

V Summary and Conclusion

The epidemic proportion staggering throughout India reveals the devastation that is impending and inadequacy proliferated to deal with it. A sweep of around 3.5 million people will be plagued every year by neurological disabilities causing brain dysfunction. One of the major causative factors of this epidemic is Epilepsy. The scarce in facilities related to neurological problems and a dearth of neurologists mandates urgent changes in national health policy. Two types of brain related disabilities have been deliberately categorized by neurologists. One is epilepsy, which afflicts an incredible population of 10-12 millions according to the estimates. Three quarters of the population are not getting suitable treatment and they suffer from varying degrees of neurological disability which may aggravate with lack of treatment. The main motivation behind this research work was to invent an effective methodology to adjunct the needy people of the rural areas in providing them with firsthand information about the disorder. Acquiring such information could pave the way for further prognosis.

This research work aimed to design and implement an Automated Seizure Detection System using Electroencephalogram (ASDEEG) by incorporating enhanced signal processing and soft computing techniques. To implement ASDEEG, the following objectives were formulated.

- To design and develop preprocessing techniques that reduce the artifacts that obscure the underlying cerebral brain activity.
- To design and develop feature extraction technique to identify patterns to help the subsequent steps of ASDEEG.
- To design and develop a classification model that uses the features extracted to detect the presence or absence of seizure.

An amalgamation of these algorithms provided an efficient means of detecting Epilepsy by implementing some of the features in the algorithms like

- i. Adopting robustness in the algorithms to remove outliers from the signal data.
- ii. Achieving the characteristics of adaptivity, with an ability to perform efficiently given any amount of data.
- iii. Ability to converge rapidly
- iv. Ability to achieve high accuracy in diagnosing Epilepsy.

This research work introduced a real time detection of epileptic seizures by introducing novel techniques. In this chapter, the thesis contributions are reviewed. Some of the apexes and the limitations of the research are deliberated. Some directions for future research work are also discussed to address the limitations.

5.1 Findings of the research

EEG signal acquisition and processing offer prolific information to the physicians in diagnosing brain functionality and its abnormalities, which are discoursed in this work. The proposed system bears the potential of providing several credible benefits such as fast diagnosis, high accuracy, good sensitivity and specificity, time saving and user friendly. The extra benefits of this proposed system include low cost, and ease of interface. Aforesaid characteristics indicate the usefulness of the tool as an efficient one.

More elusive forms of artifacts are traced from biological origins and are more difficult to correct. This research work focuses on detecting epilepsy which includes artifact removal algorithm. The absence of these artifact removal algorithms would be adequate for detecting epilepsy, but would have an adverse effect on the performance of ASDEEG at its totality. An amalgamation of spatially constrained ICA and DWT with Thresholding exemplified a remarkable

performance in removal of artifacts. The blending of these algorithms derived 6 algorithms proposed for this thesis work namely; spatially constrained InfomaxICA with Otsu thresholding, spatially constrained InfomaxICA with Fuzzy Shrink thresholding, spatially constrained Extended InfomaxICA with Otsu thresholding, spatially constrained Extended InfomaxICA with Fuzzy Shrink thresholding, spatially constrained fastICA with Otsu thresholding and spatially constrained fastICA with Fuzzy Shrink thresholding. Multifaceted artifacts like electrical disturbances, eye ball movement, eye blink, jaw clenching and spit swallowing that thwart the underlying EEG signals, are considered in this study. The initiative behind choosing ICA based algorithms is that it does not require separate analyses for removing different classes of artifacts. With the completion of training, artifact-free EEG records can be derived by simultaneously eliminating the contributions of various identified artifactual sources in the EEG record. The algorithms encumbered for artifact removal provides scalability, such that it can acclimatize to remove any varied range of artifacts. As ICA and WT complement each other by removing the limitation of each ICA is used as a pre denoising tool with WT. WT removes overlapping of noise signals that ICA cannot filter out. ICA can distinguish between noise and signals that are nearly the same or higher amplitudes which WT has difficulty with. Another advantage in choosing ICA-WT based algorithms is that this method preserves and recovers most of the neural activities than regression and PCA.

A new feature extraction technique was performed on high-dimensional time-frequency representation on the multi-channel EEG signals using Fast Walsh Hadamard transform. This was developed to identify the most important frequency representations of signals with the following features Delta, Theta, alpha, beta and gamma. Selecting a singular powerful attribute circumspcctly to improve the performance of classification, by reducing the curse-of-dimensionality was the foremost challenge in feature selection in this research work. Estimating PSD,

though highly prevalent is a very tedious task in DSP. Several factors counteract in its evaluation, of which the major hindrances are due to excessive record length, trade-offs resulting due to frequency resolution and reduction of variance. Welsh periodogram estimator used in this research work is computationally efficient and employs smoothing of data and preserves fine frequency fluctuations.

Classification strategies proposed in this research are Hybrid Extreme Learning Method (HELM) and Fast Artificial Neuro Fuzzy Inference System (FANFIS). The performance of the aforementioned classifiers are compared with SVM, ANFIS and ELM. Extreme Learning Machine unearthed its existence in the year 2006 by its discoverer Huang –bin Guang, but its contributions are still dearth in the field of epilepsy. The implementation of Hybrid ELM with a blend of Modified Levenberg Marquardt algorithm lurches upon another novelty in the locale of detecting seizures. The algorithm is computationally efficient and the computational requirements are not excessive even for fairly large EEG data sets. A good generalization of classification algorithms is achieved by circumventing overtraining, under training and over fitting.

This work concentrates upon the diagnosis of Epilepsy, but the same compendium of algorithms upon trivial amendment could be made highly suitable for diagnosing types of diseases like Sleep study, Dementia, Schizophrenia, and Alzheimer etc., which rely upon EEG.

5.2 Limitations and Future research directions

EEG is more applicable in practical systems due to its effectiveness, compactness and simplicity in usage. One of the foremost problems encountered with an EEG based system is the difficulty in identifying appropriate EEG signatures corresponding to the origin of the brain. The reason is due to poor spatial resolution of EEG systems. For studies involving brain tumor the origin of

epilepsy should be explicitly recognized. Such problems could be overcome by acquiring signals from both EEG and fMRI signals simultaneously, which would be potentially advantageous because of the superior resolution in temporal and spatial domains, achieved from each of the devices respectively. Deploying ambulatory EEG systems would be another improvement over the usage of conventional EEG systems.

Different flavors of ICA do exist like SOBI, Constrained ICA, JADE, runICA; etc which is not considered in this study. Underlying principles of ICA could be deeply and thoroughly investigated by making a relative study using a complete set of ICA. Multitude wavelets subsist, but the research is restricted to Daubechies. This study could be further extended by concerning all the different wavelets.

A non parametric method for PSD estimation is only used considering certain advantages like smoothening and robustness. But a parametric model could be suitable, if the considered mathematical model is properly tuned. A feature selection would be more appropriate after performing a comparative study.

Different modes of classification could be still concentrated upon. There exist different types of seizures and an attempt to classify them is not in the scope of this thesis. An attempt to extend this work by concentrating on classification of seizure types could be highly useful in assisting the neurologists in diagnosing to the core.

Portion of brain damage can be a factor for the arousal of seizure. In such situations it is superfluous to consider all the channels in the entirety. Studies circumscribing the channels and focusing only on a particular lobe has not been adopted in this study and could be a very significant factor for future investigation. This could be carried out by slight amendment to this current research work by

considering readings, sheerly from the localized area of the brain and by incorporating a counter to denote the number of arousals.

The research was mainly aimed to suit patients of Indian origin and hence the real time data has been collected from hospitals based from Coimbatore with a collection of 160 patients. The real efficiency of HELM could be best perceived upon the enormity of the database. A 10 second data was captured for each patient from the hospitals, and a long term monitoring would be required for handling distinctive epilepsy scenario where the patient needs to be observed for a longer time. The integration of algorithm at phase II could be best observed for a lengthy signal and such a state of affairs is circumvented. The two points of consideration would be of high concern in collecting the database by overcoming the limitation.

A discussion on different datasets available worldwide is comprehended subsequently. The Swartz Center for Computational Neuroscience (SCCN) at the University of California, San Diego had come forward and released EEG data on the internet as there was no publicly savailable database for EEG with a collection of 32-channel data from 14 subjects (7 males, 7 females) acquired using the Neuroscan software. Some of the other datasets referred by SCCN are also highlighted.

EEG dataset with 109 subjects published on PhysioNet uploaded by Gerwin Schalk's team at the Wadworth center in Albany, NY which expounds over BCI dataset. Psychophysics dataset illustrates 122 subjects recorded in a study on Alcoholic Controls using 64 channels. DEAP dataset expounds EEG and other modalities for emotion recognition. Enterface dataset is used for Emotion Detection in the Loop from Brain Signals and Facial Images. Epilepsy data is a very comprehensive database of epilepsy data files comprising of 21 subjects. Sleep data contain Sleep EEG from 8 subjects. Animal and human EEG database hold a few trials of EEG data with visual evoked potential and epilepsy in rats.

Continuous EEG is a database in a few seconds of 64-channel EEG recording from an alcoholic patient. Epilepsy data is another database added by Ralph Andrzejak from the Epilepsy center in Bonn 10 patients with 750 trials each. Five data sets containing quasi-stationary, artifact-free EEG signals both in normal subjects and epileptic patients were put on the web by Ralph Andrzejak from the Epilepsy center in Bonn, Germany. Each data set contains 100 single channel EEG segments of 23.6 sec duration. Currently, the EU database is uploaded by Freiburg university contains annotated EEG datasets from more than 200 patients with epilepsy, 50 of them with intracranial recordings with up to 122 channels. Each dataset provides EEG data for a continuous recording time of at least 96 hours (4 days) at a sample rate of up to 2500 Hz.

ASDEEG can be used in the domain where the similar observations like frequency analysis of Delta, Theta, Alpha, Beta and Gamma exist. Children with ADHD are known to have high theta/beta ratios compared with less hyperactive kids. ADHD the main concern is of theta and beta waves. Hence it is prominent that each one of the brain disease will have its acuteness in any particular region of frequency.

The implementation of ASDEEG was executed by a thorough study of the theoretical aspects of signal analysis in order to acquire the interpretation of biomedical signals to improve the processing of medical information. Algorithms were developed with an intention to support the use of software for a real time medical environment and to aid in therapeutic improvement.