA8 is done to 128 samples and then the DELTA band is reconstructed successfully by recombination of CA7 and up-sampled CA8 through Inverse Discrete Wavelet Transform using Daubechies order-2. Similarly THETA subband is of frequency range 4-8 Hz so CA9 and up-sampled CD8 are recombined.

After recombining all coefficients falling in their respective subbands, delta, theta, alpha band with 256 samples and beta with 1024 and gamma with 4096 samples are achieved as shown in Table 1.

Table 1
Subbands with their Frequency Range, Recombining Coefficients and no of Samples

Subband	*Frequency*	*Coefficients*	*Samples*
DELTA	0-4 Hz	CA7, CA8(up-sampled)	256
THETA	4-8 Hz	CD8(up-sampled), CA9	256
ALPHA	8-12 Hz	CD9, CA11(up-sampled)	256
BETA	12-30 Hz	CD11(up-sampled), CD10, CD6, CA4	1024
GAMMA	> 30 Hz	CD4(doubly up-sampled), CD1	4096

5. RESULTS AND CONCLUSION

The method for frequency band separation for epilepsy detection is implemented in MATLAB 2011a. Each EEG signal is sampled at 173.6Hz. From each segment 4096 samples are used for evaluation. EEG segment is decomposed to 6 levels discrete wavelet transform and then inverse discrete wavelet transform is used to recombine the various frequency band to form delta (0-4)Hz , Theta (4-8)Hz , Alpha (8-12)Hz , Beta (12-30)Hz, and Gamma (>30)Hz. The delta, theta, alpha band have 256 samples and beta have 1024 and gamma have 4096 samples. The required frequency and the actual frequency achieved after decomposition and recombination is given in Table 2. Thus it can be concluded that the recombined subband frequency closely match with the required frequency in Delta, Theta, Alpha, Beta and Gamma subbands as shown.

Table 2
Required Frequency and Achieved Frequency of Each Subband

Required Frequency	*Frequency Achieved*
0-4 Hz	0-4.05 Hz
4-8 Hz	4.05-8.1 Hz
8-12 Hz	8.1-12.15 Hz
12-30 Hz	12.15-32.5 Hz
> 30 Hz	>32.5 Hz

6. FUTURE WORK

In this work EEG signal of each patient acquired by placing 10-20 electrode system, is decomposed into five EEG subbands: delta (0-4 Hz), theta (4-8 Hz), alpha (8-12 Hz), beta (12-30 Hz), and gamma (>30Hz) using discrete wavelet transform. The subbands yield more accurate information about the neuronal activities of brain. In future the statistical features can be extracted from each subband and form a feature Vector for classification of epileptic or healthy patient.

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