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Sleep Disorder Detection by Welch Algorithm Based PSD Analysis on EEG Signals

Rimpee Verma[1], Rahul Dekar[2]

[1] CS Student, Dept of CSE, BIET, U.P (Lucknow), India
[2] Assistant professor, Dept of CSE, BIET, U.P (Lucknow), India

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Abstract: *This work helps in understanding the sleep disorder called rapid eye behavior disorder, importance of EEG signal. This paper helps the reader to have quality knowledge about sleep disorder and its types also about EEG signal how it helps in the treatment of sleep disorder. Sleep disorders may be one of the reasons for disturbed sleep. Disturbed sleeps include many inabilities such as to fall asleep, to go back to sleep and frequent waking up during the night. Sleep disorders can be classified under primary and secondary sleep disorders. Sleep apnea, restless legs syndrome, insomnia, periodic limb movement disorder, narcolepsy, and adequate sleep hygiene includes primary sleep disorder. Whereas snoring and eating sleep order includes secondary sleep disorder. By the improved recognition of sleep disorders, there is increase in the variety of treatments available.*

By the analysis of several patients of rapid eye behavior disorder (RBD) and normal people we have calculated an accurate PSD estimate (Welch method). Most importantly MATLAB® helps a lot in the calculation of PSD estimation. Programs related to image processing, blurring an image and many more are learned by MATLAB software. The whole project is a step by step learning procedure, firstly MATLAB is learned then collection of sleep data of patients and normal persons is done, secondly analysis of the collected data is done, and lastly by programming PSD is estimated (by Trapezoidal integration method).

Keywords: Sleep Disorder, Welch algorithm, Rapid Eye Behavior Disorder(RBD), PSD Estimation, EEG Signals, Hanning Window, Low Pass Filter.

1. INTRODUCTION:

The intruding sleep patterns are due to sleep disorders which are also brain disorder. They prohibit people from getting ample amount of sleep. The requirement of sleep by a normal person is 7 to 10 hours per day. In human body the adjustment of sleep is done by brain and moreover brain is the organ which gets profit from the sleep. The aspect of life can be damaged by not capturing sufficient sleep. The sleep disorders which are not diagnosed properly can bring some serious medical issue. Sleep disorder is common in children mainly school going children suffer from this disorder. To give a quick and active performance during daytime a quality sleep is required otherwise the performance can be affected. Sleep disorder hike the exposure of the problem of behavior and learning in children. A child sleep needs attention for the proper diagnose of the problem. Sometimes it is challenging for parents to look after the complication of their child sleep. There is treatment available for some sleep disorder. Many of them can be cured also while some of them are cannot be cured but manageable. In children's sleep the sleep unit plays a specialized or important role. There are sleep specialist who work on child's sleep and diagnose the problem related to sleep. The definition of sleep can be explained on physiological and behavioral criteria in two ways i.e. non rapid eye movement (NREM) and rapid eye movement (REM). The master clock positioned in the suprachiasmatic nuclei of the hypothalamus controls the circadian rhythm of sleep-wakefulness. The neuroanatomical substrates of the NREM sleep are positioned basically in the ventrolateral preoptic nucleus of the hypothalamus and those of REM sleep are placed in pons. During sleep an arrays of important physiological change appear in all body system which are the output of practical alterations in the autonomic and somatic nervous systems. There are mainly eight categorization of sleep disorder. The main four sleep disorder involves insomnia, excessive day time sleepiness, abnormal movements or behavior and inability to sleep at the correct time. If a person suffers from sleep disorder, this trouble can be determined by retrieving a schedule history of family. Overnight polysomnography, actigraphy, maintenance of wakefulness and multiple sleep latency are the necessary test for determining sleep disorder. Physicians must have essential knowledge of the notable features of common sleep disorders such as parasomonia, insomnia, narcolepsy- cataplexy syndrome, obstructive sleep apnea syndrome and circadian rhythm sleep disorder. The first step of the treatment of sleep disorder is to detect the cause of the disturbance of sleep and diagnosing the condition of sleep disorder. The treatment should be definitive for sleep disorder. Many sleep

disorder can be handled with specific consultations of the physician. Only sleep specialist can diagnose the sleep disorder. According to scientific view the definition is based on physiological and behavior differences that arise in brain's electrical rhythm of sleep. The behavioral standard of sleep involves lack of slow eye movements, reversible unconscious state, mobility or sight mobility, increased reaction time, specific sleeping posture, an impaired cognitive function, reduced response to external stimulation and elevated arousal threshold.

The searching of EEG, electromyography (EMG) and electro-oculography (EOG) comes under physiological criteria. Fatigue and sleepiness are completely two different things. Fatigue can be considered as alternate effect of sleep disorder. The point of sleep outset is characterized by steady variation in lots of physiological and behavioral changes in many behavioral and physiological characteristics.

On the basis of three physiological analysis (EEG, EOG and EMG) the division of sleep takes place in two forms with separate objective and control: non rapid eye movement (NREM) and rapid eye movement (REM) sleep fluctuations in periodic manner (absolute of 5 to 7 cycles are acclaimed while sleep in adult), the duration of each cycle finish on an moderate from 100 to 120 min. This is seen in adult that first third portion of sleep is pacified by slow or normal wave sleep and the third last portion of sleep is concurred by REM sleep.

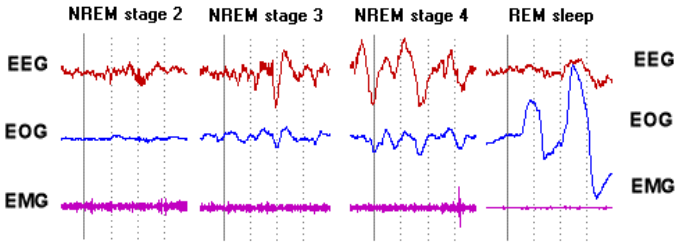


Figure1.1 Sleep stages and associated EEG, EOG and EMG measure

The NREM sleep is divided into four stages (NREM stages 1 to 4) and the percentage of NREM sleep in adult is80 to 85 percent. This division is done on the ground of EEG signal. The total percentage of REM sleep is about 30 to 35 percent of whole sleep. The EEG tracings throughout REM sleep are characterized by theta waves and fast rhythms, many of them consist of saw-tooth appearance. Rapid eye movement in various directions represents the hallmark of sleep and mentions the absence or diminution of chin muscles in EEG. There are phase swing in heart rate, blood pressure, phasic tongue movements and irregular respiration due to phasic rapid eye movement. In between REM sleep fewer periods of hypopnea or apnea may generate.

2. BACKGROUND:

Sleep is a fundamental system for attaining physical as well as mental health. In 1913, French Scientist Henri Pieron authored a book entitled "Le probleme physiologique du sommeil," which was the first text to examine sleep from a physiological perspective. This work is usually regarded as the beginning of the modern approach to sleep research. Dr. Nathaniel Kleitman, now known as the "Father of American sleep research," began work in Chicago in the 1920s questioning the regulation of sleep and wakefulness and of circadian rhythms. Kleitman's crucial work included studies of sleep characteristics in different populations and the effect of sleep deprivation. In 1953 he and one of his students, Dr. Eugene Aserinsky, made the landmark discovery of rapid eye movement (REM) during sleep.

Another of Kleitman's students, Dr. William C. Dement, extended Dr. Kleitman's path of research. Dement described the "cyclical" nature of nocturnal sleep in 1955, and in 1957 and '58 established the relationship between REM sleep and dreaming.

It is believed that approximately 80 per cent of dreams occur during REM sleep and 20 per cent occur during NREM sleep. It is easier to recall REM dreams than NREM dreams. It is also easier to recall dreams if an individual is awakened immediately after the onset of REM dreams, rather than trying to remember them the next morning upon getting out of bed. REM dreams are often vivid, unrealistic and bizarre. In contrast, dream recall, which sometimes may partially occur upon awakening immediately from the NREM dream state, is more realistic. Most of our dreams take place in natural colour, rather than black and white. In our dreams, we employ all five senses. In general, we use mostly our visual sensations, followed by auditory sensations, tactile, smell, and taste sensations are represented least. Some people have frequent, frightening dreams called nightmares or dream anxiety attacks, which appear to arise from intense, anxiety-provoking incidents in the dreamer's life. Nightmares are very common in children, beginning around the age of three to five years. Nightmares decrease in old age. Sometimes in fearful dreams, the individual may enact past stressful events (for example, a scene in a battle field or a car accident). The neurobiological significance of dreams remains unknown. Dream enacting behavior

associated with abnormal movements during sleep constitutes an important REM parasomnia called REM sleep behaviour disorder.

Sleep is not a uniform state, but is characterized by a cyclic alternating pattern of non-rapid eye movement (N-REM) and REM sleep [1-6]. Non- REM sleep encompasses the deeper stages of sleep (sleep stages 1 and 2, and slow wave sleep with sleep stages 3 and 4), whereas REM sleep is a highly activated state of the brain accompanied by dreaming. Sleep patterns in humans undergo a marked change from birth to old age. In sleep 0 (awake) stage, the patient's eyes are open and the EEG is rapidly varying. The voltage is low and the ''beta waves'' are prominent. Eyes move very slowly, the EEG frequency will be 6—8 Hz and alpha waves are more predominant in the sleep 1 (drowsiness) stage. Sleep 2 stage is the light sleep state, where the eye movements stop and our brain waves become slower. Special waves 'K-complexes' and sleep spindles begin to appear. In this state, EEG amplitude is medium and EEG frequency is 4—7 Hz. In stage 3 (deep sleep), extremely slow brain waves called delta waves begin to appear, interspersed with smaller, faster waves. EEG signal will have the frequency 1—3 Hz and amplitude will be high. By stage 4 (deep sleep, slow wave sleep), the brain produces delta waves. It is very difficult to wake someone during stages 3 and 4, which together are called deep sleep. In stage 4, the amplitude of EEG will be high, but the frequency will be less than 2 Hz. The subject's eyes move rapidly along with the occasional muscular twitches in sleep 5 (REM) stage. Theta wave is more predominant in this sleep stage. In adults, sleep-wake cycle is categorized in awake, non-rapid eye movement (NREM) and rapid eye movement (REM) sleep stages. NREM sleep is further divided into three stages: N1, N2 and N3 [7], the last of which is also called delta sleep or slow wave sleep (SWS). Moreover, the sleep stages during a night sleep, proceeds in cycles of NREM and REM, each cycle normally being N1 to N2 to N3 to N2 to REM. The cycles typically happen 4 to 6 times during whole night sleep [8]

3. METHODOLOGY:

PSE is most important application area in Digital Signal Welch method have two basic modifications to the Bartlett method. These are allowed the data length to imbricate.

(i) Dataset divided into K probably overlapping segments of length L

(ii) Window enforced to each section

(iii) K periodograms are averaged

$$P_w(e^{j\omega}) = \frac{1}{k}\sum_{k=1}^{K} Px^{(k)}(e^{j\omega}) \qquad (3.2)$$

Where,

$$P_x^{(k)} = \frac{1}{N}\sum_{n=0}^{L-1}\left|w_{(n)}\, x^{(k)}(n)e^{-j\omega n}\right| \qquad (3.3)$$

Where, Window is represented by $w_{(n)}$ data x(n) located in Kth segment is represented by $x^{(k)}(n)$

MATLAB, Hs = spectrum. Welch ('rectangular', segment Length, overlap %); defines Welch spectrum object.

Step 1: Load the EEG data

Step 2: EEG Signal Extraction

We have downloaded one minute data from physionet bank on sleep disordered breathing in all the sleep stages and cut the selected channels:

ROC-LOC,

C4-P4,

C4-A1,

F4-C4,

ECG1-ECG2,

EMG1-EMG2,

P4-O2.

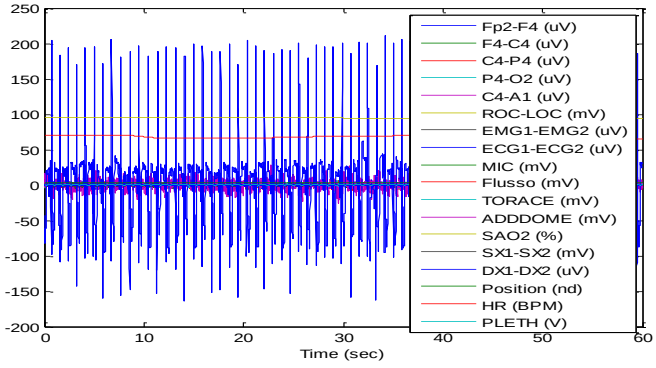


Figure 3.3 Extraction of the signal

Step 3: Removal of Noise Component (if necessary)

The high frequency component of signal's FFT is actually the not required for biomedical signal and it represents signal ripples at higher frequency, so by making it to zero, we can remove high frequency ripple component

Step 4: Removal of high frequency components through low pass FIR filter of cut off frequency of 25 Hz. Removal of high frequency component using Low pass fir filter of cut off frequency 25 Hz. Fir filters are designed using the Signal Processing functions and Direct-Form II Transpose Filter .Fir filter function 'filtfilt' performs zero-phase digital filtering by processing the input data, in both the forward and reverse direction.

After filtering the data in the forward direction, 'filtfilt' reverses the filtered sequence and runs it back through the filter. The result has the following characteristics:

(i) Zero-phase distortion

(ii) A filter transfer function which equals the squared magnitude of the original filter transfer function

Step 5: PSD Estimation (Welch Method)

PSE is most important operation area in Digital Signal Processing. Welch method is nonparametric method that comprise the period gram that have the choice of possible application using the fast Fourier Transform.

The period gram is an approach of estimating the autocorrelation of finite length of a signal. The period gram procedure based on Welch method is capable of contributing good resolution if data length samples are chosen optimally. It can be noticed that PSE based on the Hamming give better results than Henning window.

The period gram estimate of the PSD of a length-L signal $x_L[n]$ is

$$P_{xx}(f) = \frac{1}{LF_s}\sum_{n=0}^{L-1} x_{L(n)e^{-j2\pi f_n/F_y}} \quad \ldots\ldots\ldots (3.6)$$

Where, F_s is the sampling frequency.

The actual figuring of Pxx(f) can be executed only at a finite number of frequency points, and normally apply FFT. Most applications of the periodogram method compute the N-point PSD estimate at the frequencies:

$$f_k = \frac{kF_s}{N} \qquad k = 0,1 \ldots, N-1 \quad \ldots\ldots\ldots (3.7)$$

Step 6: Area corresponding to delta, theta, alpha and beta bands are calculated using Trapezoidal Integration method to calculate average power.

Area Estimation of delta, theta, alpha, gamma frequency bands are evaluated by using Trapezoidal method. Delta (δ) wave having frequency range 0.5 to 4 Hz , theta (θ) wave having frequency range 4 to 8Hz, alpha (α) wave having frequency range 8 to 13 Hz, beta (β) wave having frequency range 13 to 30 Hz.

Step 7: Power ratios are calculated by dividing average power of individual sleep wave frequency band by the total average power of all the bands.

In order to determine the average power for individual frequency bands for the full night, a 60 s window was enforced to the start of the signal, after the basic steps of DC component removal and low pass filtering were executed.

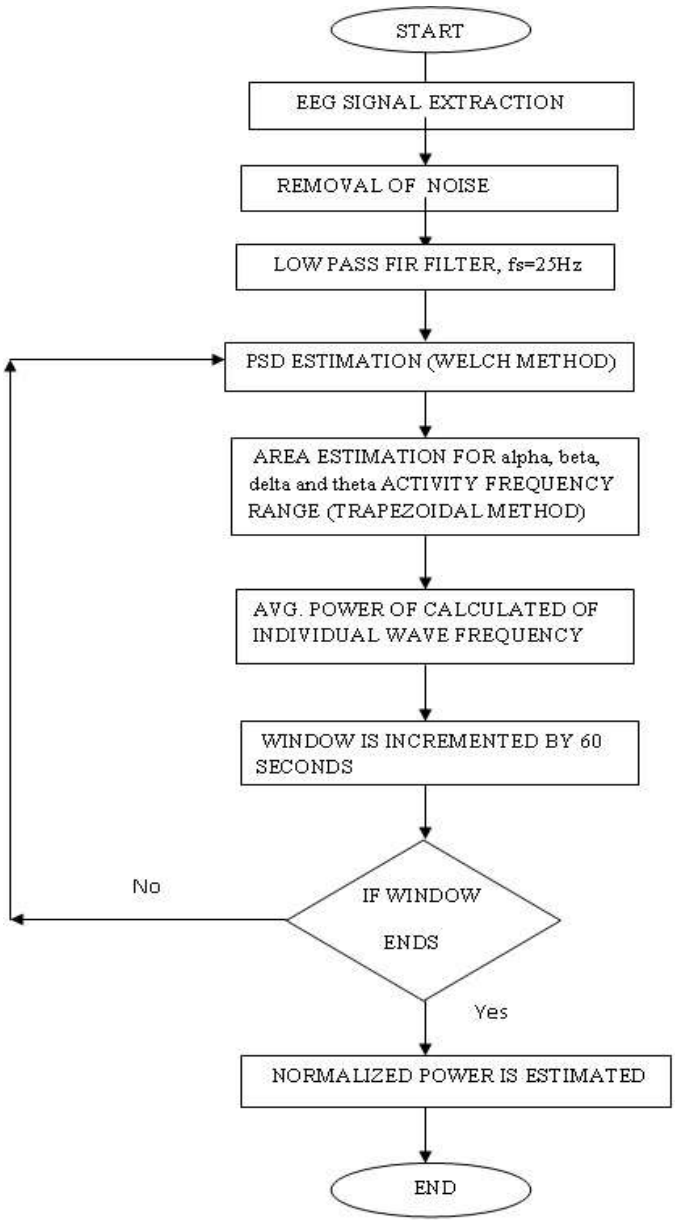
The average power in a given frequency band approach uses a rectangle approximation of the integral of the Hs signal's power spectral density (PSD).

The average power is the total signal power and the total average power is enclosed in the one-sided or two-sided spectrum. The PSD estimate was computed for the 60s window and average power of frequency bands delta, theta, alpha and sigma were determined and then normalized.

Step 8: Difference in power ratios of analogous frequency bands are evaluated.

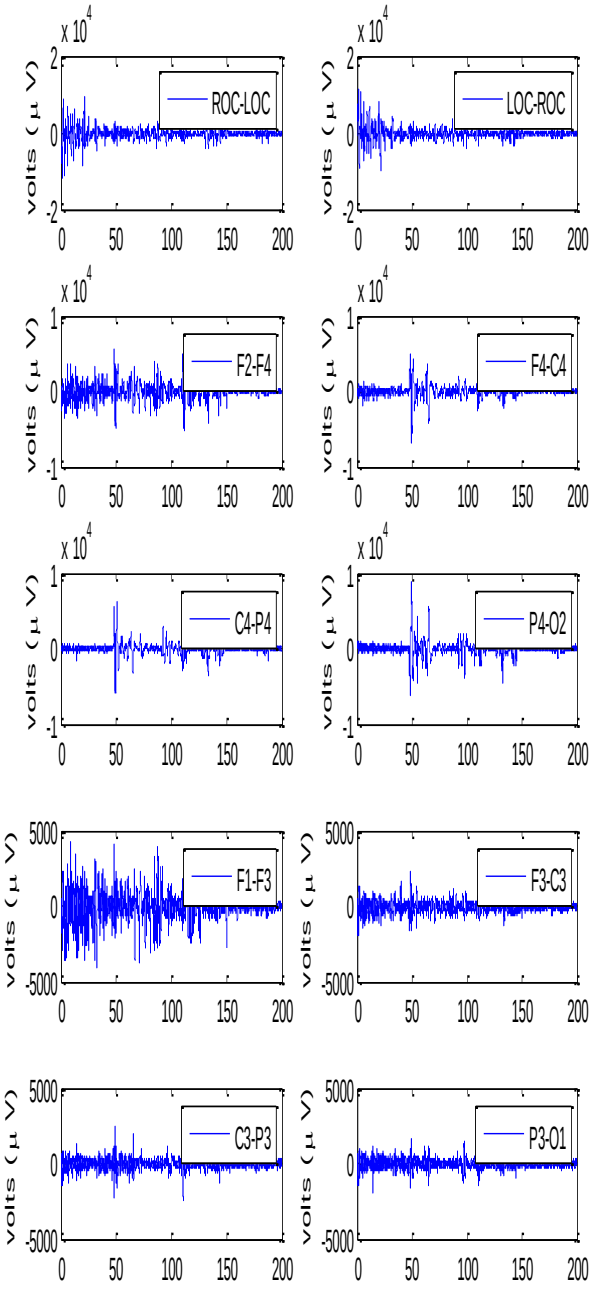
Step 9: Slide the window and repeat the step 5 to 8 for the entire signal duration.

3.1 Flowchart Representation of The Algorithm



4. RESULT

Shows various signals consisted by our biomedical signals. All signals are obtained by performing signal data extraction of data file named as n1_edfm.mat.



Plot of recorded signals of data 'n1_edfm.mat' from signal 1 to 10.

4.1 Observation Table OBSERVATIONS

TABLE 4.1: Power calculated for normal and RBD subject for S0 stage.

Stage	So	So	So	So
Patient	Normal	Normal	Normal	RBD
Signal	n1_edfm.mat	n2_edfm.mat	n3_edfm.mat	rbd1_edfm.ma
P_delta	$5.6x10^5$ High	$2.4 x10^5$ High	$1.3x10^6$ High	$1.6x10^5$ Lowest
P_theta	1.2	65842	$2.1 x10^5$	73254
P_alpha	0	0	0	0
P_beta	654.92	9956.4	856.6	923.46

TABLE 4.2: Power calculated for normal and RBD subject for REM stage.

Stage	REM	REM	REM	REM
Patient	Normal	Normal	Normal	RBD
Signal	n1_edfm.mat	n2_edfm.mat	n3_edfm.mat	rbd1_edfm.mat
P_delta	$8.0886 x10^5$ High	$1.1306 x10^5$ High	97244 High	62714 Lowest
P_theta	$2.5675 x10^5$ High	91824 High	63133 High	27235 Lowest
P_alpha	0	0	0	0
P_beta	1964.7	6746.5	1066.8	363.93

From table 4.1 it can be observed that the PSD for P_{delta} is higher foe normal cases and lowest for the case of RBD disorders during the S0 stage. Similarly for figure 4.2 it has been further observed that P_{delta} is found to be higher for normal case while it is lowest for RBD during the REM stage.Same observation are again found in the case of P_{theta} i.e. PSD is higher in normal cases as compared to case of RBD disorder.

TABLE 4.3: Power S0 and REM stage for normal

Stage	So	REM	So	REM
Patient	Normal	Normal	Normal	Normal
Signal	n2_edfm.mat	n2_edfm.mat	n3_edfm.mat	n3_edfm.mat
P_delta	$2.4 x10^5$ High	$1.3 x10^5$ Low	$1.3 x10^5$ High	$1.0 x10^5$ Low
P_theta	65842	$1.0 x10^5$	$2.1 x10^5$	64669
P_alpha	0	0	0	0
P_beta	9956.4	9264	1856.6	1195.7

S0 stage and REM stage for normal cases are considered it is observed that (Table 4.3) the P_{delta} is always high for normal cases in S0 stage as compared to REM stage.

TABLE 4.4: %PSD for S0 stage of Normal

Stage	So	So	So	So	So	So
Patient	Normal	Normal	Normal	Normal	Normal	Normal
Signal	n1_edfm.mat	%PSD	n2_edfm.mat	%PSD	n3_edfm.mat	%PSD
P_delta	1.3766e+006	68%	2.447e+005	55%	1.3766e+006	68%
P_theta	2.1207e+005	24%	65842	21%	2.1207e+005	24%
P_alpha	22853	7%	56705	20%	22853	7%
P_beta	1856.6	0.45%	9956.4	4%	1856.6	0.45%

TABLE 4.5: %PSD in S0 stage of RBD Patient

Stage	So	So	So	So
Patient	RBD	RBD	RBD	RBD
Signal	rbd1_edfm.ma	%PSD	rbd2_edfm.ma	%PSD
P_delta	1.5986e+005	46%	1.3719e+005	50%

P_theta	73254	34%	74270	36%
P_alpha	27105	19%	23104	13%
P_beta	923.46	.75%	882.01	.55%

From table 4.4 and 4.5 it has been observed that the percentage of P_{delta} is high in S0 stage for normal cases (above 55%) as compared to RBD disorder (below 50%). While the percentage of P_{theta} is higher (34 to 36%) in RBD as compared to normal cases (21 to 24%).

5. CONCLUSION

In this project, different channels are analysis is done. Almost 7-8 channels are observed and the data is extracted from them. In fact there are more channels, but due to unavailability of data only few channels are selected. The source from where the data is from a website known as physio.net.org, the idea of considering this website is taken from a research paper mentioned in the references. Almost every possible effort is done to get more accurate results. PSD is calculated from Welch method which is the good enough approach for calculating the PSD. The use low pass filter is chosen because of its stepper response and the use of Hanning window is selected on the basis of less complication. The chosen window is less complex to work with.

The programming is done with Matlab software, essentially handling of the software is learned then the usage. Different programs based on image processing and how to label the graph is learned. On the basis of the learned programs the main program is accomplished successfully. Step by step procedure is followed to complete the project. In the main program the whole method is depicted, firstly the EEG signal (frequency 0-25 hertz) is taken as the input signal then it is passed through the low pass filter after this, with the help of window power spectrum density is calculated. A loop is followed for calculating the accurate normal PSD, in this loop the process of windowing is continued until the normal PSD is obtained.

Normalized power (P norm) of normal cases having no indication of sleep is figure out and correlated with pathological cases all along different sleep stages. Normalized power shows the percentage of a specific EEG activity out of complete power. So it is found a better explanation of assessment of detection of features in reverse of taking average power of peculiar EEG activity.

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