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An Overview on EEG Signals for Epilepsy Identification

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ABSTRACT: Electroencephalography (EEG) is a medical analysis that measures the electrical potential differences created by a vast number of neurons from the cerebral cortex. The potential determined by the EEG reproduce the superposition of fields created by various synaptic currents. The signals are recorded to diagnose any abnormalities in functioning of the brain. Usual brain signals differ a lot from abnormal brain signals. The signals so recorded can be infected by noise which should be filtered to acquire the actual brain signal. The purified signal so achieved can verify several brain disorders, epilepsy being one among them. Since from a last few decades various researches are focusing and working towards automate the analysis of EEG signals to detect and classify the diseases. This paper presents a review on EEG signals and describes how it functions, filtering process and reviews a few algorithms which are being utilized to identify epilepsy.

KEYWORDS*:* EEG signal, Epilepsy, Adaptive filter, ICA, Entropy, Neural network.

I. INTRODUCTION

The human brain is an astonishingly amalgamated organ of the human body, which inhabit billions of interacting physiological and chemical progressions that give rise to investigational observed neuroelectrical activity. The signal electroencephalographic (EEG) is stated as a revelation of post-synaptic potentials that are created by cortical level during synchronous activity of around 105 (10 rates to 5) neurons [1]. The (EEG) which presents imminent information signifying the brain's electrical activity is the most employed signal to assess and recognize irregularities in the electrical activity of the brain, The EEG signal seizes the helpful information together with unneeded or noise information. EEG of brain is an evolution that can discriminate abnormalities related to the electrical signals in the brain. Signals flow all the way through the brain cells to process information and pass information. In an EEG, 10 to 20 minute and flat discs like arrangement prepared by metal, called electrodes are fastened to the scalp with wiresat places as resolved by the International Federation of Societies for electroencephalography. These electrodes inspect the electrical signals in the brain and send signals to a computer, where the results are recorded. The cortical nerve cell inhibitory and excitatory postsynaptic potentials generate the EEG signals [2]. EEG facilitates to identify Epilepsy or other seizure disorder, brain tumor, head injury, brain dysfunction that may have a multiplicity of reasons (encephalopathy), swelling of the brain (encephalitis), stroke, sleep disorders, dementia. It is employed to validate brain death. A constant EEG is utilized to find the accurate amount of anesthesia given to somebody in a medically persuaded coma. Conversely, EEG of the brain cannot determine intelligence or detect mental disease [3]. EEG waveforms are categorized on the basis of frequency, amplitude, and shape, close place on the scalp at which they were recorded. EEG signals have alpha, beta, theta and delta waves. This paper is presented in five sections including the introduction. Section II presents the overview on epilepsy. Section III presents acquisition of EEG signal and its types. Section IV presents artifacts elimination processes. Section V gives the conclusion of the work.

II. EPILEPSY AN OVERVIEW

Epilepsy seizure is the consequence of the transient and unpredicted electrical disorder of the brain signal. Epilepsy is one of the primitive neurological turmoil that has been recognized in human beings. It is described by chronic seizures in which uncharacteristic electrical activity in the brain makes the loss of awareness or an entire body seizure. Patients may not be aware that they are having seizures owing to the haphazard nature of them which may raise the menace of physical injury. Epileptic seizures are originated by disturbed brain activity – which merely means that the usual activity of the brain is all of a sudden interrupted and changes. EEG waveforms can be utilized to discover preictal state which is the state prior to the

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actual seizure take places. This state may last for few minutes to more than a day. The next state is the ictal state that is the state when the seizure occurs. The third state is postictal state that is the state following the seizure has seized. The state amid the postictal and preictal stage is called interictal stage. Figure1shows normal, interictal and ictal EEG signals. Epilepsy is a universal chronic neurological disorder. Epilepsy seizures are the effect of the transient and unexpected electrical disorder of the brain. Around 50 million people worldwide have epilepsy, and nearly two out of every three fresh cases are discovered in developing countries [5]. Epilepsy is most likely to occur in young children or people over the age of 65 years; although, it can happen at any time [6]. In epilepsy, the normal model of neuronal activity twist into troubled, creating bizarre sensations, emotions, and behavior, or intermittently convulsions, muscle spasms, and loss of consciousness [7]. There are numerous feasible basis of epilepsy. Whatever thing that upsets the normal model of neuron action varying from illness to brain injuries to unexpected brain growth can lead to seizures. Epileptic seizures are signs of epilepsy [8]. EEG patterns seen in epileptic patients are either non specific or specific. Non specific pattern can be seen in many conditions besides epilepsy, such as stroke, head trauma and brain tumor. Slow EEG signals are an example of a non specific pattern which is commonly seen in epileptic patients.

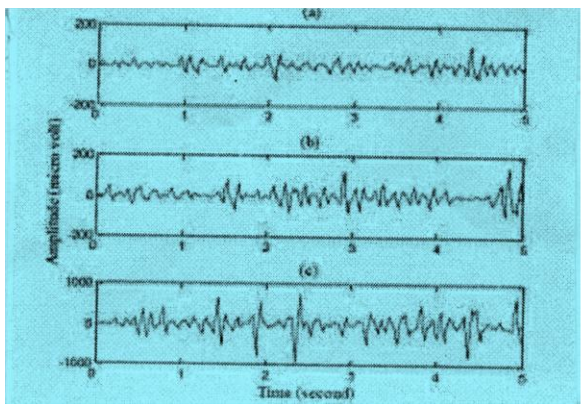

Figure1. Normal, Interictal and Ictal EEG signals.

III. EEG SIGNAL ACQUISITION AND TYPES OF EEG

Two different modes of EEG signal recordings, namely differential mode and referential mode are used. In differential mode the two inputs to each differential amplifier are from two electrodes whereas, in referential mode one or two reference electrodes are used [9]. Queen Square process of electrode positioning has been presented as a standard in recording the pattern of inducing potentials in medical examination [10]. Bipolar or unipolar electrodes can be employed in the EEG measurement. In the first approach the potential difference among a pair of electrodes is measured. In the second approach the potential of both electrodes is compared either to a neutral electrode or to the average of all electrodes. Figure 2, shows arrangement of electrodes positioning for simple EEG signal compilation [12]. The raw EEG signals have amplitude of the order of micro volts and contain frequency components of up to 300Hz. To retain the useful information the signals have to be amplified before the ADC and filtered to remove the noise, artifacts and make the signals suitable for processing and visualization. Filtered signals are in the form of analog signals, for analysis these signals need to be digitized. The conversion from analog to digital EEG is performed by means of multi channel ADC'S.

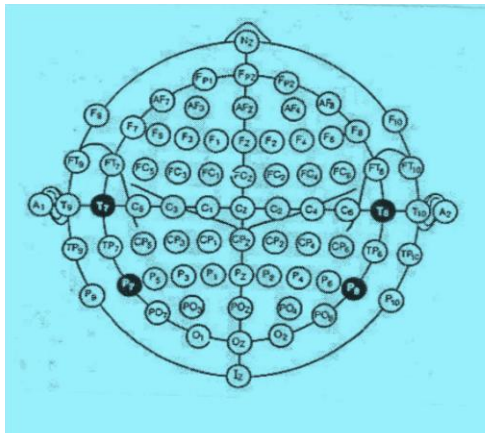

Figure2.Positioning of electrodes for EEG signals compilation [12].

EEG waveforms are categorized on the basis of frequency, amplitude, and shape, close place on the scalp at which they were recorded. EEG signals have alpha, beta, theta and delta waves as shown in Figure3.

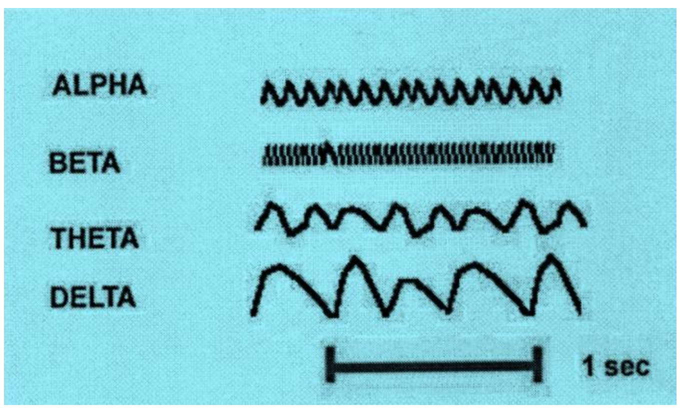

Figure3. Electroencephalogram (EEG) signals [13].

From the EEG signal (Fig.1) it is feasible to distinguish alpha (α), beta (β), delta (δ), and theta (θ) waves as well as spikes related with epilepsy, and signal associated with brain death [13].

The following Table shows the different EEG signals and their frequencies with implication:

Table1: Different EEG signals and their frequencies with implication [13]

Wave forms	Frequency	Position of Scalp	State of the Subject
Delta	0.5 to 4Hz		Infants Deeply sleeping adults
Theta	4 to 8Hz		Infants Children Drowsy Adults
*Alpha	8 to 13Hz	Occipital	Normal relaxed adults
Beta	13 to 30Hz	Frontal Parietal	All anxious subjects
Gamma	26 to 100Hz		

From above EEG signals it is clear that, EEG may transmit frequencies or waves which are superfluous in nature. Such signals are called artifacts. EEG artifacts are recorded signals that are non cerebral in origin. There are two kinds of EEG artifacts: Physiological artifacts and Non physiological artifacts. Non physiological artifacts can be classified as:-1) Power line noise 2) Baseline noise

1) Power line noise: - Power line noise arises owing to interference of the external power sources as well from internal electrical defective recording system.

2) Base line noise: - Base line noise happens due to poor contact of the electrodes with the patient or from perspiration of the patient under the electrode. Physiological artifacts occur because of pulsation of the scalp arteries, different body movements, together with movements of head, eyes, tongue, distorted quantity of conduction caused by conductance of tissues and fluids among the cerebral cortex and the recording electrodes. One of the most familiar artifacts is regarded to be ocular artifact, i.e., artifacts linked with eye movements. In EEG, signal to noise ratio is extremely small [15]. This is shown in Figure3.

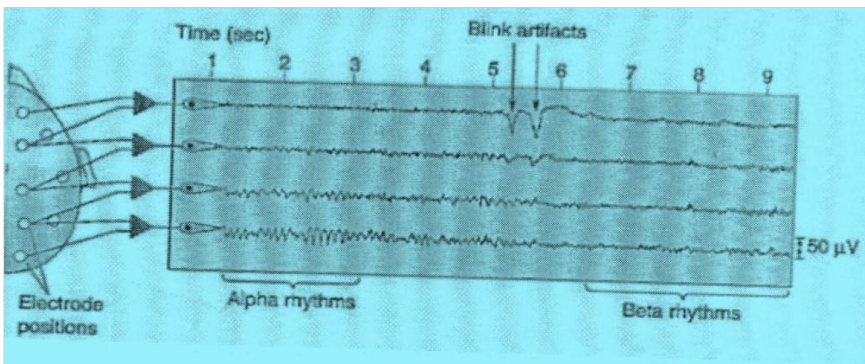

Figure3. Effect of artifacts in EEG signals [15].

IV. ARTIFACT ELIMINATION APPROACHES

The EEG signal acquired from the EEG mechanism is accessible in the EDF format (European Data Format). It is transferred into wave format for any additional processing. The signals are then filtered.

4.1 Adaptive Filters: - For filtration of EEG signals, traditional filters such as band-pass, low-pass or high pass filters cannot be employed to remove or attenuate the artifacts without sacrificing considerable frequency constituents of EEG signal. Since, EEG has biological noise whose spectra overlaps with EEG signals [15]. Owing to this cause, the adaptive interference cancellation method is a very proficient method to resolve the issue when signals and interferences have overlapping spectra. Adaptive filters are based on the optimization theory and they have the ability of adapting their characteristics as per the selected features of the signals being evaluated. The purpose of an adaptive filter is to modify the coefficients of the linear filter, and thus its frequency response, to produce a signal similar to the noise present in the signal to be filtered. Then the signal so produced is subtracted from the EEG to obtain the EEG signal to be evaluated for numerous brain activities. Figure 4 describes the adaptive filter approach [16].

x (n): the input signal

d (n): the reference signal or the desired output signal (some noise component are present in it).

y (n): the output signal

e (n): the error signal which is compute as e (n) = d (n) – y (n)

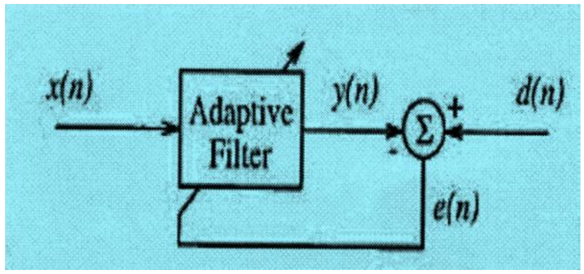

Figure4. Adaptive filter approach [16].

Least mean square (LSM) algorithm is applied to compute the function for the noise function generation. It can be stated that an improved option to LMS function is normalized least mean square (NLMS) function of noise generating signals [1]. But, Kalman filter for EEG forecast presents more accurate results.Figure5 illustrates the functioning of adaptive filter [16].

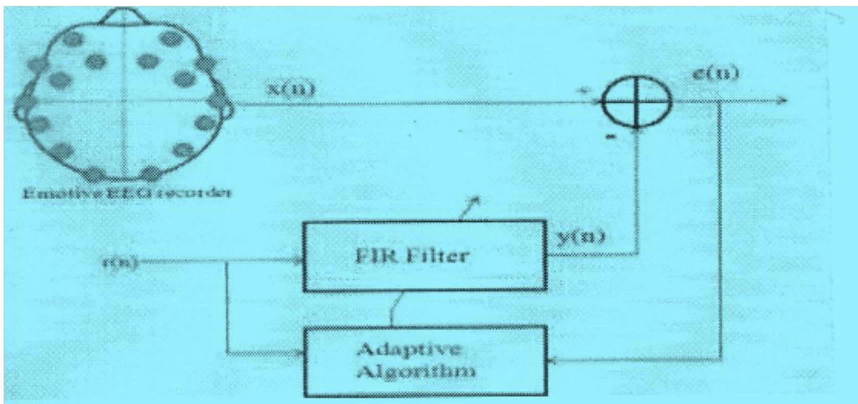

Figure5.Working of adaptive filter [16]

in conjunction with the above mentioned adaptive algorithms, finite impulse response and infinite impulse response filters can be employed in adaptive filtering, most frequent being finite impulse response (FIR) filter which is utilized for normalizing the signal.

4.2 Independent component analysis (ICA):- EEG signals endures from what we call cocktail-party problem [18]. A capable approach which has ascertained itself as a significant element of EEG study is the application of independent component analysis (ICA) for data decomposition and partition of neuronal action from artifacts. The scheme vital for this approach is that the EEG signal is a combination of linearly independent source components (IC) that can be partitioned by ICA, visually observed, and classified as artifact or EEG signal constituents. Once the artifact elements have been recognized, they can be eliminated and the residual EEG signal constituents can be anticipated back to the original time domain. This process gives up the reconstruction of an artifact-free EEG [20]. ICA makes use of linear decomposition process. ICA presumes that time series recorded on the scalp are spatially steady combinations of the actions of temporally independent cerebral and artifactual resources, that the addition of potentials occurring from various sections of the brain, scalp, and body is linear at the electrodes, and that propagation delays from the sources to the electrodes are insignificant. In EEG study, EEG signals recorded at various electrodes supplies to the rows of the input matrix X, and the columns are measurements recorded at diverse time intervals. For artifact elimination, ICA locates an `unmixing' matrix, W, which decomposes or linearly unmixes the multi-channel scalp data into an addition of temporally independent and spatially fixed components. The rows of the output data matrix, U = WX, are time itinerary of creation of the ICA components. The columns of the inverse matrix, inv (W), present the respective projection strengths of the particular components at each of the scalp sensors. These scalp weights provide the scalp topography of every component, their physiological origins [21]. One of the ICA algorithms employed for EEG filtering is EWASOBI which is weight adjusted variant of SOBI.

Algorithms for identifying Epilepsy applying EEG

(a) Wavelets and Statistical Pattern Recognition: - Figure6 shows the flow chart of the proposed logic for detection of epilepsy seizure by using wavelets.

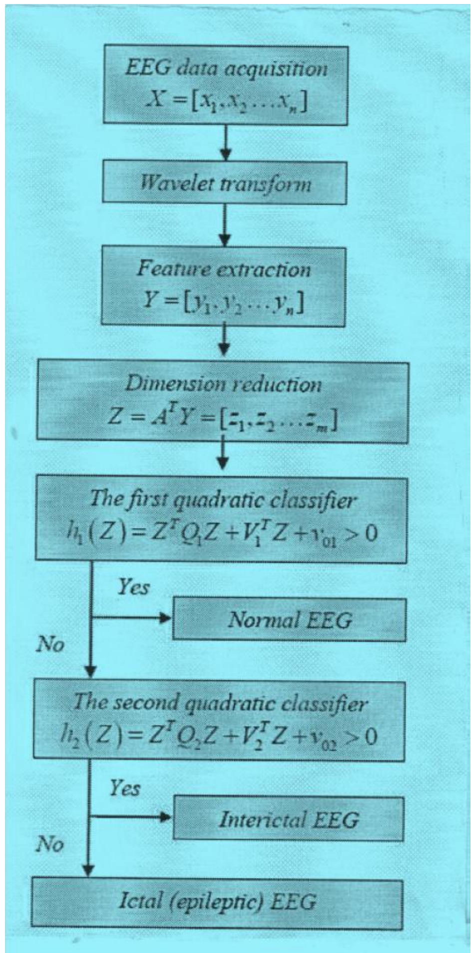

Figure6. Flowchart of proposed logic using wavelets

Wavelet transformation is a linear approach can decompose a signal into several frequency sub bands using wavelet functions and scaling functions. These sub bands so created helps in better understanding of EEG signals. Following wave transformation, feature extortion is employed to reduce the dimensionality space and extort the feature vector Y = [y1, y2….yn]. Having dimension too large might cause difficulty in designing a classifier. Quadratic classifier is employed since; the EEG signal is categorized in three parts, i.e. normal, interictal and ictal. Two classifiers are employed in the proposed approach.

1st Classifier: separates normal from (ictal + interictal)

2nd Classifier: Separates interictal and ictal.

The algorithm is very simple and robust. The algorithm provides relatively precise result and it offers an automatic, objective process that addresses all accessible features in a definite mode and as well makes a verdict based on data, but since it also permits insight into the severity of the brain status. The algorithm should too consider the non- linear study of the data and from the flow chart, it can be stated that the algorithm does not deal with the preictal state of the seizure.

(b) Improved Approximate Entropy (IApE) and Artificial Neural Network (ANN): - improved approximation entropy (IApE) along with artificial neural network(ANN) has been used for epilepsy seizure detection [23]. Following is the flow chart of the proposed logic.

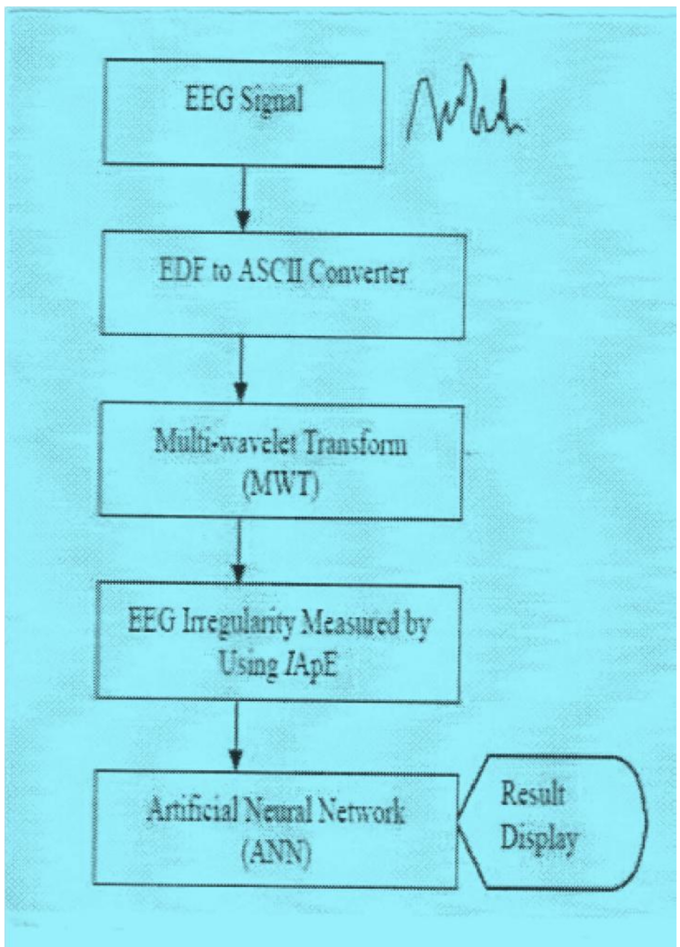

Figure7. Flow chart of IApE and ANN approach [23].

This approach too makes use of wavelet and scaling for extraction of features of EEG. But, as compared with the previous method this approach employs not one, but multiple wavelet and multiple scaling functions for extraction of features. In this approach, the abnormality of the EEG waveform has been estimated employing improved approximate entropy. In case of IApE the method uses variable run length instead of fixed value as in case of ApEn. In this approach a feed forward neural net work (FFNN) has been employed for the analysis of EEG signal. A neural network is an artificial intelligence system that can be trained in a set of input data. It consists of neuron like structures. It can have any number of layers of such neuron like structures, any number of neurons per layer. The input to the system is through network inputs and out is through network outputs. Figure8.shows feed forward neural network (FFNN).

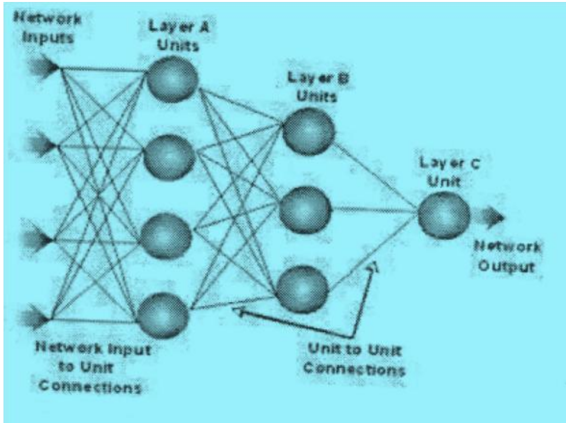

Figure8. Feed forward neural network (FFNN).

Figure8 is an example of three layer neural network. Every unit in a layer is connected to all the neuron units in its preceding layer. The connections have dissimilar strength representing the knowledge of the network. Back propagation algorithm is applied to train the neural network with explicit data series. In the stated algorithm, the neural network is trained for different EEG signals and is employed to identify epileptic EEG signals. Artificial neural networks hold the benefit of features like adaptive learning, robustness, self-organization, and generalization capability. In the above algorithm, training of the neural network is time consuming. The network requires to be trained for thousands of epochs or data series. Hence, training can be time-consuming, depending on the network size, number of examples, epochs limit, and error limit. Secondly, such training is merely feasible if sufficient data for training is existing.

(c) Nearest Neighbor Classification: - It is used to categorize the EEG signal whether it is normal or abnormal. Fifure9 shows the flow diagram of the proposed logic [22]

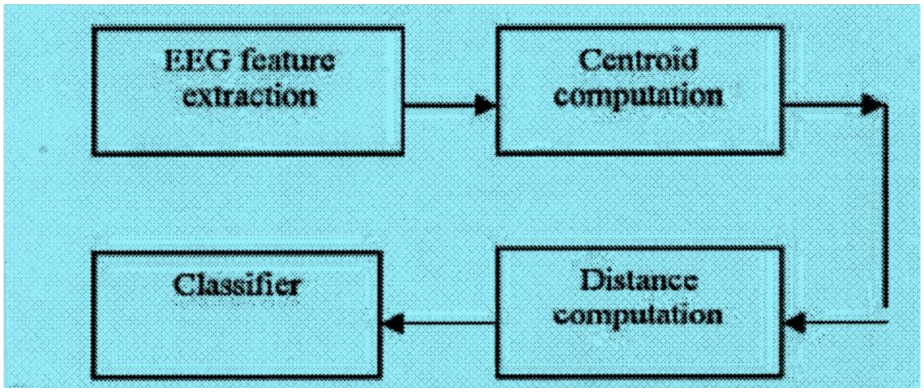

Figure9. Nearest Neighbor Classification

In this algorithm, feature extortion is followed by centroid computation.

EEG signal is normalized -> mean computation of each channel -> median of each channel.

This median is regarded as centroid in the algorithm. In this method, centroid of normal and epileptic signals is by now known. A reference is produced for the normal by computing the mean of centroids of all normal signals. Likewise, a reference is computed for epileptic signals. Using nearest neighbor rule, a signal is categorized either as epileptic or normal. The nearest neighbor algorithm employs the approach called "tell me who your neighbors are, and I'll tell you who you are."

V. CONCLUSION

The EEG signals are normally employed to clinically assess brain activities of human. The recognition of epileptic seizures and brain tumor with the EEG signals is a remarkable process in the analysis of epilepsy seizures and brain tumor. More specifically, parameters extorted from EEG signals are significantly precious for diagnostics. In this paper a comprehensive literature review of the significant and recent researches that are related with efficient recognition of Epileptic seizures employing EEG signals are presented. The main objective behind this review is to help the researchers especially the fresh entrants in the field of EEG signal analysis. Hence, to make them aware of the accessible approaches and implement the appropriate system for the recognition of neurological disorders related with their concerned research in the area of EEG.

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