

Separation Of δ , θ , α & β Activities In EEG To Measure The Depth Of Sleep And Mental Status

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ABSTRACT

The electrical activity of the human brain i.e. the EEG and its classification into various frequency bands has been of interest to researches dealing with neurology. So, here our aim is targeted to classify EEG signals traces into different fundamental frequency rhythms and determine whether a relatively short EEG record taken in a routine laboratory is normal or abnormal. The primary aim of computerized EEG analysis is to support electroencephalographer's evaluation, by representing the data in numerical and or graphical form. EEG analysis however, can go further, actually extending the electroencephalographer's capabilities giving them new tools with which they can perform such difficult and time consuming tasks as quantitative duration EEG in epileptic patients and sleep and psychopharmacological studies. This method is having several advantages over the visual screening by which it is very difficult to extract EEG information. The choice of analytic method should be determined mainly by the goal of the application. The frequency domain tool is used for EEG analysis. The system performs continuous analysis in graphical form and tabular form of recorded EEG signal. Algorithm is implemented by using C language. It is helpful to classify the depth of sleep and mental status from the percentage power in each band i.e., delta, alpha, beta and theta.

KEYWORDS

Power Spectrum, EEG, Delta, Theta, Alpha, Beta.

1. INTRODUCTION

Present day computer systems can be used for the time domain visualization of multi-channel EEG data. In this sense, they can replace the currently used (paper) polygraph systems. However, computer-based systems are much more flexible. The operator can modify the data, and enhance some of its features through digital signal processing. These characteristics are the basis for a much more productive interaction with the data. In computer based systems the operator can examine in detail the waveform features. The computer provides a ready means for adding broad class of signal processing algorithms (including linear phase filters), and for visualizing the effects of the filtering on the data. The classification of EEG signal depends upon the frequency range of each band. By using digital signal processing algorithms such as Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT), Inverse Discrete Transform (IDFT), Power spectrum and Correlation EEG is analyzed.

A. EEG Frequency Bands

1.1 Delta (δ)

Frequency: 0.5 to 4 Hz

Occurrence: This occur only once in every 2 or 3 seconds. These occur in deep sleep, in premature babies and in very serious organic brain diseases. These can occur strictly in the cortex

independently by the activities in the lower regions of brain.

1.2 Theta (θ)

Frequency: 4 to 8 Hz

Occurrence: these are recorded from the parietal and temporal regions of the scalp of children. These also occur during emotional stress in some adults particularly during disappointment and frustration.

1.3 Alpha (α)

Frequency: 8 to 13 Hz

Occurrence: they found in normal persons when they are awake in quite, resting state. They occur normally occipital region.

During sleep, these disappear .these have amplitude of 20-200 μ V with mean of 50 μ V.

1.4 Beta (β)

Frequency: 13 to 30 Hz

(At intense mental activity, the frequency increases up to 50 Hz)

Occurrence: These are recorded from the parietal and frontal regions of the scalp. These are divided into two types as beta I which is inhibited by the cerebral activity and beta II which is excited by the mental activity, like tension. Analysis of different frequency band is done in numerical form and in graphical form.[11]

1.5 Different Stages Of Sleep Pattern

Analysis of EEG done to classify different stages of sleep depends upon the percentage power in each band. [9] Different stages sleeps are:

1. Alert, wide awake person displays the unsynchronized high frequency EEG
2. Drowsy person, one whose eyes are closed, it produces large amount regularly activity in the range 8 to 13 Hz
3. The person begins to full sleep then the amplitude and frequency of the wave form decrease.

4. Light sleep, it is large amplitude and low frequency of the wave form emerges.
5. Deep sleep, then its results is even slower and higher amplitude waves [3]

At certain times a person still sound asleep, then breaks into unsynchronized high frequency EEG pattern for a time and then return to the frequency sleep pattern. The period of high frequency EEG more a wake the called paradoxical sleep because alert is whose is asleep. Then another name is rapid eye movement (REM) sleep, because high frequency EEG is a long amount of rapid eye movement beneath the closed eyelids. It is called dreaming [3].

The various frequency of EEG most human is to develop EEG pattern in the alpha range when they are relaxed eye closed it condition is to represent a for of synchronization.

The person become begins “Thinking” the alpha regular disappears and it is replaced desynchronized pattern it is said beta range.

2. METHODOLOGY

After applying the DFT or FFT to an EEG signal, the magnitude values are stored for each band. The lower cut of frequency and upper cut of frequency is defined depends upon the frequency range of each band only the signals between the upper band and lower band of EEG remain as it is and others magnitudes are zero padded., for plotting graphical results for each band like Delta, Alpha, Beta and Theta for calculation of percentage power in each bands. The lower bands and upper bands are defined depend upon the frequency range of each band which are given below.[2][11]

	Lower Freq	Upper freq
Delta	0Hz	4 Hz
Theta	4 Hz	8 Hz
Alpha	8 Hz	13 Hz
Beta	13 Hz	30 Hz

The Discrete Fourier transform is given by

$$X(k) = \sum_{n=0}^{N-1} \chi(n)e^{-j2\pi kn/N} \quad k = 0,1,2\dots N-1$$

The inverse discrete Fourier transform is given by

$$X(k) = \sum_{n=0}^{N-1} x(n)e^{-j2\pi kn/N} \quad k = 0,1,2\dots N-1$$

When the sequence $x(n)$ has a finite duration of length $L < N$, then $xp(n)$ is simply a periodic repetition of $x(n)$, where $xp(n)$ over a single period is given as

$$X(n) = x(n) \quad 0 < n < L-1$$

$$Xp(n) = 0 \quad L < n < N-1$$

Consequentially the frequency samples $x(2\pi k/n)$, $k = 0,1,\dots,N-1$ uniquely represents the finite duration sequence $x(n)$ since $x(n) = Xp(n)$ over a single period (padded by $N-L$ zeros), the original finite duration sequence $x(n)$ can be obtained from the frequency samples $x(2\pi k/n)$.

It is important to note that zero padding does not providing any additional information about the spectrum $x(w)$ of the sequence $x(n)$ However padding the sequence $x(n)$ with $N-L$ zero and computing an N Point DFT results in a “better display” of the Fourier $x(w)$ [7]

$$X(k) = \sum_{n=0}^{N-1} \chi(n)W_N^{kn}$$

Where $W_N = e^{-j2\pi/N}$

$N = N$ Point DFT

$L =$ Total number of samples

To reduce number of computations like addition and multiplication over DFT, the most powerful transform, FFT is used, for the computation of FFT the Decimation in time algorithm is used, in this $X(k)$ is decomposed into smaller value.

We can generalize the relations for the first two decompositions of Decimation in time FFT algorithm. It can be written as,

$$X_{m-r,p}(k) = X_{m-r-1,2p-1}(k) + W_N^{2rk} X_{m-r-1,2p}(k)$$

$$X_{m-r,p}(k + N/2^{r+1}) = X_{m-r-1,2p-1}(k) + W_N^{2rk} X_{m-r-1,2p}(k)$$

And at last the power spectrum is computed which is given by the formula,

$$Px = \frac{1}{N} \sum_{n=0}^{N-1} |X(n)|^2$$

Power in each band is calculated as given below,

$$Sum(1) = \sum_{Delta\ lower}^{Delta\ upper} Mg(k)$$

$$Sum(2) = \sum_{Theta\ lower}^{Theta\ upper} Mg(k)$$

$$Sum(3) = \sum_{Alfa\ lower}^{Alfa\ upper} Mg(k)$$

$$Sum(4) = \sum_{Beta\ lower}^{Beta\ upper} Mg(k)$$

$$Sum(5) = \sum_{Beta\ upper}^{N-1} Mg(k)$$

$$Sum(0) = Mg(0) + \dots + Mg(N-1)$$

Where

$$Delta\ lower = Delta\ lower * N/Fs$$

$$Delta\ Higher = Delta\ higher * N/Fs$$

$$Theta\ higher = Theta\ Higher * N/Fs$$

$$Theta\ Lower = Theta\ lower * N/Fs$$

$$Alpha\ lower = Alpha\ lower * N/Fs$$

$$Alpha\ higher = Alpha\ higher * N/Fs$$

$$Beta\ Lower = Beta\ lower * N/Fs$$

$$Beta\ higher = Beta\ higher * N/Fs.$$

Where

F_s =sampling frequency=250Hz

$N=N$ Point DFT

Percentage power in each band is calculated as:

Delta percentage power = $\frac{\text{sum}(1)}{\text{sum}(0)}$

Theta percentage power = $\frac{\text{Sum}(2)}{\text{sum}(0)}$

Alpha percentage power = $\frac{\text{sum}(3)}{\text{sum}(0)}$

Beta percentage power = $\frac{\text{sum}(4)}{\text{sum}(0)}$

Other percentage = $\frac{\text{sum}(5)}{\text{sum}(0)}$

3. RESULTS

3.1 Analytical results:

The 33 patient's data are stored in the disk under different conditions eyes open, eyes closed, epileptic patients, person awake, thinking, deep sleep. For each data file the Discrete Fourier Transform (DFT) is applied to calculate the magnitude of 8 channels. For better accuracy $N=512$ is used as a N point DFT, for example a data file containing 5000 samples of 8 channels, the sample numbers 5000 to 5120 are zero padded and the data files for each channel contains the total samples 5120, for the file containing 5120 samples, the total windows are 10. After applying DFT to each patients file, the data is processed through different filters of each band to calculate the percentage power in each band.

The table No.1 shows the percentage power for some patients file. From the percentage power the depth of sleep is classified like Alert, drowsy sleep, light sleep and deep sleep.

3.2 Graphical Results:

For each of the EEG data files the DFT is applied. After application of DFT the data file is processed with different filters. The filters upper band and lower band depends upon the frequency range of each band. Only the signal between these

frequencies is passed and other signals are zero padded. After zero padding, Inverse Discrete Fourier Transform is applied to obtain the delta, alpha, Beta and Theta activity. The graphical result are obtained window wise and channel wise or for total files. Figure No.3.1 through 3.5 shows the output windows showing the Delta, Theta, Alpha, Beta & remaining activity of Mr.Patil. The fig. 3.6 shown below shows the bar graph for the percentage power in different frequency bands present in Mr. Patil's EEG data. This makes the analysis easy and one can get the clear-cut idea about different frequency bands present in data.

Patient's Name	Delta %	Theta %	Alpha %	Beta %	Other %
Mr. Patil	12.05	14.97	9.64	3.24	60.06
Mr. Raj	29.12	1.43	1.30	1.79	66.32
Mr. Naveen	10.82	9.24	7.22	4.61	68.09
Miss Priya	15.01	10.11	4.80	2.35	67.63
Mr. Nizam	11.69	6.27	4.99	7.99	69.07
Mr. Raghu	27.72	4.72	4.98	6.79	55.79

Table No.1 : Percentage power in each band for some patient's data

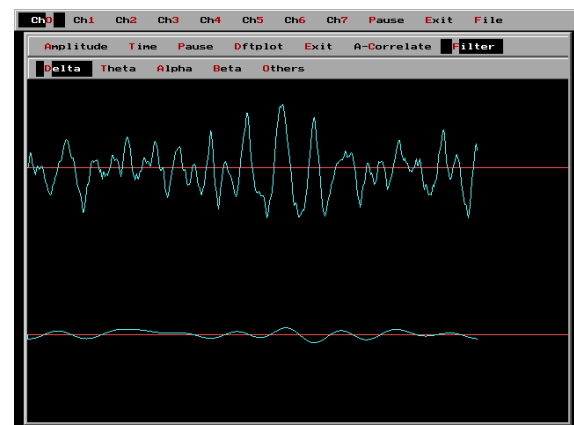


Fig. 3.1 Filtered out Delta activity

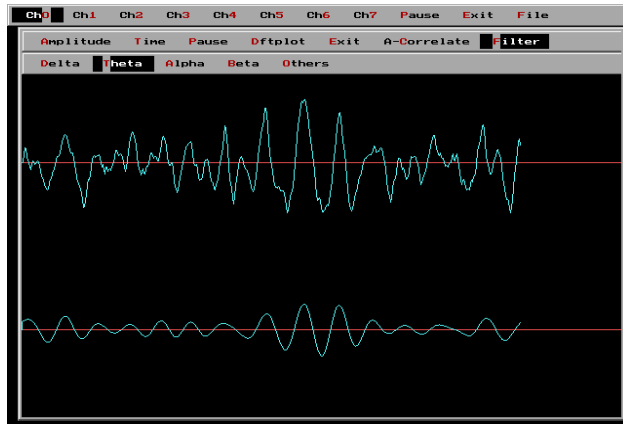


Fig. 3.2 Filtered out Theta activity

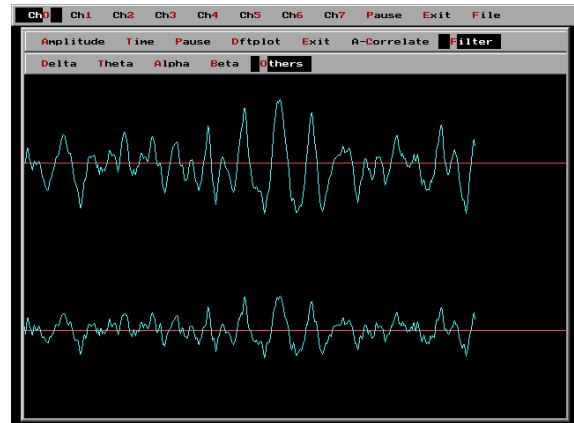


Fig. 3.5 Filtered out Remaining activities

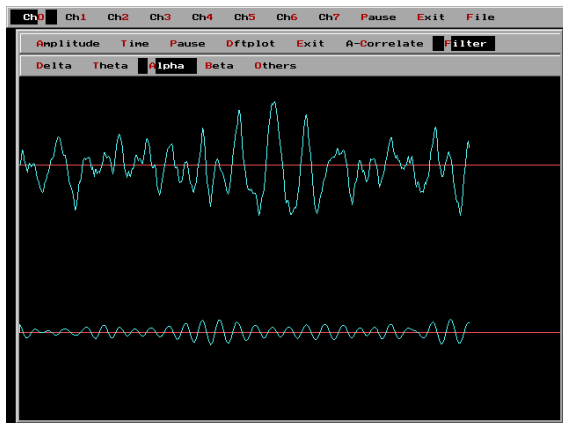


Fig. 3.3 Filtered out Alpha activity

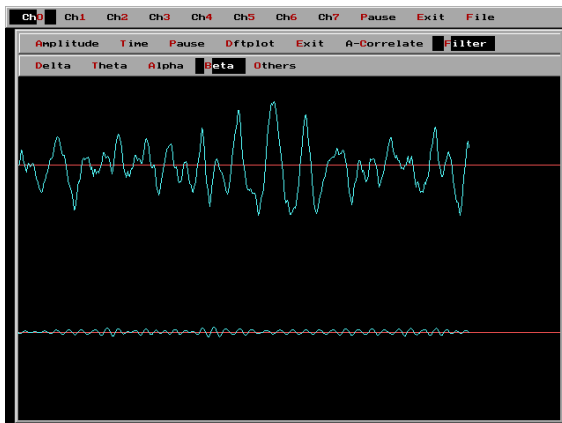


Fig. 3.4 Filtered out Beta activity

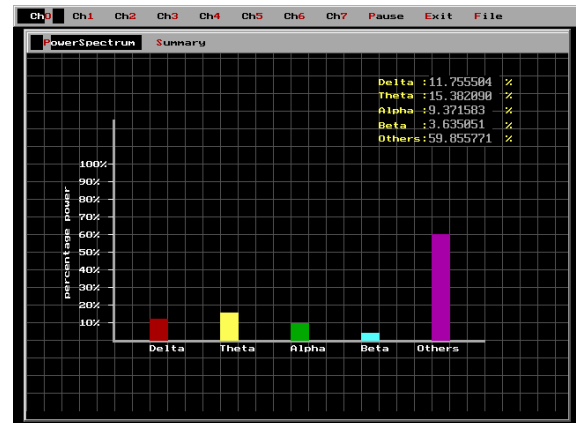


Fig. 3.6 Bar graph for the % Power of all frequency bands

4. CONCLUSION & FUTURE SCOPE

The implemented algorithms are used to study the relationship between the changes of electrical potential in different areas of cerebral cortex. The system classifies the EEG traces into four rhythms (i.e. Alpha, Beta, Theta, and Delta) analytically as well as graphically and EEG reports are presented. Depending upon this information the system also determines the depth of sleep.

The system performs off line analysis of EEG signal. The system can be designed to

perform on line analysis, which is very helpful to doctor for immediate diagnosis of the patients. The feature extraction stage is developed here is only for monopolar montages. If an expert system for other montages also bipolar recording is developed then such system can be used to routinely aid an electroencephalographer, the knowledge incorporated in the rules for system being elicited from that person. Other electroencephalographers may suggest modifications to incorporate aspects of their expertise in interpreting EGGs. The feature extraction stage approach is easy to modify by adding rules, which incorporate new information. EEG signals reflect the activities in the underlying brain structure and particularly in the cerebral cortex below the scalp surface. All of us are aware of the many different states of brain activity, including sleep, wakefulness, extreme excitement, and even different levels of mood such as exhilaration, depression and fear. All these states result from different activating or inhibiting forces generated usually within the brain itself the system can be developed to study these different states of brain and the relationship between the changes of electrical potentials in the different areas of cortex and sub cortex formation. The system performs off line analysis of EEG signal. The system can be designed to perform online analysis, which is very helpful to doctor for immediate diagnosis of the patients.

5. REFERENCES

- [1] Fernando lopes da Silva, “EEG analysis: theory and practice”
- [2] R S Khandpur, “biomedical instrumentation and measurement”
- [3] Harold J Kaplan, “comprehensive textbook of psychiatry- III”
- [4] John r Glover, Periklis Y Kotonas and Narasimhan Raghaavan “a multichannel signal processor for the detection of epileptogenic sharp transients in the EEG”, IEEE transactions on biomedical engineering vol. BME, 33 no. 12, December 1986
- [5] Alison A dingle, Richard D Jones and others “A multistage system to detect epileptiform activity in the EEG”, IEEE transaction on biomedical engineering, vol. 40, no., December 1993
- [6] Johnny R Johnson “introduction to digital signal processing”
- [7] John G Proakis “ digital signal processing”
- [8] “The time domain analysis tool for EEG analysis” by S.Park, J. Smith, IEEE transaction on BME, Vol. 37, august 1997
- [9] “Estimating alertness from the EEG power spectrum” by Magnus Stuisimo, T.J. Signowski, IEEE transaction on BME, Vol. 44, No. 1 Jan. 1997
- [10] Seughun park and Jose C principle, “time domain analysis tool for EEG analysis”, IEEE transactions on biomedical engineering, vol. 22, no.8, august 1984
- [11] “Introduction to Biomedical Equipment Technology” by Joseph J. Carr & John M. Brown.