A Survey Study:Mobile Alert System for Abnormal EEG Activity

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Abstract

This survey study is about the remote analysis of the patient having neural disorders, through the combination of electroencephalography (EEG) recording and telecommu-ication domain for transmission. This study points to the system that will monitor and analyze the EEG data for any abnormal activity like epilepsy and then transmit that data to a doctor on a mobile device wirelessly. This will help the doctors to monitor their patients remotely and respond quickly at the time of emergency such as during an epileptic seizure or syncope. The aim of the study is to develop an algorithm to detect the neural disorders by processing the real time EEG signals and transmitting information to the doctor on his mobile device in case of any abnormal activity recorded.

***IndexTerms*—EEG, Signal Processing, Seizure Detection, Remote Diagnostics, Health monitoring, Wireless Body Area Networks (WBAN).**

I. INTRODUCTION

Electroencephalography (EEG) is a neuro-imaging technique used for the analysis of different functionalities of brain and neurological disorders, such as brain tumor, epilepsy, sleep disorder and stress monitoring. The important information about the functioning of brain is contained in the oscillations i.e. frequency and the energy content of the EEG signals [1-3]. Earlier, EEG signals analysis was done by the physicians by looking at the EEG recordings, but now, different computer programs have been developed that pre-detect and analyze the EEG signals and prepare a report themselves to help the physicians [4]. This advancement has increased the use of EEG by physicians for analyzing the patients having neural disorders [5], as shown in Fig. 1.

One of the problems of under developing countries is that there exists a few numbers of such professional doctors and the latest equipment, so idea is to globally connected and accessed to the concern doctors irrespective of their locality. Mobile phone system and advance GPS, 3G, 4G, LTE technologies have to bear of the distance and unavailability of a doctor.

Wireless Sensor Networks are becoming popular in various remote diagnostics systems such as; Wireless Body Area Networks (WBANs), shown in Figure 2. WBANS are currently being used in a number of physiological signal monitoring systems such as for leg motion sensing, oxygen level in blood sensing, and EEG sensing.Nevertheless, most of the work has been done to sense and transmit the sensed data only.

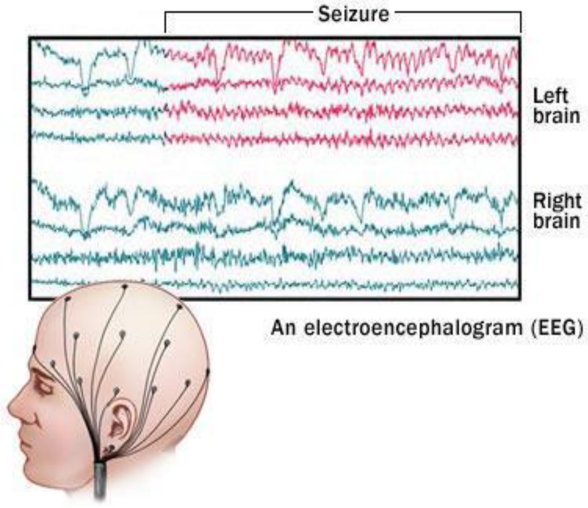

Fig. 1 EEG recording shows brain signal response of epileptic seizure at the left and right lobe of brain [5].

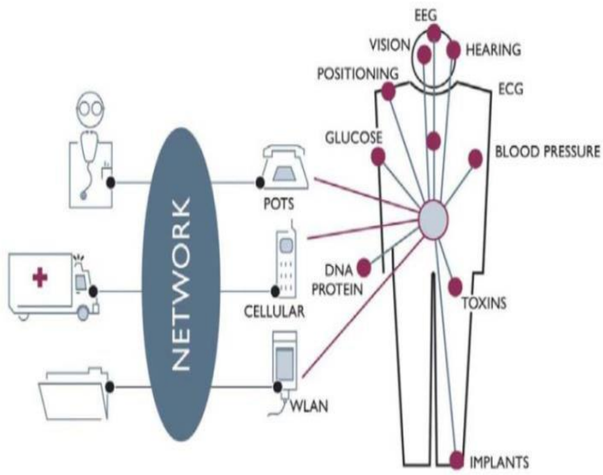

Fig. 2 Wireless Body Sensor Networks transmitting signals to a remote location.

In this paper, a survey study which points to the remote diagnostic system for EEG data is proposed which captures the brain signals through EEG electrodes and analyzed them for some abnormal activity and alerts the physician by sending him the activity data. If in case, it finds some abnormal brain activity.

Moreover, application software for the mobile device is also proposed which will help the doctor to view and analyze the received data in a user friendly environment.

II. PROBLEM FORMULATION

Currently, there are many developed systems that transmit the human body activity data through Wireless Body Area Networks. These systems usually capture the data from Body sensors such as EEG electrodes and transmit them to the remote devices through some communication medium e.g. Internet, Bluetooth and ZigBee but they do not analyze the data at their own.

The need for the proposed system came from the concept that there should be some intelligent devices which captures data as well as analyze it and transmit it; in case of any abnormality in data. This will automate a major part of the data analysis and also will be more cost effective and efficient in terms of data transmission.

Unlike ECG, EEG is hard to read and proper training is required to understand EEG signals.

In general nursing, even normal doctors do not read and understand EEG signals. Only neurologists, neuro-scientists, neurosurgeons and EEG trained doctors and nurses can read and understand EEG signals. This problem substantially reduces the number of medical professionals who can read and understand EEG. According to a survey in 2011 there is only 1 neurologist per 20,000 populations in Holland whereas it is only 1 per 150,000 in the UK that can handle and understand EEG signals [29].

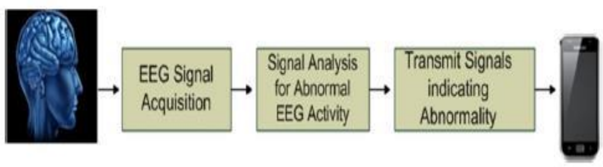

Fig. 3 Block Diagram of the Proposed System

III. LITERATURE REVIEW

An extensive study has been done on the different techniques being deployed for the analysis of real time EEG signals as well as different protocols being used in wireless communication for transmission of the signals.

N.Pradhan [7] used Artificial Neural Networks to detect Seizure Activity in EEG Signals. They used a neural network named Learning Vector Quantization (LVQ). Their system was trained on the data of a single individual and was capable of detecting Epileptiform Discharges (EDs) of other individuals. The sensitivity and specificity was comparable to that of expert visual analysis.

Q. Hao and J. Gotman [8] developed an algorithm for the early detection of an epileptic seizure. Their algorithm used the method of template matching to detect seizure onset. In this method they recorded the onset of a seizure of a specific patient and then compared the long term EEG recordings in epochs with that template. The algorithm checks for the following features of each epoch for each EEG channel: average wave amplitude, average dominant frequency, and average wave duration, average power in a main energy zone and the brain region is involved in a seizure. The system use to generate an alarm in case of a good match. Their method was capable of 100% detection rate for a specific patient patient's template as compared to the previous methods which have detection rates of up to 83%.

Petrosian D [9] applied Recurrent Neural Networks in combination with the Signal Wavelet Decomposition Sub bands as an input to the training of Recurrent Neural networks. They showed that existence of some minutes of pre-ictal stage before an epileptic seizure is quite feasible and can be predicted. It was the signal's high frequency component that makes the prediction feasible.

T. Gautama [10] used the "delay vector variance” DVV method for EEG signal characterization to perform a non-linearity analysis. The aim was to verify that the time series was generated by a linear stochastic system. Surrogate data method was used for assessing the non-linearity present in the time-series. At the analysis stage, the DVV method was compared to the third-order auto-covariance and the asymmetry due to time reversal methods. The proposed method provided a detail characterization of the EEG time-series to differentiate between epileptic and seizure-free activity.

M.K. Kiyimik [11] used the Periodogram and the Autoregressive Spectral Analysis Methods (AR) as an input to the Artificial Neural Networks and compared them to predict the onset of epilepsy. They found that the signal classification accuracy of AR is better but the processing speed of the periodogram method is much faster. When the time frame is long Periodogram Spectral Analysis Methods gives better results but when the number of samples is less AR modeling gives better results.

N. F. Guler [12] used the non-linear dynamics tool named Lyapunov Exponent and the Elman Recurrent Neural Network to discriminate the normal EEG signal and the epileptic EEG signals, their results showed that the RNNs achieved higher accuracy rates as compared to the feed forward neural network models. This shows that the RNNs employing the Lyapunov exponents can be useful in the early detection of the electroencephalographic changes.

R. Uthayakumar and P. Paramanthan [13] used the autocorrelation functions to the brain activity and applied the clustering techniques to locate the critical cortical sites in a brain. Their algorithm gives accurate dimensions and the time complexity in the signals is very low. This method was also useful in identifying the exact seizure portion in the human brain.

Srinivasan [14] employed a special recurrent type of neural network termed as Elman Network (EN) to detect an epileptic seizure. They used pre-processing EEG patterns of 1 s each for training. Two time-domain features and three frequency-domain features were used for evaluating the performance of the system. Five types of training schemes were tested & employed and they found that the accuracy of the epileptic detection can be achieved at 99.6% even with a single input feature which was better than found that of using LAMSTAR with two input features. This can be a very fast method to be used in real time processing.

R. Oweis and E. Abdulhay [15] applied the Hilbert - Huang transform to classify the normal and ictal activities in the EEG signals. Through this technique they tracked the amplitudes and frequencies of the signals made a comparison using t-test and Euclidean Clustering lead to a précised & accurate 94% and specific 96% results. Their proposed system was capable of fast diagnostic, high accuracy, good sensitivity and specificity.

M.V Yeo [16] proposed an automatic method to detect drowsiness during driving using Support Vector Machines (SVM). The experiments were performed at about on twenty human subjects while driving with EEG monitoring. Alert EEG was marked by the sign, the dominant eta activity while the drowsy EEG was marked by alpha dropouts. SVM was trained by using the samples from both the data sets using a distinguished criterion of four frequencies across four principle frequency bands. The classification accuracy of the system came out to be 99.3%. It suggested that SVM is a better tool for developing an automatic drowsiness detection system for driving safety.

IV. RELATED WORKS

D. Suresh and P. Alli [19] studied the research issues in the Modern Healthcare Monitoring System Design using Wireless Body Area Networks. They studied various sensors to meet the requirements of the modern healthcare systems. They suggested that wireless sensor based modern health care systems are very important in future to diagnose the patients remotely specially the persons who are unable to conversate or to communicate to the physician such as mentally disordered persons and old aged persons.

A.T. Tzallaset [20] has proposed a method to automatically detect the epileptic activity based on the Time-Frequency analysis and the artificial system Neural Networks. In this method the TF analysis was performed on EEG multiple segments and several features were extracted from the spectrum of the signal. These features were fed into an artificial neural network which classified these segments. This method was tested using four different classifications. The average accuracies were 96.71%, 97.13%, 96.7% and 96.8% for 64, 128, 256 and 512 points length windows, respectively. The limitation with the system was that several artifacts were removed from the database using visual inspection. Moreover in this study, the high frequency components 9 greater than 40 Hz) were neither measured nor taken into consideration. Some further aspects like several different techniques for feature reduction and alternative classification algorithms can be studied and used to make the system more efficient.

F.Gollas and R. Tetzlaff[21] proposed an algorithm for the analysis of brain electrical activity in epilepsy based on the results of spatio-temporal dynamics of the Reaction-Diffusion Cellular Non-Linear Networks (RD-CNNs). The obtained results are given for the intracranial long time EEG recordings for RD-CNN and analyzed by Local Activity theory, but these results are not using the real-time EEG data.

N. Acir and C. Gezelis [22] presented a two stage automatic epileptic spike detection algorithm based on Support Vector Machine. The procedure was divided into two stages. In first stage, a modified non-linear digital filter is used to differentiate between the spikes and the trivial non- spikes. In the second stage, the spikes are separated from each other using the SVM that functions as a post classifier. Visual evaluation by experts confirmed the sensitivity to be 90.3%, selectivity to be 88.1 % and 9.5% as a false detection rate.

H.Chen [23] developed a real-time EEG monitoring system based on Wireless Body Area Networks and ZigBee Internet Gateway. They developed an EEG Sensor Node named zEEG to acquire EEG signals and to filter, amplify and sample them. Then another circuit named Zigbee Internet gateway (ZigW) was used to take data from the EEG sensor node through ZigBee and transmit it to a remote server using Internet. Internet was used as a medium of communication because it is a far and wide spread and cheaper communication infrastructure.

G. Yeongjoon [25] developed a portable wireless electroencephalogram monitor. They used a commercially available WSN device, a Body Sensor Network node and a ZigBee module. The BSN consisted of an ultra-low power microcontroller, 2.4 GHz RF module and a 512 kb serial memory. The BSN node requires TinyOS developed by Imperial College, UK which is a small, an open source, energy efficient sensor and easy board operating system. The signals are acquired by an EEG signal conditioning board which amplifies the signals as well as well as cancels noise. This circuit then transfers the signals to the BSN node which forwards the data through a ZigBee transmitter to another BSN node connected with a PC. They also developed a Microsoft Visual Studio based client application to display the signals at the PC. The system is capable of transmitting the signals into the range of ZigBee which is around 10 to 75 meters.

V. CHALLENGES & RESEARCH ISSUES

The most significant challenge in the project is the analysis of the real time EEG data. A number of methods have been developed and are currently in research phases but the major problem with all of them is that EEG data is very sensitive to analyze because it gets contaminated with noise introduced from artifacts such as eye blinking and so on [3],[5].[26],[27].

Secondly, simple linear techniques are not enough to process the EEG signals because brain produces complex chaotic signals. A number of techniques such as Independent Component Analysis. Principal Component Analysis Approximation Entropy use statistical approaches to find the abnormal activity in the recorded signals, not the real time signals, but in the presence of noise added by the artifacts, the efficiency seems to be very low.

Moreover, selecting a feasible wireless communication protocol is also very important. There are a number of protocols that can be used such as Bluetooth, ZigBee and GPRS etc. The most suitable one will be used depending upon the range, data rate, and cost effectiveness of the communication system.

VI. Hypothesis And Research Objectives

The analysis of EEG signals and then transmitting the analyzed data to a remote location is a new dimension in the EEG research area. This can lead to the quick diagnosis and

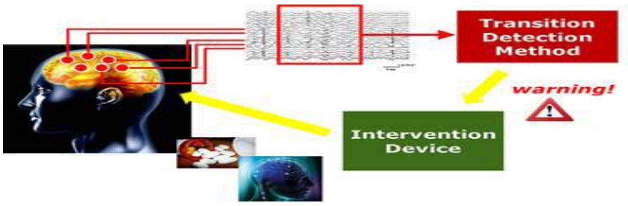

Fig. 4 Detection of Abnormality Alert generation and selection of suitable wireless protocol

warning system for the patients of Epilepsy, frequent drowsiness and other neurological disorders. This system will aid neurologists in effective monitoring of their patients remotely. It will improve the monitoring and treatment applicability of the patients.

The major objectives of the proposed system are as follows:

* To develop and implement an algorithm to analyze real time EEG signals: This will be done by using signal processing techniques to monitor the randomness and abnormality in the signals.
* To choose a suitable telecommunication protocol.
* All the available wireless protocols will be studied and the best one will be selected for this project. The criteria of selection will be based on the range of communication, data rate and cost
* To develop a mobile application for the receiver side to present the data in a meaningful way: The application will be made for cross-platform systems, so that it may be used on all notable platforms.

VII. Methodology

The proposed project will be completed in three parts. First, an algorithm for real time EEG signal processing for abnormality detection will be developed and implemented. Secondly depending on the nature of the results a suitable protocol for wireless data transmission will be selected and implemented. Next, a mobile application will be developed for the Graphical User Interface at the receiver side. This has been shown in the flow chart in the Fig. 5.

VIII. Preliminary Results

EEG recordings of a person using 19 channels Brain Master EEG Amplifier and Neuro Guide Software filtered the data for artifacts like eye blinking and to notable muscle movements. Then used MATLAB to filter EEG recording of a single channel into EEG sub-bands. The results are shown in figures 6 and 7.

IX. Conclusion

This survey study demonstrates that the sensor based healthcare systems is surely be the future trend in the medical

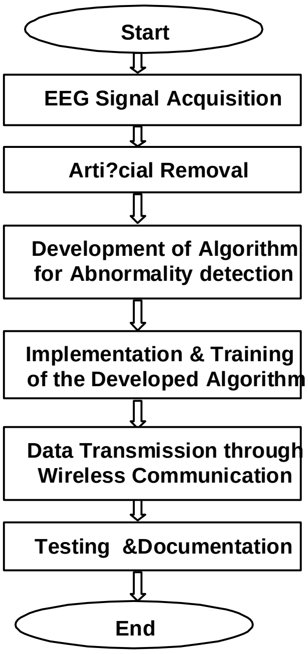

Fig. 5 Methodology Flow Chart

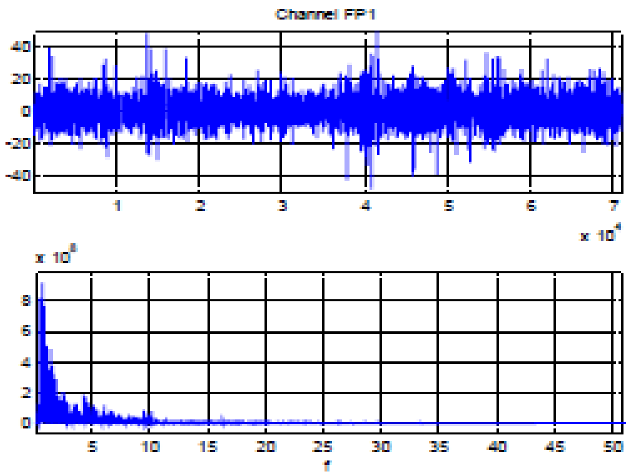

Fig. 6 Time and frequency Domain Plots of EEG Signals of One Channel

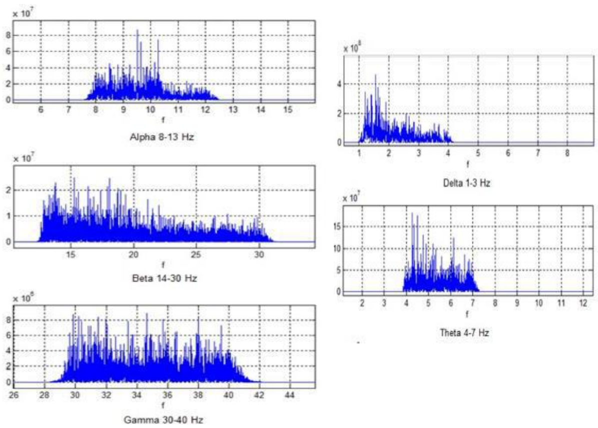

Fig. 7 EEG Signal separated into sub-bands.

and electronics field of study and there is room for further research in this field. In this survey study, previous methods to detect epileptic seizure are compared critically. In addition, a proposed methodology is presented. Currently, we are working on optimizations of different algorithms to obtain better accuracy in detection of epilepsy.

X. Acknowledgement

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Quotations

- It's clever, but is it art?
  Kipling, The Conundrum of the Workshops
- Art is not end in itself, but a means of addressing Humanity.
  M. P. Moussorgsky
- Art is indeed not the bread but the wine of life.
  Jean Paul Richter
- Art is difficult, transient is her reward.
  Schiller
- The artist does not see things as they are, but as he is.
  Alfred Tonnelle
- When a dove begins to associate with crows its feathers remain white but its heart grows black.
  -German Proverb
- If you always live with those who are lame, you will yourself learn to limp.
  Latin Proverb
- He that walketh with wise men shall be wise.
  Proverb. XIII. 20
- I am an atheist, thank God!
  Anonymous
- I don't believe in God because I don't believe in Mother Goose.
  Clarence Drrow
- The fool hath said in his heart, There is no God.
  Psalms CIV I
- That the universe was formed by a fortuitous concourse of atoms, I will no more believe than that the accidental jumbling of the alphabet would fan into a most ingenious treatise of philosophy.
  Swift
- By night an atheist half believes in God.
  Young, Night Thoughts
- Audacity, more audacity, always audacity.
  Danton, during French Revolution
- Fortune favors the audacious.
  Erasmus
- Every great advance in natural knowledge has involved the absolute rejection of authority.
  Huxley, Lay Sennons
- All authority belongs to the people.
  Jefferson
- The highest duty is to respect authority.
  Pope Leo XIII
- He who writes prose builds his temple to Fame in rubble; he who writes verses builds it in granite.
  Bulwer-Lyiton
- The pen is the tongue of the mind.
  Cervantes, Don Quixote