MULTIMODAL SYSTEM TO PREDICT EPILEPTIC SEIZURES USING MACHINE LEARNING TECHNIQUE

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Abstract— In this paper we proposed a method to an automatic prediction of epilepsy using Multimodal signal. Major aim is to develop a new wireless sensor based system for detecting and monitoring epileptic patients in a non-clinical environment. In order to achieve this, a mechanism will be developed for capturing multi-modal data such as electroencephalogram (EEG), electro dermal activity (EDA), accelerometry (ACM) and heart beat from epileptic patients using EEG cap and wrist-worn biosensor. The captured multi-modal data from sensors will be sent to smart phone through wireless transmission for processing Support Vector Machine (SVM) will be developed and used as classifier The proposed system will sense the aura of pre-ictal stage in advance and takes the necessary safety measures such as alarm, sending SMS along with location information using GPS to emergency medical service, relative and doctor automatically, in order to prevent Sudden Unexpected Death in Epilepsy (SUDEP).

Keywords—Electroencephalogram (EEG)signal classification, epilepsy / seizure detection, Support Vector Machine (SVM), Sudden Unexpected Death in Epilepsy (SUDEP).

I. INTRODUCTION

Epilepsy is one of the most common serious neurological disorders that have potentially deadly consequences. Epilepsy is a disorder of the brain characterized predominantly by an enduring predisposition to generate epileptic seizures transient manifestations of abnormal, excessive or synchronous neuronal activity in the brain. Epilepsy is not one condition, but a variety of disorders reflecting underlying brain dyes-function that may result from many different causes. In children and young adults, epilepsy is often attributed to birth trauma, congenital abnormalities or genetic disorders affecting the brain. Nonetheless, more than half of the time the underlying cause is unknown. Moreover, the risk of sudden death in people with epilepsy is 24 times higher compared to the general population and the pathophysiology of sudden unexpected death in epilepsy (SUDEP) remains unclear. Epilepsy imposes huge physical, psychological, social and economic burdens on individuals and their families monitoring the patient’s EEG for several days is often needed for diagnosis and identification of the epileptic seizures. This process is tedious, expensive, and time-consuming. Accordingly, a reliable real-time seizure-detection system would facilitate long-term monitoring and treatment of seizures. Moreover, provided the partial seizure is detected at the initial steps of its development its primary focus could be localized based on the clinical symptoms and the EEG patterns, which is helpful in pre-surgical evaluations.

To provide wireless communication channel low cost network using MiWi protocol is utilized. MiWi is a standard protocol developed by Microchip Inc, USA, based on IEEE 802.15.4. Heart beats are to be monitored continuously. Any sudden variation in heart beat which is caused by the onset of epileptic seizures is detected and confirmed with the MEMS signal. When the seizure is confirmed, message is transmitted to the surroundings for initiating necessary protective measures for the patient. The device is designed as wireless, wearable and personal equipment. The device can sense the aura of pre ictal stage in a few minutes advance and takes the necessary safety measures automatically. Hence a technician’s assistance is not required for the patient. Therefore this device will be extremely useful for patients (especially youngsters) who wish to be active in their life. The user gets absolute freedom from wires and can be used when moving. It will be helpful for the person who suffers from the seizure, and also the patient can be easily taken away from the source point of attack to the nearest hospital and the data which was recorded in the Micro SD card for the future reference of the patient.

The products or the information which we are using in our project is EEG cap, EDA sensor, wireless transmitter, GPS locator for information collection and transmission. Previous system that we studied are not comfort and resistant in high level and vary to change according to patients seizure level.

II. ELECTROENCEPHALOGRAPHY (EEG)

The EEG is the most important clinical tool in evaluating patients with suspected seizures. Figure 1 illustrates EEG recording of a normal brain showing no unusual activity. Apart from the patient history and the neurological exam, the EEG (electroencephalograph) is the most influential tool in the diagnosis of seizures and epilepsy [6]. It provides a record of ongoing electrical activity in the brain. An EEG machine is a recording device connected by wires to electrodes pasted at key points on the patient's head. The electrodes pick up signals produced by electrical discharge of neurons in the related areas of the brain; the amplified signal from each electrode causes pens writing on a moving belt of paper to jump—similar to the action of a seismograph when an earthquake occurs.

The resulting EEG tracing, with its record of electrical discharge, provides a record of activity in key areas of the brain during the period of the test. Excessive discharge (of the type that, if large enough, might cause a seizure) may show up as a sharp spike or series of spikes; some patterns (such as the 3-per-second spike and wave of absence seizures) are unique to particular forms of epilepsy.

EEG recordings of patients while awake are made with the eyes open and with the eyes closed. A flashing light is used to assess whether the patient is photosensitive—that is, if he or she will have a seizure in response to the stimulus of a flashing light.

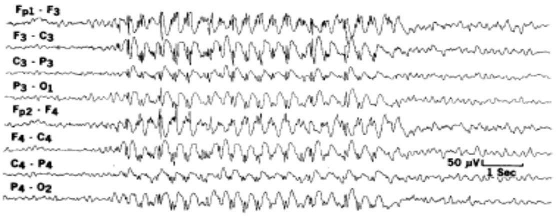


Figure 1: EEG recording of an absence seizure showing the distinctive 3-per-second spike and wave discharge

Not all seizures are due to epilepsy. There are other medical conditions that might cause someone to have a seizure for example, diabetes. The difference between epileptic seizures and other seizures is that epileptic seizures are caused by a disruption in the way the brain is working. The fact that epileptic seizures always start in the brain is important when considering the EEG. An EEG looks at what is happening in the brain – the activity of the brain cells. It does not look at the structure of the brain (how the brain is made up).

The electrical signals from the brain are picked up by small electrodes (about one centimetre across), which are placed on the person's head. The electrodes only record the electrical activity of the brain; they do not give out electricity. The electrodes cannot pick up the electrical signals from individual neurones – the cells are far too small and the electrical charge is also too small. Instead, they record the electrical activity from small areas of the brain. The EEG shows brain function, and looks for the presence or absence of specific brain activity in specific areas of the brain. The EEG cannot interpret what the messages are 'saying' (or what you are thinking!), only that brain activity is happening.

Because the electrical signals are still quite small, they are amplified (made stronger) so that they can be recorded. The activity is recorded on an electroencephalograph either on paper or more usually on computer.

Despite some limitations, however, the EEG remains the most important clinical tool in evaluating patients with suspected seizures.

III. ELECTRODERMAL ACTIVITY

Electro dermal activity (EDA) is a sensitive index of sympathetic nervous system activity. Due to the lack of sensors that can be worn comfortably during normal daily activity and over extensive periods of time, research in this area has traditionally been limited to lab settings or articial clinical environments. In this chapter, we describe a novel, unobtrusive, non-stigmatizing, wrist-worn integrated sensor and present, for the very rest time, a demonstration of long-term (multi-day), continuous assessment of EDA outside of a lab setting. In general, regulation of physiological states of arousal is achieved by a balance of activity within sympathetic and parasympathetic subdivisions of the autonomic nervous system (ANS). While the parasympathetic nervous system promotes restoration and conservation of bodily energy, the sympathetic nervous system stimulates increased metabolic output to deal with external challenges. As such, increased sympathetic activity (sympathetic arousal) elevates heart rate, blood pressure and sweating as well as redirects blood from the intestinal reservoir toward skeletal muscles, lungs, heart and brain in preparation for motor action. Sympathetic postganglionic consisting of non-myelinated class C nerve surround eccrine sweat glands and their activity modulates sweat secretion. Since sweat is a weak electrolyte and good conductor, the sweat ducts results in many low-resistance parallel pathways, thereby increasing the conductance of an applied current. Changes in skin conductance at the surface, or more generally in to as EDA, react activity within the sympathetic axis of the ANS and provide a sensitive and convenient measure of assessing alterations in sympathetic arousal associated with emotion, cognition and attention.Stress is generally denied as a disruption of the autonomic balance involving a state of high sympathetic activation. Given that EDA is solely determined by the activity of the sympathetic branch of the ANS which is predominant in stress states, tonic EDA parameters may be regarded as suitable measures of ANS activity induced by stress. The hypothalamus, which is responsible for ANS activity, plays a major role in eliciting ipsilateral EDA under the direct in of limbic structures. These in uences appear to stem from antagonistic actions of the amygdala (excitatory) and hippocampus (inhibitory). Autonomic responses in the skin such as sweating, piloerection and vasomotor changes can thus be elicited by various emotional states via the Papez circuit in the limbic system [9]. In addition, it is widely recognized that attention-grabbing stimuli and attention demanding tasks also evoke increased EDA responses. Despite improvements in measuring equipment since the discovery of electrodermal phenomena more than 100 years ago, much of the research in this area is limited to observational measurements performed over short periods of time in lab settings or artificial clinical environments. The need for monitoring patients over extensive periods of time has stimulated interest in wearable unobtrusive devices that can be worn during normal daily activity to gather physiological data over periods of several weeks or months Long-term monitoring of EDA will allow the observation of patterns of sympathetic arousal and regulation at a significantly longer time scale (days to months) compared to existing studies (minutes to hours) and could potentially reveal previously unobservable trends. In addition, long-term measurements taken in a person's natural home environment also provide a clearer picture of the person’s physiological state than a short period of assessment in an unnatural clinical setting. Clinically, wearable EDA sensors can be used in psychopathology, dermatology and neurology for diagnostic purposes and therapy evaluation. Potential clinical applications include screening for cystic brosis, classification of depressive illnesses, prediction of functional outcome in schizophrenia, discrimination between healthy and psychotic patients, characterization of sympathetic 42 arousal in autism, early diagnosis of diabetic neuropathy and providing biofeedback in treating chronic hyperhidrosis, epileptic and psychogenic non-epileptic seizures. To achieve widespread, continuous and long-term assessment of EDA, there is a need for a sensor that not only is low-cost, compact, and unobtrusive, but also comfortable to wear and non-stigmatizing to the user. In this chapter, we present a novel solution in the form of a wearable and fully integrated EDA and accelerometry sensor that full these characteristics. The study focuses on comparing the performance of the proposed system with an FDA-approved EDA measurement system during classic arousal experiments involving physical, cognitive and emotional stressors. We validate the performance of the proposed sensor during EDA measurements from traditional palmar recording sites. In addition, we study the use of the ventral side of the distal forearms as a recording site for EDA measurements that is non-encumbering. We also investigate how the choice of electrode material a performance by compare the use of conductive fabric electrodes to standard Ag/AgCl electrodes. Finally, we present a weeklong recording of EDA during daily activity. To the best of our knowledge, it is the demonstration of long-term, continuous EDA assessment outside of a lab setting.

IV. HEART BEAT SENSOR

The heartbeat of the patient is to be monitored accurately. For this purpose, a pulse oxy meter is used. Pulse oxy meter measures heart beat by sensing the difference in absorbance of infrared radiation by blood during systolic and diastolic activities of heart. The volume of blood flowing through arteries varies widely during each heartbeat. Hence if infrared radiation is incident on it, the absorbance of IR also varies according to the heart beat. These variations are sensed using a photo detector to determine the heartbeat.

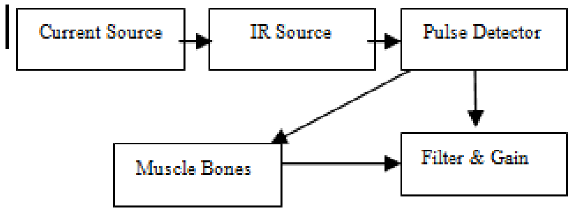


Figure 2: Pulse Oxy meter and its principle of operation

The pulse oxy meter designed here works using reflective principle. The IR source emits IR radiation which is reflected in accordance with the flow of blood. The reflected rays are detected using a photo detector. A sensor is placed on a thin part of the patient's anatomy, usually a fingertip or earlobe, and light of infrared wavelength is made incident on the body. Changing absorbance of the infrared is measured, allowing determination of the absorbance’s due to the pulsing arterial blood alone, excluding venous blood, skin, bone, muscle, fat, and (in most cases) fingernail polish. The circuit of pulse oxy meter consists of a trans-resistance amplifier, voltage follower, difference amplifier, and filter. All these stages are cascaded together to from the complete circuit of pulse oxy meter. The circuit works in 5 V supply. In order to get perfect amplification sans noise, ultralow offset operational amplifier OP07 and FET input operational amplifier LF 356N is selected. A trans resistance amplifier is used in the first stage to convert the photodiode current to voltage. The major design parameter of this sensor is its output voltage and the output frequency. The output frequency is band limited to 15 Hz using filters. Low pass first order butter worth filter is used. Low pass filter is designed at 15 Hz upper cut off frequency with a gain of 1.5. A high pass first order butter worth filter with lower cut off frequency of 0.5 Hz is cascaded with the low pass to remove the dc voltage. An amplifier is set at the output of the meter in order to raise the output signal level to +5V (approx). Amplifier with amplification factor of 50 is designed. Typical output of the sensor is shown on the graph below. Normal heart beat is 72 beats per minute. That is the frequency of the signal is 1.2 Hz for a healthy person. The output amplitude varies from 70mV to 120mV.

V. MICRO ELECTRO MECHANICAL SENSOR

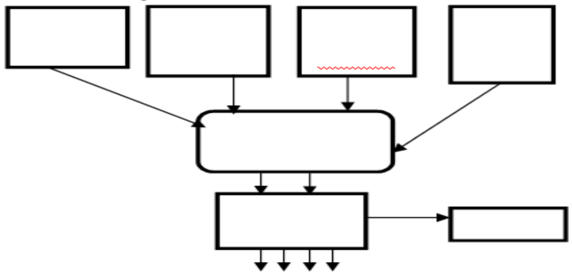
Seizures are involuntary muscular movements which occur during epilepsy. Muscular movements are sensed using MEMS (micro electro mechanical sensor) accelerometer. A 3D accelerometer is used to sense the muscular movements. The ADXL330 is a low cost, low power, complete 3-axis accelerometer with signal conditioned voltage outputs, which is all on a single monolithic IC. The ADXL330 is a complete acceleration measurement system on a single monolithic IC. The ADXL330 has a measurement range of ±5 *g*. The sensor is a polysilicon surface-micro machined structure built on top of a silicon wafer. Polysilicon springs suspend the structure over the surface of the wafer and provide a resistance against acceleration forces. Deflection of the structure is measured using a differential capacitor that consists of independent fixed plates and plates attached to the moving mass. The fixed plates are driven by 180° out-of-phase square waves. Acceleration deflects the beam and unbalances the differential capacitor, resulting in an output square wave whose amplitude is proportional to acceleration. Phase-sensitive demodulation techniques are then used to rectify the signal and determine the direction of the acceleration. The demodulator's output is amplified and brought off-chip through a 32 kΩ resistor. The signal bandwidth of the device is set by adding a capacitor This filtering improves measurement resolution and helps prevent aliasing.

VI. DESIGN OF WEARABLE BIOSENSOR

We propose an Idea for Ubiquitous health care systems to provide a smarter and cheaper way to efficiently deal with patients suffering from chronic diseases. For implementation of this system wireless wearable or implantable sensors required to monitor patient activities. In this we use a multimodal system to measure various parameters .Mainly EEG cap, Pulse oxymeter, MEMS sensor, *EDA* Biosensor and extravascular monitors. In following sections a brief survey of wearable sensors will be given regarding their design.

VII. DESIGN OF PROPOSED SYSTEM

In our Proposed System we combine four main measurable parameters (EEG, EDA, and Muscular Movements, Heart beat) to detect epilepsy. When the four parameters matched to the test data feed up then the system works to prevent the person. The proposed system will be implemented and evaluated based on performance indices such as sensitivity, specificity and accuracy parameters, Our sensor measures exosomatic EDA (skin conductance) by applying direct current to the stratum corneum of the epidermis beneath measuring electrodes. To achieve a wide dynamic range of skin conductance measurements, the analog conditioning circuitry utilizes non-linear feedback automatic bias control with low-power operational amplifiers. In addition, the sensor module also contains a tri-axis accelerometer for measurements of physical Activity (actigraphy). A microcontroller digitizes the analog signals via a 12-bit A-D at a sampling frequency of 20 Hz. The data is then written to an onboard microSD card. We integrated the sensor module into a regular wristband made out of terrycloth, resulting in a comfortable, attractive and lightweight wearable sensor (Fig. 1). Since all electronics and wiring are concealed within the wristband, the resulting device is inconspicuous, non-stigmatizing and allows for discrete monitoring of EDA. Furthermore, the electronic module can be easily detached when the user desires to wash the wristband. We used Ag/AgCl disc electrodes with contact areas of 1.0 cm2 for our recordings as recommended in the literature. These electrodes are disposable and can be snapped onto or removed from the wristband with ease. Although the electrodes are commonly placed on the palmar surface of the hand, we use the ventral side of the distal forearms as recording sites. Placement of electrodes on the forearm are less susceptible to motion artifacts and highly correlated to palmar recordings. A 3.7 V lithium polymer battery with a capacity of 1100 mAh provides around 40 hours of operation; the battery can be recharged via a micro-USB cable.



Uplink to corresponding terminals

Figure 3:Multi-Modal System to process Epilepsy sample data

VIII. WEARABLE SENSOR

User comfort is a major consideration in the design of any wearable device intended for long-term and continuous use. Regardless of the capabilities of a wearable system, users will not be inclined to wear them on a daily basis over a period of

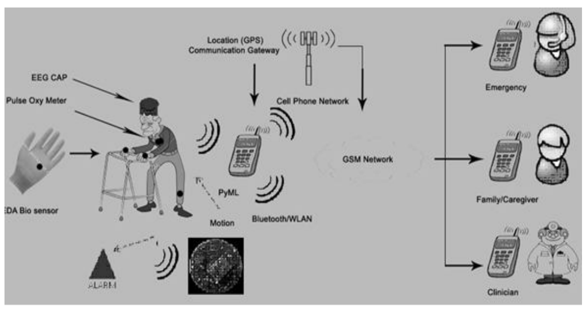


Figure 4: Illustartion of the Overall System

days or weeks if the sensors are bulky and cumbersome. In view of this, we integrated the electronic module into a regular wristband made out of terrycloth, resulting in a comfortable, attractive and lightweight wearable sensor. Since all electronics and wiring are concealed with in the wristband, the resulting device is also inconspicuous, non-stigmatizing and allows for discrete monitoring of EDA. Furthermore, the electronic module can be easily detached when the user desires to wash the wristband.

IX. PROCESSING UNIT

The processing unit contains PIC 18F4620 microcontroller which is clocked at 40 MHz. PIC18F4620 have 64 Kbytes of Flash memory. The microcontroller has inbuilt 10 bit ADC which is used to digitize the output from Multimodal System. It also includes a comparator which is used to process the heart beat waveforms from the Pulse oxy meter, EEG, EDA, Muscular Motion. The incoming signal is processed using logics implemented in the software which runs the device. The processing unit continuously checks for symptoms in the incoming signal. As soon as it detects any abnormality, it triggers a warning vibrator and the wireless transmitter.

X. WIRELESS TRANSMITTER AND RECEIVER

Wireless transceiver consists of a board consisting of MRF24J40 IC. The transmitter transmits a coded signal which is decoded by a receiver to generate control signals. The control signal activates an alarm device, mobile messaging device and automatic vehicle control system appropriately. Apart from the above important blocks, a buzzer circuit and a DC to DC convertor blocks are also implemented. With those a GPS Tracker also attached for searching the exact location of the patient.

XI. MOBILE SOFTWARE DEVELOPMENT

Developing the system to incorporate real-time classification of EEG data required a number of steps. Firstly, this required a direct connection between PC and the Emotiv EPOC over Bluetooth had to be established, and values sensed from the Emotiv EPOC at a rate of 128Hz. The Captured signals are classified using Support Vector Machine (SVM) in PyML (Machine learning in python language). The classified signals are transmitted to the cell phone network from where the signals will received by the corresponding Emergency and to the family members. The signals also used for the GPS location for identifying the exact longitude and latitude of the patient.

XII. MACHINE LEARNING (SUPPORT VECTOR MACHINE)

It is the ability for a machine (ie. computer) to learn from past examples and continually adopt to new situations (information). Machine learning is currently a challenge (read: opportunity for research) in wireless sensor networks, Challenges include battery constraints, radio, communication, slow processors (compared to PCs), and limited memory available. Easy and popular algorithms such k-NN, which assigns the same class to a test point as the majority of its n nearest neighbors, Neural networks were (and perhaps still are) very popular and has been subject to extensive research. More recent research is in the area of kernel learners such as the support vector machine. Clustering: K-means for example, Regression analysis like least-square-regression in the simplest form. Linear and non-linear classification, Instance-based (a good feature for wireless sensors): It allows selected data to be sent around in a sensor network. You can say that the algorithm is somewhat transparent to the existing application, Instead imagine a neural network or some other model based algorithm. It would probably not be immediately clear which 10% of the data points to send from one node to the next. Parameter C controls misclassification behavior / penalty, Parameter controls shape of separating hyper plane.

$$f(\mathbf{x},\alpha,b) = \{f \pm 1\} = \mathrm{sgn}\left(\sum_{i=1}^{l} \alpha_i y_i k(x_i, X) + b\right)$$

XIII. DATA ANALYSIS

All data files were analyzed using custom software written in MATLAB (The Math Works, Inc.). The raw EDA signals were filtered with a 1024-point low-pass filter (Hamming window, cutoff frequency of 3 Hz) to reduce motion artifacts and electrical noise. Pearson's correlation coefficients and the corresponding *p*-values were calculated for the filtered recordings from the different sites and systems as a measure of similarity between signals. Ictal video-EEG recordings were retrospectively reviewed by a team of epileptologists blinded to the EDA data. Each EEG seizure was reviewed for preictal onset and offset times, EEG location and seizure semiology on video recordings. EDA recordings were analyzed using custom written software in MATLAB (The Mathworks, Inc.). EDA recordings were low-pass filtered (1024 points, Hamming window, cut-off frequency of 3 Hz) to reduce motion artifacts. For each seizure, the resulting change in EDA amplitude (difference between response peak and pre-ictal onset baseline) and recovery time was calculated. Recovery time was determined as the time from the response peak to point where EDA fell below 37% of the EDA response peak.

CONCLUSION

In this paper, we have presented a new patient-specific system for the prediction of epileptic seizures. The system has been designed to be suitable for an implantable realization, and hence is characterized by low computational requirements compatible with the possibility of performing real-time analysis. Existing detection mechanism is not compromises of multi data analysis .Electrodes are encumbering, easily lost, and frequently subjected to motion and pressure artifacts, the proposed Multi-modal system does not suffer anywhere near as much from these problems. We have presented a novel algorithm for generalized tonic-clonic seizure detection with the use of the multimodal system. In our proposed system the results we acquired in our device is of approximate 80%, where the device can capable of predicting the seizure correctly, to enhance the 100% result, some additional components and test data has to be added for the better performance of the product. This is the demonstration of the utility of EDA to supplement ACM signals for seizure detection as light weight, rugged, cost-effective wearable device is developed which helps millions of victims of epilepsy around the globe. The With the device in possession an epilepsy victim can move around freely like normal people sans worries

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