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Research Article

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A novel adaptive system proposal for seizure prediction and alarm for epileptic patients using EEG signals

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ABSTRACT

Epilepsy is a major neurological disorder causing sudden or recurrent seizures. The seizures cause an abrupt loss of motor control and prove to impact fatal consequences or hazardous situations in patients. These seizures occur without any warning, forcing the patients to develop an anxiety in their daily life. This proposed system shall predict and alarm the patients or care-takers to improve the patients' quality of life and safety. An EEG (Electroencephalogram) electrode cap is attached to the patient's scalp connected to a battery powered flat, shock-proof, battery powered system. The system is attached to patients back as parachute is attached in air divers. The system uses grid SVM (Support Vector Machine) technique to analyze the EEG data acquired for early prediction of seizures. The patient is subjected to continuous analysis for a week or minimum of three seizure occurrences in the clinic. The inter-ictal pattern just before the pre-ictal period or pre-ictal pattern is stored in the pattern storage module a reference pattern. Now the adaptive system is ready to use out of clinic or hospital care units. The periodically generated pattern shall be checked with reference patterns. Alarm is given when pattern matching is found and band power of beta waves is high. This system is adaptive due to pattern recognition technique.

Keywords: EEG, iEEG, SVM, seizure, epilepsy

INTRODUCTION

Epilepsy is second most serious neurological disorder that brings high risk of mortality in humans next to that of brain stroke. Nearly 60% of the epileptic seizures are convulsive, that produces violent uncontrollable movements of the affected epileptic patients. The other 40% are non-convulsive that may cause only unconsciousness or decreased level of consciousness lasting for shortest period of time. The convulsive epileptic seizures fall under a category of diseases that causes death or increasing risk factors leading towards death. Thus convulsive epileptic seizures are to be the primary factors to be diagnosed and treated to avoid risks of epilepsy being fatal.

Human brain controls other voluntary and involuntary organs by providing them with proper signals. The signals may be in the form of electrical impulses, chemical neuro-transmitters and receptors, electric fields, bio-photons etc. For past few decades, many researches had analyzed the electric fields using Electro-encephalography (EEG) or Magneto-encephalography (MEG) and had been working on it. These methods are to be one of the prominent methods used in the field of medicine in diagnosis of brain signals.

A. Major Causes of Epilepsy

Epilepsy affects more children than adults. Cause of epilepsy is still unknown but some of the factors can be listed as following.

B. Genetically Influenced Epilepsy

As per my verbally inquired survey in nearby localities, out of 48 epilepsy affected children, 18 had reported that their parents had epilepsy during their childhood days. They also reported that the epilepsy subsided as the child entered adult phase.

The other factors may be Brain cell disruption during formation of embryo, Genetic conditions such as tuberous sclerosis, Major or Minor accidents that affect the brain cells of the fetus during pregnancy, side-effects of medications that affect the fetus during pregnancy, low oxygen during birth, infections like meningitis, Brain tumors, stroke, abnormal levels of vital substances in blood, increased level of mental stress in day-to-day life, allergy to drugs or hyper dosage of medications, severe head injuries.

C. Frequency of seizures

For frequency of seizures, a local survey was done for about considering 90 patients. Nearly 84 patients rarely had convulsive seizures of once or twice in a year. The remaining 6 patients were children below 10 years of age and had frequent attacks of once in two weeks or once in a month. This might be an approximate survey detail, but it shows us clearly children were most prone to such convulsive frequent seizures. The seizures in children lasted for about 2 minutes and the impact of the attack was heavy that their conscience returned after 3 hours or so. The survey also inferred that a few of people who had seizures frequently were stressed mentally due to their livelihood. Parents of the epileptic children were stating that they had no prior information of the seizure attacks in their children.

D. Types of Epileptic Seizures

Epileptic seizures are of six types [1]. They are Tonic-clonic, Tonic, Atonic, Clonic, Myoclonic and Absence seizures. Tonic refers to seizure characterized by muscle stiffening; Atonic refers to loss of muscle tone in legs or arms resulting in sudden fall; Clonic refers to rhythmic jerks that involves in both sides of the body; Myoclonic refers to non-continuous sudden jerks that may resulting in involuntary actions like dropping or throwing materials in hand; Tonic-clonic being a general seizure refer to clonic seizures followed by tonic seizure that may result in tongue biting or uncontrolled urinary bladder; absence seizures refer to short loss of consciousness without any sign of other seizures.

E. Components of EEG signals

The primary components of EEG signals consists of five major useful waves alpha(α), beta(β), gamma(γ), theta(θ) and delta(δ). The predominant frequencies and amplitudes of the wave components are shown in Table 1. (Arranged in order of increasing Frequency). The data given here are of a normal human who is not a patient of any neurological disorder.

TABLE 1. EEG SIGNALS - FREQUENCY BANDS AND AMPLITUDE (NORMAL) [6]

WAVE COMPONENTS	FREQUENCY BAND/RANGE [IN HZ]	AMPLITUDE /RANGE [IN μV]	PROMINENT LOBES OF OCCURRENCE
δ (Delta)	0.1– 4	20 – 200	-
θ (Theta)	4 – 7.5	10	-
α (Alpha)	8 – 13	2-100	Occipital & Parietal
β (Beta)	14 – 26	5 – 10	Frontal & Central
γ (Gamma)	30- 45	-	-

F. Tapping EEG Signals

In scalp EEG, electrodes that trap electrical field emission of brain shall be placed on the subject's skull at various nodal points as shown in the Fig. 1. This scalp EEG is a non-invasive method and invasive intracranial EEG (iEEG) can also be used.

A processor operated waveform analyzer, is able to display the wave patterns sensed by each electrode individually from their respective node–skull juncture. This enables to study the wave pattern generated by particular lobe of the brain effectively and efficiently. The wave patterns infer about the activity regarding the lobe functions. Numerous researchers had analyzed the lobe functionality and their patterns emitted in different circumstances experienced by the subject at various testing conditions.

Epilepsy in Children is most vulnerable and prediction of epileptic seizure is a must to ensure their safety. Children shall never subject themselves to continuous hospitalization. Thus a system should be developed to ensure their safety by alerting ictal period of the seizure by early predicting it in inter-ictal period or pre-ictal period itself. This adaptive system is being suggested and proposed in order to alert or warn the parents or care-takers of such children to avoid risks during seizures.

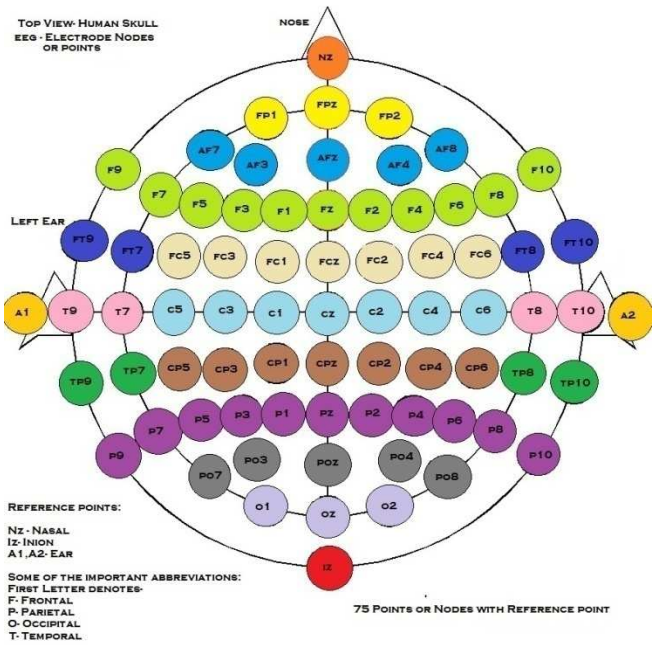

Fig 1. Schematic view EEG Nodes or points [2]

This system was inspired from suggestions given by parents of a local survey done with 48 children (already quoted in introduction). They all were insisting that safety of unattended children with epilepsy was at risk and was a trouble for them to monitor the children always. Thus the system was proposed by using EEG preprocessing, Seizure analysis, Pattern storage, pattern matching and warning alarm.

EXPERIMENTAL SECTION

The proposed system consists of a wearable EEG cap fitted with electrodes well connected to a parachute-bag like structure as in the Fig 2. The prediction system consists of a processor system acting as EEG signal preprocessor, Support Vector Machine (SVM) [4] for feature extraction and synchronized beta band power calculation, pattern storage, pattern recognition and seizure-prediction warning or alarm.

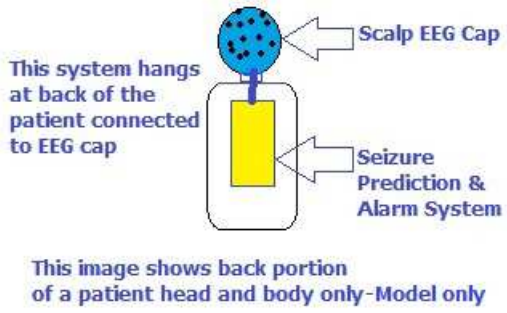

Fig 2. Seizure prediction Alarm System attached to a patient's body

The wearable EEG electrode cap shall not be generalized for all patients. According to previous records of a patient's EEG signals, particular electrode channels are deployed for the patient suggested by the concerned physician. Thus the electrode positions in the cap may vary according to their medical records. Let us estimate at the maximum in this proposed system 16 channels are used due to limited resources of the hardware and to reduce the time latency of the system.

The block diagram shown in the fig 3 shall indicate the process flow of the system.

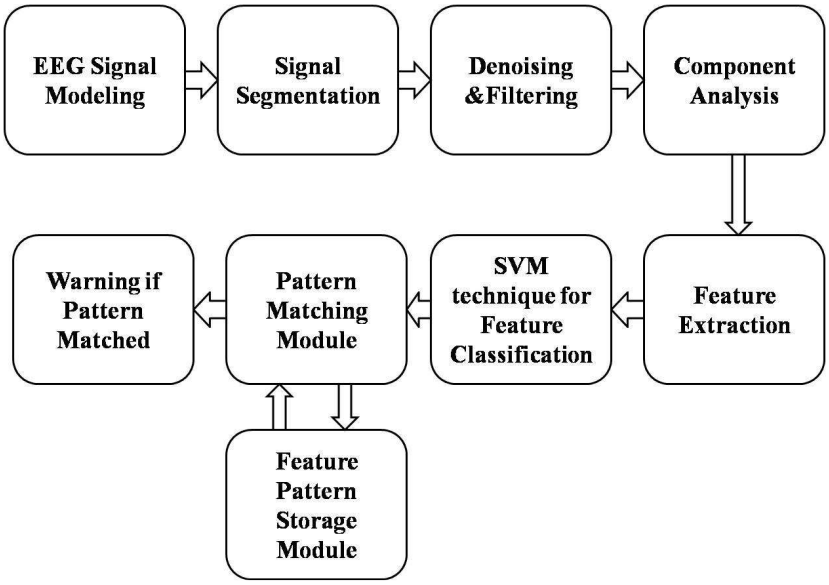

Fig 3. Blocks of Adaptive Seizure Prediction Alarm System [5, 9]

A. ***EEG signal modeling***

A mathematical model showing abnormal EEG signals with all EEG information is formulated. The model shall differentiate EEG signals from noise, background activity, artifacts (signals due to eye blink or heart-beat or line power or equipment radiations or muscular movements

$$X(n) = F(n) + \sum_{i=1}^{n_p} P_i(n - t_{pi+} \sum_{j=1}^{n_a} R_j(n - t_{aj}) + B(n) \quad (1)$$

Where X(n) is sampled EEG signal, F(n) is background activity, P_i is the required abnormal signal, R_j is artifact signal and B(n) is noise signal.[5]

B. Signal Segmentation

Signal segmentation is process which divides EEG signals into segments of similar characteristics such as frequencies and phase.

C. Denoising and Filtering

Denoising and filtering process does remove artifact signals R_j and noise signal B from the segmented signal. Using proper Low-pass filters that allows frequencies below 30 Hz without attenuation shall be employed for denoising and filtering process. Notch filters are used in the case of rejecting 45 Hz to 65 Hz to reject line power artifacts (due to line power of 50 Hz or 60 Hz usage). In case of gamma waves, low-pass filters with cut-off of 100 Hz shall be used. Adaptive Digital filters shall be employed for efficient rejection of noise and extraction of desired EEG signals.

D. Component Analysis & Feature Extraction

Each segment is taken and Band power of each channel in that particular segment is calculated by using spectrum entropy, mean, skewness. Synchronization between all the channels in particular segment is also analyzed.

E. Classification using SVM Classifier Technique

Grid SVM technique has been proved efficient for high specificity and sensitivity [4] and shall be used for classification of unknown data.

F. Pattern storage & Pattern Matching

In clinical process, classified data using SVM technique and using proper prediction algorithm [8] by comparing pre-ictal or inter-ictal phases of three consecutive seizures, a reference pattern is stored. The stored reference pattern is matched with current segment pattern.

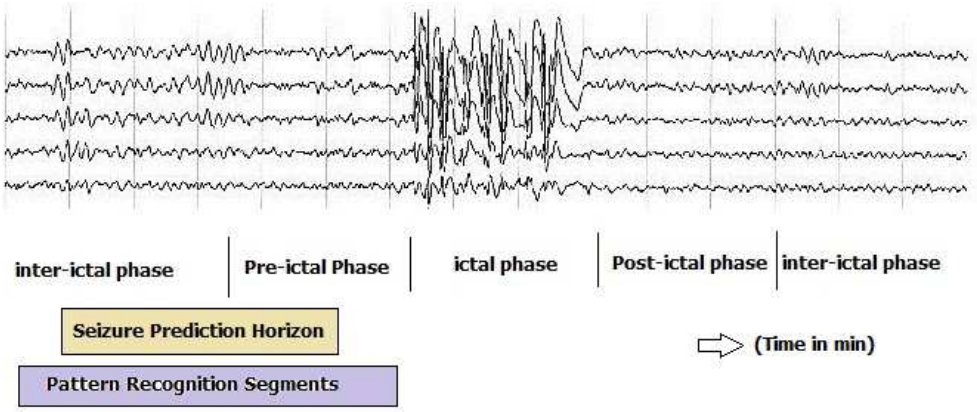

Fig 4. Pattern Recognizing Segments and seizure prediction Horizon

RESULTS AND DISCUSSION

In real-time, the patient is admitted in clinic for training the system and pattern storage. The fig 5 shows the process of pattern storage. Using the same system, reference pattern is collected for minimum of three seizure phases. The pattern is selected such that it is a repeated pattern in all the three seizure samples and falls in inter-ictal phase to pre-ictal phase junction as shown in the fig 4 as pattern recognition segments. This pattern is stored as reference pattern in the system.

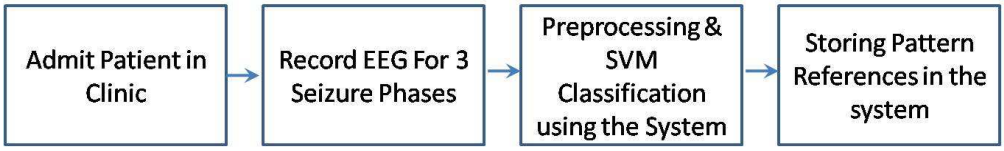

Fig 5. Clinical process for preparing the system to function as standalone

As shown in fig 6, the system calculates and classifies the EEG signals according to band power (primary) and other features [7] and then simultaneously pattern of current segments are matched with reference segments. The pattern matching provides a warning signal to the alarm buzzing module and can also give minor warning beeps to the patient and patient's care-takers. This shall caution them for next alarm that buzzes if the band power of the classified signal using SVM is higher that desired reference level. If both the alarms are invoked, there shall be a possibility of seizure within a few minutes. This shall provide safety and security to the patients. If the patient is a child or children below thirteen years of age, the alarms shall be useful for the care-takers to monitor them with safety. The alarm or warning shall also given through mobile and other communication gadgets to alert the care-takers who are in reachable distance.

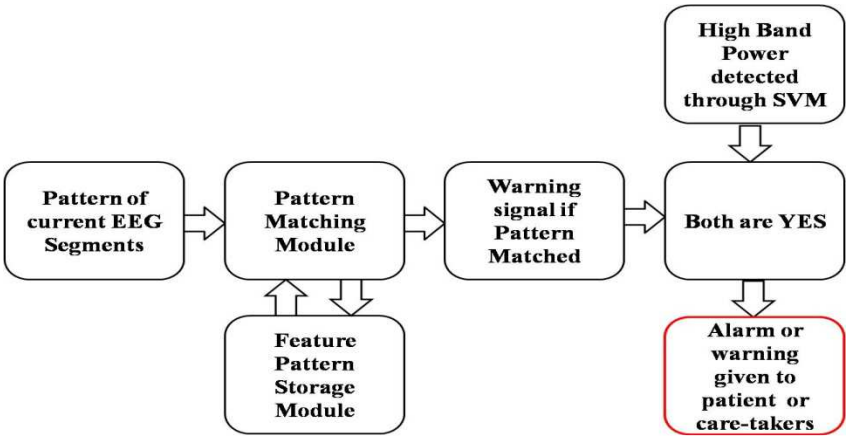

Fig 6. Real-time Alarm or warning Process in the adaptive system

CONCLUSION

This proposed system in real-time shall handle the transitional change of beta band power from inter-ictal period to pre-ictal period. The system becomes adaptive because it recognizes the current pattern with reference pattern and then produces a warning signal. The system hardware shall become complex when the channels of EEG are more in number. Even gadgets like tabs can be used with MATLAB programming for signal processing. The proposed system in real-time shall be very useful for the parents and care-takers of children who are affected with epilepsy.

ABBREVIATIONS

EEG- Electro-EncephaloGraphy, MEG – Magneto-EncephaloGraphy, iEEG-Intracranial Electro-EncephaloGraphy, SVM-Support Vector Machines

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