Mobile Application based detection of Seizures using Inertial Measurement Units and Emergency Care

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Abstract:-A seizure refers to the changes that may occur in the human body after a brief episode of abnormal excessive or synchronous neuronal activity in the brain. The seizures may be caused due to various reasons and some seizures have an advert effect on the person's health, some causing even death. Thus, it is important to continuously monitor the person in order to prevent so.Currently, for monitoring epileptic seizures, a combination of video and Electroencephalography (EEG) is used. EEG is the recording of the electrical activity along the scalp and it makes use of electrodes that have to be attached to the scalp. This makes it uncomfortable for the patient when he sleeps and this also requires long term home monitoring which is not feasible.Instead of making use of EEG, our objective is to make use of sensors i.e., Inertial Measurement Unit(IMU)to monitor the patient. The IMUs are attached to the wrist and seizures in any direction (X, Y, and Z) can be detected.We also intend to make use of a smartphone application to detect the presence of a seizure,along with a mobile (3G or 4G) network torelay informationurgently from these sensors to the nearest hospital and call for immediate care.

Keywords*: Seizures, EEG (Electroencephalogram),IMU (Inertial Measurement Unit), Accelerometers, Gyro meters, Magnetometers,FFT (Fast Fourier Transform)*

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1. Literature Survey

1. In [1], the EEG was used as a sensor to obtain information about seizures for which software called "OpenViBE" is used in support with the Saolucas Hospital and the Inscer Brain Institute. The automatic spike detection was performed using MATLAB and provided a sensitivity of 90%. This spike detection was performed using private cloud resources. In addition, a smart phone is also used to connect with the cloud and to perform data analysis during emergencies. This approach therefore intends to reach more patients and reduces costs.

2. The EpiCare[1] Free epilepsy sensor is a wrist-worn device from Tunstall Emergency response. It has the ability to detect tonic-clonic seizures in adults and children above the age of 10. The advanced 3-axis accelerometer is able to detect convulsions and vibrations that occur during the seizure. In such a situation, an in-built app on the patient's phone will detect and immediately sends an SMS to the designated people along with the GPS coordinates of his/her location.

3. According to [2], the sensor unit consists of 3 axis accelerometer, microprocessor and a rechargeable battery. Here, the seizure is detected real time by an algorithm that helps the control unit to trigger an alarm. It also creates diaries for patients suffering from frequent seizures so that they can be provided with more attention.

The following researches were carried out:

1. Seventy three consecutive patients (age 6-68 years; median 37 years) at risk of having Generalized Tonic-Clonic Seizures (GTCS) who were admitted to the long term video–electroencephalography (EEG) [3] monitoring unit (LTM) were recruited in three centres. The reference standard chosen was the seizure time points. These were based on the video-EEG recordings blinded to the accelerometers. Seizure time points detected real-time by the sensor were compared with the reference standard. Patients were monitored for 17–171 h (mean 66.8; total 4,878). Thirty-nine GTCS were recorded in 20 patients. The device detected 35 seizures (89.7%). In 16 patients all seizures were detected. In three patients, more than two thirds of the seizures were detected. The mean of the sensitivity calculated for each patient was 91%. The mean detection latency measured from the start of the focal seizure preceding the secondarily GTCS was 55 s (95% confidence interval [CI] 38–73 s). The rate of false alarms was 0.2/day. Our results suggest that the wireless wrist accelerometer sensor detects GTCS with high sensitivity and specificity.

2. Six of 40 patients had a total of eight tonic-clonic seizures. Seven of the eight seizures were detected. Non-seizure movements were detected 204 times, with opportunity for cancelling transmission by the patient. It was observed that only one false detection occurred during sleep [4].

3. Seizure detection results based on the visual analysis of three-dimensional (3D) accelerometry (ACM) and video/EEG recordings [5] are reported for 18 patients with severe epilepsy. They were monitored for 36 hours during which 897 seizures were detected. This was seven times higher than the number of seizures reported by nurses during the registration period. The results demonstrate that 3D ACM is a valuable sensing method for seizure detection in this population. Four hundred twenty-eight (48%) seizures were detected by ACM. With 3D ACM alone it was possible

to detect all the seizures in 10 of the 18 patients. Three-dimensional ACM also was complementary to EEG in our population. ACM patterns during seizures were stereotypical in 95% of the motor seizures.

2. Introduction

3.1 Seizures

Seizures are changes that occur in the brain's electrical activity. Seizures may have dramatic, noticeable symptoms or even no symptoms at all. The symptoms of a severe seizure include violent shaking and loss of control. Mild seizures also cause medical problems and have to be recognized. Some seizures can lead to injury or they are an evidence of an underlying medical condition and it is important to seek treatment when a person experiences it.

3.2 Effects of seizures

Seizures can lead to injury, such as falls or trauma to the body if convulsions are involved. If left untreated, seizures can worsen in terms of symptoms and would become progressively longer in duration. Extremely long seizures can lead to coma or death.

3.3 How are seizures diagnosed?

Doctors can have a difficult time diagnosing seizure types. Lab tests are conducted. They are:

- Blood testing to check for electrolyte imbalances
- Spinal tap to rule out infection
- Toxicology screening to test for drugs, poisons, or toxins

EEG is used to diagnose a seizure. EEG measures the voltage fluctuations resulting from ionic current flows within the neurons of the brain.

Seizure detection in homes is a field of great interest. While the EEG signals are being used to provide real time brain signals to detect on-going seizures, they are uncomfortable to the patient at home. This paper presents the use of a wrist-worn Inertial Measurement Unit as the sensor in place of the electrode caps attached to the scalp. These Units provide real time information regarding the motion of the wrist of the patient. Studies suggest that during a seizure attack, a patient's wrist tends to move at the rate of about 15 times a second. Using this idea, a smartphone application is built to process the data from the IMU and determine the event of a seizure and call for immediate care.

3. Aims and Objectives

Seizures are a common symptom of several disorders as specified above, most common with a neurological disorder called epilepsy. In the neurology department of one of the hospitals, Sao Lucas, there are nearly 200 to 300 patients diagnosed with this disorder. Hence, it is necessary to look for better ways to treat this disorder.

The seizure attacks are dangerous and may also cause death if not treated on time. The electroencephalogram (EEG) is the best way to record and diagnose a seizure activity, but has several limitations including a large amount of data that needs to be manually analysed and the high cost and sophisticated equipment that is required(such as the electrodes).Also, they pose a hindrance to mobility of the patient.
This paper thus deals with an alternative method of detection of such attacks by the use of Inertial Measurement Unit as the sensor. These sensors are lightweight and can be easily worn by the patient on his wrist, unlike electrode caps. Apart from this, a Smartphone application is provided to the patient for identifying the event of the seizure and notifying the nearest hospital using the internet networks. Thus, this paper aims at discussing a closed loop system for seizure patients who require immediate care from the nearest hospital.

This paper thus looks at a better and faster way to treat a patient having a seizure, making use of the mobile applications which make data processing and action faster and simpler, thus providing complete, comprehensive care to the patient.

4. Research Methodology

5.1 Detection based on Wireless Inertial Measurement Unit:

A Wireless Inertial Sensor [11] can be used to detect human body movements. Wireless Accelerometer, Gyroscope, and Magnetometer form the Bluetooth compatible IMU (Inertial Measurement Unit) that can send the real time data from the IMU to the Bluetooth enabled Smartphone device.

In general,the signals from the IMUs can be collected and saved in a flash memory unit and can be sent via Bluetooth to the smartphone.The IMU requirements would include a data-sampling frequency of atleast 20Hz (given that for our application,we consider the possibility of a patient's wrist moving at the rate of 20 times every second during a seizure attack).

The hardware architecture of the IMU consists of an accelerometer connected to the processor through an I^2C module and the gyroscope,magnetometer and temperature readings passed as analogsignals to it.This processor is also connected to a micro SD module,a Bluetooth module and a battery management module [12].It also manages a user-interface which consists of a controller which allows the user to turn off the device when unnecessary.

Sensor requirements:

i. Accelerometers
They measure the linear acceleration whose measurements are required to be accurate.The commercially available accelerometer that serves this application well is LIS3LV02DQ from STelectronics as it has 640Hz of bandwidth that can support this application as it demands a bandwidth of 20 Hz [12].In general,the sensitivity of the accelerometers is required to be at least +/-2 G for a seizure

patient.The data obtained from it has to be digitized and sent to the microcontroller.

ii. Gyroscopes
They measure the angular speed.This application demands a sensitivity of atleast 20 degree per second.

iii. Magnetometers
They are required for the measurement of orientation information.For this application,they require to have a full scale of +/-6 Gauss [12].

iv. Microcontroller Unit
The MCU unit must have atleast 128kB of flash memory and 16kB of RAM memory.It has one ADC with atleast seven input channels of 10 bits because we are assuming seven analog input channels(three each from gyroscope and magnetometer and one from the temperature sensor).The MCU must also allow the sleep mode of operation in order to support power management.

The algorithm used will divide the data into short windows (with atleast 50% overlap to prevent data loss) of around 512 bytes and sent to the micro-SD card [12].Once a window is filled in with data,the microcontroller is alerted and the data is sent via the Bluetooth network to the smartphone.

When a seizure is detected, a Wireless sensor network is used to send an alarm to hospital staff or the relatives of the patient.It is proposed to use such a deviceon the wrist of the patient in order to track his rate of movement.

5.2 Smartphone application

The Smartphone application can access the real time data provided by the accelerometer via the Bluetooth standard.The inertial data in terms of the windows is first captured, and then the features related to the window are calculated by the application which is capable of detecting the on-going seizures.For this,first the feature computation is performed,and second a threshold must be applied to this data to determine the occurrence of the seizure.The feature extraction steps include filtering of the received data,feature computation and feature reduction [13].The second step of seizure determination involves model parameters to be evaluated to judge the presence or absence of seizures.

The smartphone contains a domain specific Digital Signal Processing Module that is capable of performing feature extraction. But the signal needs to be pre-processed in the microcontroller unit itself before it is sent via Bluetooth to the smartphone.The pre-processing steps involve down-converting the frequency to about 10 Hz and reducing the window size to about 128 bytes.

The smartphone application must extract the frequency domain characteristics from the power spectral density of each window obtained using a 256 point Fast Fourier Transform[13].From this, the peak frequency value in the signal is determined .The smartphone application algorithm is then written to detect in case this determined peak frequency crosses the threshold value set to 10Hz.The decision making algorithm then sends an email notification via 3G/4G network to the emergency ward of the nearest hospital(whose location is determined by the GPS installed in the phone itself) along with the GPS location of the smartphone,thus calling for immediate care.

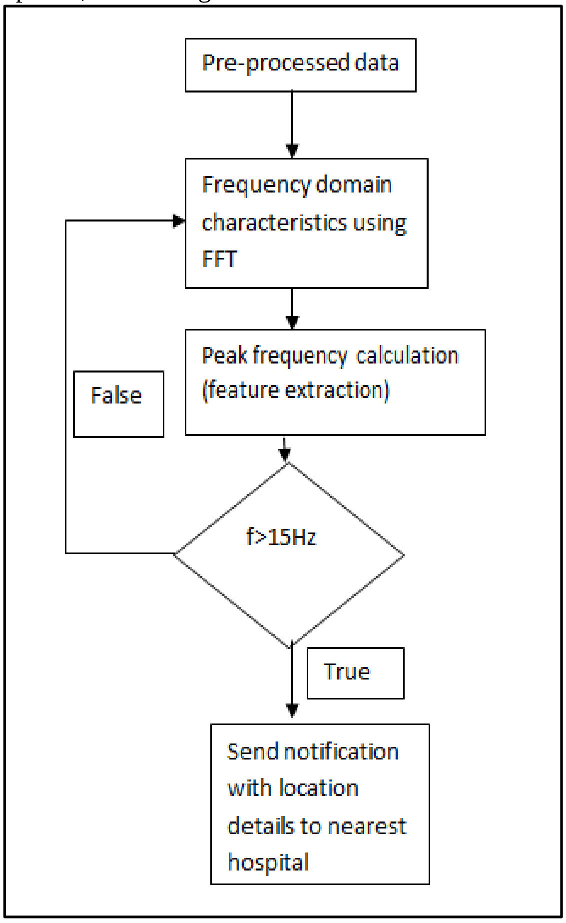

Fig.1. Seizure detection and the required Emergency Care Process

5.3 Location detection and e-mail notification application on smartphone

As soon as the threshold level of 10Hz is detected by the smartphone application, the current location of the smartphone is detected using the GPS receiver of the smartphone and the location of the nearest hospital is determined by an open-source Map such as the Google maps. Using an online pre-installed database, an application on the smartphone is used to determine the contact e-mail Address of the emergency ward of that particular hospital. An e-mail notification is sent to the hospital with the patient's name and condition along with his GPS location through the available 3G/4G network on the smartphone.This hospital is then required to act immediately on this notification, and reach the patient on time.

5. Conclusion

In this paper, we have presented a new patient specific system that makes use of a Inertial Measurement Unit for detection of seizure,aSmartphone application that can access the real time data provided by the accelerometer via a

Bluetooth standard (IEEE 802.15.1) and this real time data is processed continuously by the application. High frequency detection application and a location detection application are used respectively to indicate a seizure and to locate the nearest hospital or any other form of notification. Thus, this seizure-detection system can be used as long-term and in home situations for early intervention and prevention of seizurerelated side effects including SUDEP (sudden unexpected death in epileptic patients).

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7. References

[1] Daniel Callegari, Denis Fernandes, Fernando Burmeister, Romulo Severino, Epicare- A home care platform based on mobile cloud computing to assist epilepsy diagnosis.
[2] Sandor Beniczky, TilmanPolster, Troels W. Kjaer, HelleHjalgrim, Detection of GTCS by a wireless wrist accelerometer: A prospective, multicentre study.
[3] Sandor Beniczky, TilmanPolster, Troels W. Kjaer, HelleHjalgrim, Detection of GTCS by a wireless wrist accelerometer: A prospective, multicentre study.
[4] Lockman J, Fisher RS, Olson DM, Detection of seizure-like movements using a wrist accelerometer.
[5] Tamara M.E. Nijsen, Johan B.A.M Arends, Paul A.M. Griep, Pierre J.M Cluitmans, The potential value of three-dimensional accelerometry for detection of motor seizures in severe epilepsy.
[6] Fisher R, van Emde Boas W, Blume W, Elger C, Genton P, Lee P, Engel J, Epileptic seizures and epilepsy: definitions proposed by the ILAE and IBE.
[7] Joseph H. Ricker - Differential Diagnosis in Adult Neuropsychological Assessment, Springer Publishing Company. P 109.ISBN 0-8261-1665-5.
[8] Healthline – Seizures and its symptoms.
[9] KatholiekeUniversiteit Leuven, Thesis on Detection of Epileptic Seizures based on Video and Accelerometer Recordings.
[10] Krumholz A, Wiebe S, Gronseth G, et al. Practice parameter: evaluating an apparent unprovoked first seizure in adults (an evidence-based review): report of the Quality Standards Subcommittee of the American Academy of Neurology and the American Epilepsy Society. Neurology. 2007;69:1991-2007.
[11] Golshan Taheri Borunjeny, MehranYazdi, Alireza Keshavarz-Haddad, Arash Rafie Borunjeny, Detection of epileptic seizures using wireless sensor networks.
[12] Daniel Rodriguez Martin,Carlos Peres Lopez, AlbertSama, Joan Cabestany, AndreuCatala, A Wearable Inertial Measurement Unit For Long-Term Monitoring In Dependency Care Area.
[13] A.Temko, E.Thomas, W.Marnane, G.BoylanG. Lightbody, EEG-based Neonatal seizure detection with Support Vector Machines.