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# A Review on Automated Detection, Classification and Clustering of Epileptic EEG Using Wavelet Transform & Soft Computing Techniques

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**Abstract: - EEG is an important tool for diagnosis, monitoring and managing various nervous disorder .It is a neurophysiologic measurement of the electric activity of bioelectric potential of brain. The electrical activity of brain changes in accordance with various parameters inside & outside environment. To study human physiology with respect to EEG, bioelelectric potential of brains is recorded with help of electrodes. These raw signals are firstly processed with help of mathematical tools in order to make them more and more informative. The informative signal thus calculated from recording is known as ERP (event related potential). These ERP data are very specific and it changes with every physiological & biological change in human body. The analysis of ERP has got a wide range of clinical importance. It serves as a base for diagnosis and detection of various diseases. ERP are also helpful in designing various emotion sensor interfaces.**

**EEG has got diversified applications in field of biomedical engineering. This is a review paper elaborating various elementary ideas about EEG Signal pre-processing and analysis. In this paper we have collaborated various soft computing tools available for EEG signal processing. Generation of ERP from raw EEG should be very precise to be effective. With help of mathematical and computational tools we can classify specific EEG signals which are further useful for prediction & diagnosis of diseases and other emotion based applications.**

***Key Words*: *EEG; Signal Processing; muscular artifacts; spike detection; Brain waves; ,Wavelet transform; Neural network; EEG lab.***

## I. INTRODUCTION

***1.1 BRAIN WAVE CLASSIFICATION -*** In study of EEG waveforms four types of sub bands can be seen i.e; delta band, theta band, alpha band, beta band and gamma band. These sub bands are classified on the basis of frequency ranges. The frequency range for these sub bands is as follow-

*Delta Sub Band* – The wave that indicates slow wave sleep is called delta sub band .It has highest amplitude but it is the slowest wave .It occurs frontally in adults and posterior in children (Up to 4 Hz).

Theta Sub Band – The wave which is predominant in young children but rare in adults is called theta sub band. Presence of theta in excess is considered as an abnormality. It represents focal disturbance in focal

Sub cortical lesions, metabolic encephalopathy and many other abnormal conditions. (4 Hz – 8 Hz).

Alpha Sub Band – This wave is better obtained during wakefulness but with closed eyes and relaxed mental state and get altered with eye opening and mental exertion .It is found in posterior region of brain in both sides and has high amplitude in affected side.(8 Hz – 12 Hz).

Beta Sub Band – The wave recorded with increased alertness or attention is called beta sub band. It is symmetrical in both sides. It gets attenuated with active movement. Beta with varying frequencies but low magnitude represents active concentration and busy mental state. Beta with dominant effect of pathological drugs (13Hz – 30Hz).

*Gamma Sub Band* – This wave is difficult to record. Generally it is a response to some stimuli .Gamma waves represents resemblance of known objects, sounds etc. Decrease in gamma band is considered as an abnormality. It occurs with cross model sensory processing e.g. an effect that combines two senses sound and vision (Above 30 Hz).

Many neurological disorders can be easily identified by brain rhythms which can be easily recognized by visual inspection of the EEG signal. The amplitude and frequency of these signals varies with human asleep or awake state, age, health etc. There are four major brain waves with their frequency ranges. These are alpha ($\alpha$), theta ($\theta$), beta ($\beta$), delta ($\delta$), and gamma ($\gamma$).

***1.2 EEG Signal-*** Electroencephalogram is most important tool to measure the electrical activity of brain to distinguish between seizure and non-seizure states. To record the EEG signals surface electrodes are placed on the scalp of patient with the help of gel to increase the conductivity of scalp surface. After recording the
EEG signals, these signals are sent to an amplifier to increase its magnitude since EEG signals are voltages of low magnitude .Amplification of low voltages make the analysis easy. The output of the recording comes in the form of waveform which is nothing but oscillations of current EEG can be recorded simply in two ways-with stimulus and without stimulus. The EEG recorded without internal or external stimulus is called spontaneous EEG while it is called Event Related Potential (ERP) when recorded with internal or external stimulus. When these brain potentials are synchronised, it indicates the normal state of brain but when there is some abnormality in brain electrical potential, it indicates mental disorder. Event-related potentials are patterned voltage changes embedded in the ongoing EEG that reflect a process in response to a particular event (e.g., visual or auditory stimuli).ERPs are measured from the same "raw data" (i.e., scalp electrical activity over time and space) as EEG. ERP reflects sensory, motor, and/or cognitive events in the brain. It reflects synchronous post-synaptic potentials of large neuronal populations engaged in information processing. Signal averaging is most common method of extracting the signal. EEG is sampled for ~1 second after each stimulus presentation & averaged together across like stimuli. The time-locked signal emerges in which noise averages to zero.[1] We have to extract time locked activity by averaging these raw data.EEG signals are basically stimulus related processing whereas the noise are tonic background activity related to ongoing process(level of arousal..etc).There is a severe problem of signal to noise in EEG data .Since EEG is of the order of ± 50 micro volts. But ERP are on order of 2- 20 micro volts. We often want to detect difference of 1-2 microvolt thus precision is the important prerequisite in analysis of ERP.

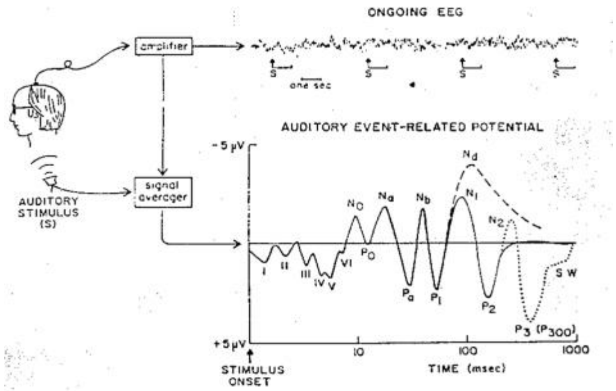


**Figure 1.Generation of ERP from raw EEG signal**

In a clinical diagnosis, artifacts are rejected by visual examination of recording. There are simple criteria for artifact recognition, which can help in the search of an appropriate online cleaning technique. Some simple criteria, for a corrupted EEG signal, are as follows:-

i. High amplitude of delta wave (0.5-4 Hz) in channels Fp1 and Fp2.
ii. Similarity of signals in channels Fp1 and Fp2.
iii. Rapid decline of delta wave posterior (the amplitude of delta wave in Fp1 and Fp2 is much higher than in other channels).

***1.3 Generation Of EEG signals -*** An EEG signal is generated due to the currents that flow between the brain cells in the cerebral cortex region of the brain. When the neurons are activated, current flows between dendrites due to their synaptic excitations. This current generates a magnetic field and a secondary electric field. The magnetic field is measurable by electromyogram (EMG) machines and the electric field is measured by EEG systems over the scalp [2].During recording EEG signals noise can be internal (generated within the brain) or external (over the scalp).Large number of activated neurons can generate enough potential to have a recordable signal. These signals have to be amplified and process [3]. Signal and noise (in each epoch) sum linearly together to produce the recorded waveform for each epoch (not some peculiar interaction). The evoked signal wave shape attributable solely to the stimulus is the same for each presentation. The noise contributions can be considered to constitute statistically independent samples of a random process[1].

***1.4 Recording of EEG signals*** -EEG systems consist of a number of electrodes, differential amplifiers, filters and needle (pen) type registers [3]. Plotting of EEG signals can easily be done on paper. The Recent systems use computers for digitization and storing purpose. For digitization sampling, quantization and encoding is done. The effective bandwidth of the EEG signals is almost about 100 Hz. Thus a minimum of 200 samples per second is necessary for sampling (Nyquist criterion).The conventional electrode arrangement recommended by the International Federation of Societies for Electroencephalography and Clinical Neurophysiology for 21 electrodes (called 10-20 electrode position) [4].

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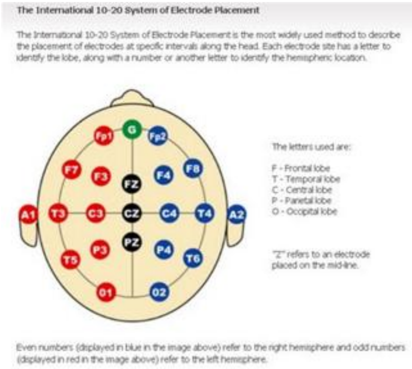


**Figure 2.EEG electrode position for conventional 10-20 system for the placement of 21 electrodes.**

***1.5 Artifacts in EEG-*** There are certain artifacts which are present in raw EEG recording. These artifacts make the ERP contaminated and it introduces inconsistency in the output. Thus it is necessary to eliminate these artifacts from the EEG.

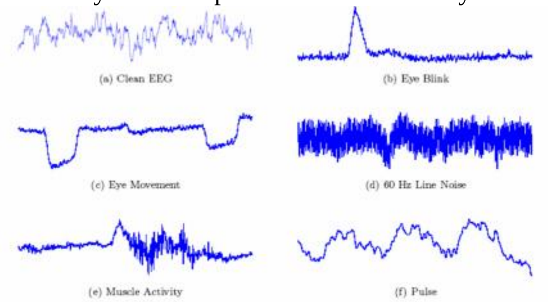


**Figure 3 (Various artifacts present in EEG Signals)**

The ERP generated from artifacts free EEG are most suitable for versatile researches and efficient diagnosis. Importance of thus obtained information is of very much importance in identifying different pathologies. Artifacts in EEG signals are caused due to two types of factors; External factors and Biological factors. The Biological factors are arised by EOG (Elecro-oculogram), ECG (Electrocardiogram), EMG (Electromyogram) and Respiratory (PNG).The External factors are caused due to line-interference, leads and electrodes. These noises have an adverse effect on EEG signals and create problem in obtaining clear cut information from EEG signals. So in order to eliminate these artifacts a number of techniques are applied to make the eeg denoised and artifact free.
Some of these methods are as follows-

i. Wavelet Transform;
ii. Regression of signals;
iii. Blind source separation(BSS);
iv. Independent Component Analysis(ICA);
v. Principal Component Analysis(PCA);
vi. Soft Computing Based Predictive system;

These are various methods for pre-processing EEG signals in order to make them informative and free from artifacts

## II. METHODOLOGIES

***2.1 Electroencephalographic signal analysis using EEGLAB Tool -*** For analysis of EEG signal EEGLAB is interactive menu-based and scripting software for processing EEG signal data based under the Matlab interpreted programming script environment. EEGLAB provides an interactive graphical user interface which allow users to have flexible and interactive process their high-density electrophysiological data (of up to several hundreds of channels) and/or other dynamic brain time series data. EEGLAB make use of common methods of electroencephalographic data analysis including independent component analysis (ICA) and time/frequency analysis. EEGLAB has become a most widely used platform for sharing and applying new techniques for biological signal processing. [5]

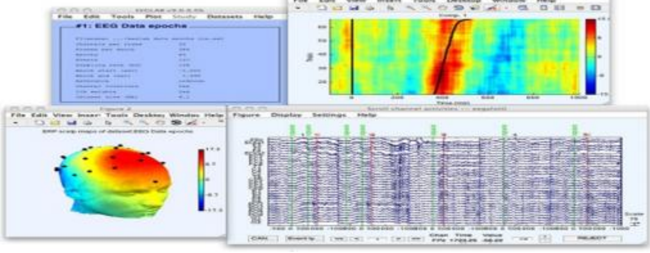

**Figure.4.Screenshot of EEG Lab**

EEGLAB provides an interactive graphic user interface (GUI) allowing users to flexibly and interactively process their high-density EEG and other dynamic brain data using independent component analysis (ICA) and/or time/frequency analysis (TFA), as well as standard averaging methods. EEGLAB also incorporates extensive tutorial and help windows, plus a command history function that eases users' transition from GUI-based data exploration to building and running batch or custom data analysis scripts. EEGLAB offers a wealth of methods for visualizing and modelling event-related brain dynamics, both at the level of individual EEGLAB 'datasets and/or across a collection of datasets brought together in an EEGLAB 'study set.'
For experienced Matlab users, EEGLAB offers a structured programming environment for storing, accessing, measuring, manipulating and visualizing event-related EEG data. For research programmers and developers, EEGLAB offers an extraordinary and wide platform through which they can share new methods with the research community at world level by publishing EEGLAB 'plug-in' functions that appear automatically in the EEGLAB menu of users who download them. For example, novel EEGLAB plug-ins might be built and released to 'pick peaks' in ERP or time/frequency results, or to perform specialized import/export, data visualization, or inverse source modelling of EEG, MEG, and/or ECOG data.

***2.2 Lab view* -**Lab view is developed by National Instruments. It is helpful for the signal analysis from different stages. The importing capability permits the user to analyze self-made datasets because it supports ASCII or MAT datasets which can be generated using MATLAB or Lab View.

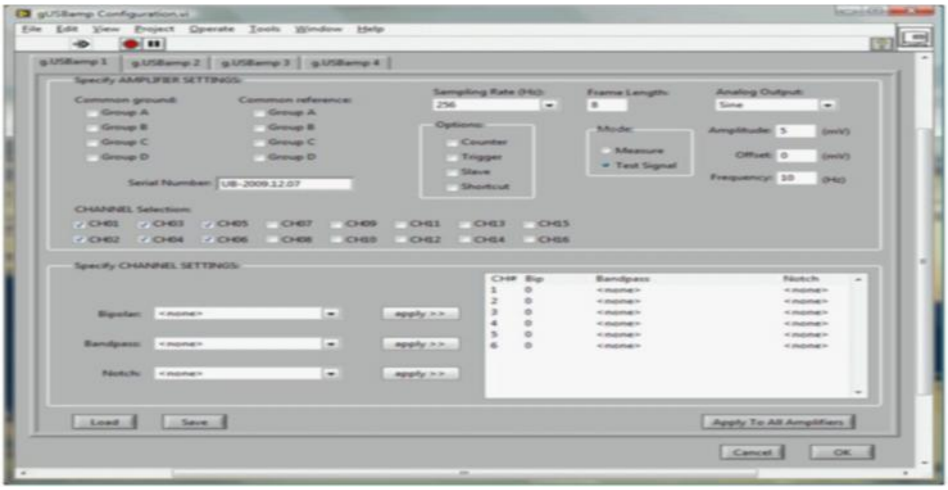

**Figure.5.EEG Signal Analysis in Lab view**

It only reads datasets that were previously processed; this means that EEGLAB cannot read data directly of an acquisition card like other software tools such as Lab View. Based on the fact that Lab View is capable to register signals directly from a data acquisition stage, the program that is being developed is able to register the signals coming from the EEG amplifier and registering them to an ASCII dataset.

***2.3 Simulink* -**Simulink is useful for optimized pre-processing; signal processing, feature extraction and classification blocks. It enables to design real-time application rapidly. Various codes can be used for off-line and on-line bio signal analysis. Algorithms for fast, accurate, flexible simulations and estimations can be combined with High-Speed Online Processing for simulink for real-time parameter estimation

***2.4 EEG Matlab Toolbox***- This toolbox has been developed to facilitate quick and easy import, visualisation and measurement for ERP data. The toolbox can open and visualise ERP averaged data (Neuroscan, ASCII formats), 2D/3D electrode coordinates and 3D cerebral tissue tessellations (meshes). All the features can be explored quickly and easily using the example data provided in the toolbox. The GUI interface is simple and intuitive. The following lists the features already available and some items that could be developed **.**This is an initial attempt to help new users gets started with the toolbox. It is unlikely to cover all aspects of the toolbox, but it appears to be a reliable starting point on several installations to date. The toolbox provides some easy ways to visualize data..

## III. LITERATURE SURVEY

***3.1 Agta Warwrocka, Andrzez Kot,*** studied method for measuring biomedical signal and may be used as a signal control. The filters are used for biomedical signal. In this research, they had problem with generation and analysis of EEG signal.[6]

***3.2 D. Easwaramoorting and R.Uthayakumar*** studied on the various methods which are useful to indicate the state of illness of epileptic patient from EEG recording. Analysis based on GFD and wavelet decomposition through discrete wavelet transform through this analysis they diagnosed the patient state.[7]

***3.3 Xiaoveri*** has suggested EEGLAB software for Brain Computer Interface development that provides an accessible solution to the EEG signal processing problem, it act as a reference point for the development of a Lab View based program. In BCI development is necessary to be able to visualize brain signals in one way or another. EEGLAB provides visualization, analysis and processing for EEG signals. [5]

***3.4 A.Khorshidtalab, M.J.E. Salami*** had shown the current scenario of research and he compared the performance of different algorithms for real-time classification of BCI-based electroencephalogram signals. Effective BCIs demand for accurate and real-time EEG signals processing. Recent advances in real-time signal processing have made BCI a feasible alternative for controlling robot and for emotion based communication. They concluded that among neural networks models, SOFNN presents a better result with EEG signals. Therefore, it slashes the pre-processing and processing time and is best for online applications. [8]

***3.5 Prof P.V. Ramaraju*** has proposed signal analysis through system orientation which eliminates the human indiscretion which may be allied with doctor in EEG psychoanalysis. [9]

***3.6 Rafal Bogacz*** et.al presented a neural-based approach to finding artifacts in EEG signal. Very low classification error was obtain due to two factors:

- Large training set containing different kinds of EEG waves.

- Coefficients computed for the windows of signal, delivered to the network's inputs.

The coefficients express the characteristic features of artifacts which distinguish them from a clear signal. They encoded large amount of domain expert's Knowledge .[10].

***3.7 Andreas Bulling*** et.al proposed in his work that in first step, blinks are removed from the raw EOG signal. In a second step, the signal is segmented based on special signal characteristics. Afterwards, for each of the segments, a classification is performed which decides whether the segment describes an eye movement or a fixation with superimposed Andreas baseline drift. Segments classified as eye movements only get denoised . In case of a fixation period, after denoising, the whole segment is replaced by the first value of the filtered signal. The offset between the segments' first and last value is assumed to be caused by baseline drift and used to adapt the signal. A final transformation maps signal levels to gaze angles.[11].

***3.8 Rafal Ksiezyk*** et.al demonstrated that application of a raw data or data parameterized, without taking into account the specificity of the problem, leads to the poor generalization, and in case of raw data to a very long computation time. The best results were found for networks using input parameters evaluated on the basis of wavelet coefficients ANN4 and ANN5 discussed in his paper. Learning rate of these networks was very high, percentage of learned examples from training set and generalization were good and the number of iterations was an order of magnitude better than for the raw data or input parameter based on correlation coefficients computed in a conventional way.

He concluded that for ANNs application in the time series classification pre-processing should include frequency information about the signal. In many other applications power spectra calculated from Fourier transform are applied. He recommend wavelet transform as more efficient and faster method, providing both - time and frequency characteristics of signal and thus offering universal preprocessing.[12].

***3.9 Petr Sadovsky*** et.al proposed that use of ICA method for artifacts removing from EEG signals is very useful. The main facility of ICA is possibility to separate the artifacts from EEG signals into isolated components. The problem is to decide whether computed independent component contains only artifact or more information for example some EEG data. The reason of this is a contrast function as a criterium of independence. It is possible to localize an artifact in the one or more independent components as segment with bigger energy than another EEG signal parts and it is possible to take away this segments from signal. It is necessary to be very careful. Some of EEG signal parts can contain energy like artifacts so they can confuse grafoelements and artifacts i.e. epilepsy signals. Signal processing EEG and polysomnographic data by ICA are very progressive tools for following research in this area. A big disadvantage is the calculation of ICA method which is impossible to be done in real time.[13].

***3.10 Chunchu Rambabu*** et.al declared in his work that VEP (Visual Evoked Potentials) signals were collected using different electrodes placed at proper locations in the Human Brain. The selection of frequency range was based upon SCS (statistical coefficient selection) technique. Wavelet Denoising Algorithm (WDA) was used to distinguish VEP components and EEG artifacts. Once the VEP signals was separated, a adaptive noise cancellation filter scheme was designed and applied to remove the EEG artifact effects in the VEP signals.[14].

***3.11 Jacqueline Fairley*** et.al proposed a novel hybrid approach to artifact detection based on a combination of a GA algorithm for feature selection and a novelty detector. The results indicate that this approach can be used as an alternative to the standard two class classification approach especially when the information about the artifact class is missing. Even though the feature selection module was not directly dictate to favour solutions with a lower number of features it frequently used only ¼ of the original variables resulting in a more compact representation of the problem. It is important to mention that most of the features were selected in a concise manner revealing a certain inherent pattern of the problem.[15].

***3.12 B.Paulchamy*** et.al estimated the results of EEGsignal with several artifact removal using Neuro-Fuzzy filter. The various artifacts mixed with EEG cannot be filtered directly because they pass through the body and turn into an interference component. In this proposed method EEG is subjected to noise signal and it is contaminated. Proposed method has the advantage that no additional denoising algorithm is applied to restore the neural activity present in the artifactual components. Then the noise is removed by means of Neuro-fuzzy filter. The SNR ratio for both noised and denoised signal is calculated and it is observed that the SNR of the denoised signal is higher than the noised one.[16].

***3.13 A Garcés Correa*** et.al developed a method in which three adaptive filters in cascade, based on LMS (least mean squares) algorithm, were described in order to cancel common artifacts (line interference, ECG and EOG) present in EEG records.

The advantages of using a cascade of three filters instead of filtering the three signals with a single adaptive filter are among others-

a) The coefficient’s adaptation in three independent filters is simpler and faster than their adaptation in a single filter.

b) At each stage output, the error signals *ei (n)*, EEG with one of the three attenuated artifacts are present; such separation (by artifact) may be useful in some applications where such output might be enough.

Advantages of adaptive filters over conventional ones include preservation of components intrinsic to the EEG record. Besides, they can adapt their coefficients to variations in heart frequency, abrupt changes in the line frequency (caused, say, by ignition of electric devices) or modifications due to eye movements. A difficulty found in this work was the determination of $L$ (filter order) and $\mu$ (convergence factor).These parameters are very important; $L$, because it leads to appropriate filtering, and $\mu$, to get adequate daptation. If $\mu$ is too big, the filter becomes unstable, and if it is too small, the adaptation may turn out too slow. Several tests were carried out to determine the optimum value for these parameters. Results show that the proposed filter attenuates, on the average, 98.3% of the line frequency interference; 29.6% of the maximum energy component of the ECG ( $\cong$ 15 Hz), and 55.8% the EOG component of maximum energy ( $\cong$ 0.5 Hz). Apparently, the ECG and EOG components were attenuated in smaller proportion than the 50Hz, however, this probably takes place because their respective spectra overlap (reason for which adaptive filtering was used instead of a classic technique).[17].

***3.14 B.Paulchamy*** et.al described a method to identify the artifact through wavelet transform and soft-like thresholding which is applied to the artifact zones. Adaptive thresholding , which is applied only to the artifact zones, does not affect the low frequency components and also preserves the shape of the EEG signal in the non-artifact zones. Power Spectral Density and correlation values are used as performance metrics in his study .In all cases, Artifacts were adequately attenuated, without removing significant and useful information. It is concluded that the proposed method involves less complexity and is a much easier technique for the removal of Artifacts with the help of wavelet decomposition. It is, thus an efficient technique for improving the quality of EEG signals in biomedical analysis.[18].

***3.15 Rubal Jeet*** et.al compared between different image processing techniques like spatial filtering, localized and Adaptive for removing blocking artifacts from the gray scale images. The comparison is made on the basis of different parameters like mean square error, peak signal to noise ratio, bit error rate and the visibility of image. Out of these techniques adaptive technique shows good results. It smoothes the artifacts more in comparison to others. He concluded that the mean square error and bit error rate is less for spatial filter. The spatial filter also removes blocking artifacts from the image but the blocking artifacts are not removed totally. The mean square error is minimum for adaptive filter and maximum for spatial filter, the peak signal to noise ratio is maximum while mean square error and bit error rate is minimum for adaptive filter. Also the adaptive approach takes less time to compute the results in Comparison to other approaches like spatial and localized method.

The adaptive technique performs better in comparison to spatial and localized filtered approaches. Also the adaptive approach takes less time to compute the results in comparison to other approaches. In future one can extend the research to modify the filter to show better results so that blocking artifacts can be reduced further.[19].

***3.16G.Geetha*** et.al proposed that EEG signals involve a great deal of information about the function of brain. Different methods of how to obtain clean EEG signals by removing artifacts were discussed. in her study. Some of the methods that are really appealing are artifact removal through Independent Component Analysis (ICA), Wavelet Transforms ,Linear filtering and Artificial Neural Networks .ICA method could be used in situations, where large number of noises need to be distinguished , but it is not suitable for on- line real time application like Brain Computer Interface(BCI).Wavelet transforms are suitable for real-time application, but the real success lies in the selection of the threshold function. Linear filtering is best when; the frequency of noises does not interfere or overlap with each other. Artificial Neural Networks (ANNs) brings in new promises in development of adaptive methods of structure recognition and solving complex classification problems which can be related to their ability to learn a certain mapping from the set of the realization examples. Performance of ANNs heavily depends on input parameters. Conglomeration of techniques results in much improved and productive exercise on automated removal of artifacts and classification of signals thereafter.[20].

## IV. CONCLUSION

From review of these papers and study of practical facts we conclude that EEG signal analysis have diversified advantages, applications and future possibilities of research. In terms of clinical applications. EEG signals are used to identify the seizures for the purpose of better treatment. EEG signals are used to monitor the depth of anaesthesia. EEG signals are used to obtain the wean-epileptic medication. EEG signals are used to monitor alertness, coma and brain death. EEG signals locate areas of damage following head injury, stroke, tumours, etc. In terms of research and development, EEG signals are used in neuroscience and cognitive science. EEG signals can also be used for the psycho physiological research. EEG signals can be used for the study of the responses to auditory and visual stimuli. The study of EEG analysis is very accurate and precise since the temporal resolution of the EEG signal is high. EEG signals basically measures the electrical activity directly .EEG is a non-invasive procedure. EEG works at very high speed and it has ability to analyze the brain activity as it unfolds in real time at a level of milliseconds.

From above study of these research papers and analysis of facts, it is evident that EEG signal analysis, real time signal processing, and generation of EEG signal opens a diversified scope of research for biomedical signal processing , disease diagnosis and disease prediction system.

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