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An Internet of Things and Machine Learning Based System to Measures Precursors of Epileptic Seizures

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Abstract

Epilepsy is a neurological disorder that affects over 60 million people worldwide. The purpose of this concept paper is to examine developing a system to evaluate precursors of epileptic seizures. Altered daily living patterns may be a sign of an oncoming episodes. The preliminary design of the application would consist of an extensive database that consists of information about precursors of epileptic seizures, data on a series of behaviors, such as abnormal motion detection, recording data in real time, heart rate monitoring. The proposed system would use the internet of things (IoT) that synchronizes the application with compatible smart devices. The framework would record data to a cloud storage system making the information easily accessible to caregivers and patients. The application would also provide emergency notifications of precursors of epileptic seizures up to several hours prior to the onset of an episode, allowing enough time for medical attention to be administrated.

Keywords: Epileptic seizures; Internet of Things; Seizure Detection Technology; Wearable Devices; Healthcare Applications

Introduction

Epilepsy is a chronic neurological disorder that affects over 50 million people worldwide. An estimated 3.4 million people are diagnosed with epilepsy annually (3 million adults and 470,000 children [1,2]. In the United States, 1 in 26 people will develop epilepsy at some point in their lifetime. A patient's quality of life can be affected by precursors as well as the onset of epileptic seizures. Precursors of epileptic seizures have been known to appear up to several hours or days before the occurrence of epileptic seizures [4]. In nearly 90% of patient's that have epilepsy, precursors such as changes in mood, headaches, changes in vision, and difficulty concentrating have been reported [2,3]. Triggers that can increase the chances of the occurrence of epileptic seizures are menstruation, stress, or sleep deprivation [3]. Scaramelli, Alejandro, et al analyzed precursors of epileptic seizures in 100 patients and discovered that 39% of the patients experienced precursors up to several hours before a seizure occurred. Precursors included changes in mood and behavior, and cognitive disturbances [3]. Patel, Puja, et al distributed anonymous seizure prediction questionnaires to survey caretakers of children that had epilepsy. Based on the 150 questionnaires that met the criteria for this study, precursors of epileptic seizures were reported; 65.6% of patients experienced tiredness, 50% experienced hazy looks, 40.6% experienced sleepiness, 37.5% experienced irritability, and 34.4% experienced changes with their emotions [2]. There is an absence of technology that can detect precursors before the onset of epileptic seizures. Though current seizure detection devices show great promise in detecting precursors of epileptic seizures, there is a high demand for a system that monitors and tracks precursors of epileptic seizures and intervenes before manifesting into full epileptic episodes [4]. This concept paper proposes an initial design of a system to detect and monitor precursors of epileptic seizures, outfitted within internet of things (IoT), which can in turn, improve quality of life, by aiding in that person's independence.

Reviews of Seizure Detection Devices

There are challenges in detecting precursors of epileptic seizures. To date seizure detection devices generally focus on the occurrence of seizures; however, these technologies are not reliable for patients with epilepsy and live alone.

During the occurrence of epileptic seizures, patients that live alone will not be able to contact medical assistance. Many seizure detection devices are not available to the public nor commercial use. These devices have not been approved by the FDA and are primarily used for scientific studies. Therefore, usage is very limited and maintains the need for the aforementioned system.

Mattress Sensors

Currently, pressure sensors used with mattresses, detect epileptic seizures. Typically, these sensors are placed underneath a patients' mattress. The sensors are adjusted to accommodate the patients' level of comfort, and still detect abnormal or absence of movement. If abnormal or absent movement is detected, sensors will emit warning signals to caregiver(s) or family members for immediate medical assistance. Several studies examined the performance of mattress sensors and their success rate in detecting seizures. Jory, Caryn, et al conducted a review on the sensitivity rate of mattress sensors. The most successful mattress in this study had a detection rate of 89% in detecting tonic-clonic seizures. Ulate -Campos, A., et al conducted a review comparing three mattress sensors; the MP5 bed seizure monitor, the ST-2 bed alarm, and the Emfit monitor. These devices shared similar characteristics, such as detecting abnormal bed movement, intensity, and noise frequency. Each device detected tonic-clonic seizures that occurred at night; the MP5 had a sensitivity rate of 62.5% and a specificity rate of 90%; the ST-2 had a sensitivity rate of 2.25%. It failed to detect seizures that occurred at night and only detected one dyscognitive seizure that occurred in a patient that was awake. For tonic-clonic seizures, the Emfit had a sensitivity rate of 30% during the day and 85% at night. Though these devices may be an ideal choice for patients with epilepsy, there are many limitations. Many mattress sensors have weight restrictions, which can cause the device to have low sensitivity and detect seizures with high rhythmic movements [5-7]. Also, the thickness of a mattress can cause pressure sensors to not record properly. In addition, mattress sensors may have a difficult time differentiating between normal and abnormal movement, which can lead to false positive reports [5,6].

Video Monitoring Systems and Cameras

Video monitoring systems (VMS) are the most accurate way to detect epileptic seizures [5-8]. These systems can capture a variety of characteristics that may be associated with seizures, such as duration, rotation, speed, displacement, and motion trajectory [6-8]. Video-electroencephalographic (EEG) monitoring units, also referred to as epilepsy monitoring units (EMUs) are most commonly used [7,8]. Epileptologists typically view eMUs, interpret the type of seizures that are being recorded. VMS can be classified as marker-based or marker-less. One study showed that myoclonic seizures could be recorded with a marker-based video monitoring system with a sensitivity rate of 75% to 100% [6,7]. Another study showed that marker-less systems are similarly effective and had a sensitivity rate over 75% [5,8].

Another VMS that is becoming popular as a seizure detection system, are red, green, blue depth (RGB- D) motion detection cameras. RGB- D motion detection cameras monitor changes in movement in real time. Among other capabilities, these devices have been used to monitor seizure-like movement displayed during epileptic seizures [8,9]. An example of an RGB-D motion detection camera is the Kinect system. The Kinect uses a red, green, and blue color camera, a depth sensor, and a multi- array microphone to capture information about a person's movement and create 3D skeletal images. Cunha, João Paulo Silva, et al conducted a study incorporating an EEG and 3D RGB-D motion detection camera, the NeuroKinect, to monitor and record epileptic seizures. The researchers concluded that their novel approach was 87.5% faster in collecting data associated with motion trajectories for seizures when compared to other RGB-D motion detection cameras studies [8].

Though VMS and RGB-D motion detection cameras prove to have a decent sensitivity rate for seizure detection, there are still many limitations. VMS that are not corroborated with EEGs can be less efficient for seizure detection; the sensitivity rates for seizure detection can range from 31% to 95%. Though EEG signals can determine the occurrence of seizures, seizure-like movement can also be misinterpreted by VMS. In addition, marker-based systems can be uncomfortable for patients, while marker -less systems can only record and monitor seizures as long as patients are in view of the camera(s) [5-9].

Wearable Wrist Devices

Wearable wrist devices are one of the most common ways to detect epileptic seizures. The most popular wearable device for seizure detection is wrist accelerometers. A wrist accelerometer can capture changes in the physical activity of the hands and arms in real time. This device can synchronize with computers and smartphones to download, process, and store data. As the wrist accelerometer can record changes in physical activity over time, associated programs can compare these changes across different locations, such as a dominant or non-dominant wrist [9- 11]. Joo, Hyo, et al proposed using inertial measurement units (IMUs), along with spectral analysis, to detect motions in the arms of patients that experienced tonic-clonic seizures. In this study, the spectral analysis approach had better sensitivity for detecting seizures and had fewer false positives. Another study proposed that measurement of physical activity was dependent on wearing a wrist accelerometer on a dominant or non-dominant wrist [10]. For 24 hours, subjects performed their activities of daily living while wearing wrist accelerometers on their dominant and non-dominant wrist. When both devices were compared, Dieu, Olivier, et al concluded that there was no significant difference, suggesting that wrist accelerometers worn on dominant or non-dominant wrists have no impact on the measurement of changes in physical activity. Though wearable wrist devices can be useful in detecting seizures, there are still some limitations. One of the most common challenges with wrist accelerometers are false positives that can be mistaken for seizure-like movements. These include brushing teeth, exercising, cooking, bathing, grooming, or eating food [9-11].

The Internet of Things as an Integrate System for Detecting Precursors to Seizures

Current seizure detection devices show great promise in filling the need in detecting seizures, however a coordinating system to integrate multiple devices. We propose use of an Internet of Things (IoT) framework. Components of an integrated system would include RGB-D motion capture system, a wrist accelerometer, and Radio Frequency Identification (RFID) tags. The goals of such a system include:

a. Capture several environmental factors and personal behaviors that are seizure precursors

b. Integrate data to create a prediction algorithm for oncoming seizures, using machine learning.

A proposed system would monitor people with epilepsy while conducting activities of daily living. Tracking of these activities will provide the training and actual data needed for the algorithms that will predict oncoming seizures. Information including body type and medical history will be included in the data capture. Monitored precursors include rapid kicking, flailing of the arms, and repetitive arm and hand movements. The wrist accelerometer will be worn on the dominant wrist of the person with epilepsy to continuously track changes in the physical activity over an extended period of time. RFID systems are made up of wireless tags that can provide essential information and operate up to 20- feet away from other high -frequency devices. The proposed RFID system will consist of three components; the RFID tag, and RFID reader, and an antenna [12]. The purpose of this system is to store information about the person with epilepsy, such as height, weight, allergies, etc. This information will be accessible to the person with epilepsy, the caregiver, and medical professionals in case of emergency. Additional tags will be attached to items used on a regular basis to assess behavior and frequency of use.

An additional component of the integrated system, the RGB-D motion detection cameras will provide continuous data capture of the person with epilepsy. This system will directly capture arm and leg movement to classify them as rapid or flailing. As different floor plans exist, viewing space for the cameras will need to be optimized. Cameras will be placed in the kitchen, living room, hallways, bedrooms and bathrooms.

Data from these systems will be stored in a cloud-based system and used for analysis using machine learning algorithms. Algorithms using this information can then send alarms to caregivers or family if the risk of seizures is great.

Conclusion

Epilepsy is a neurological disorder which causes epileptic seizures. There is an absence in technology that can detect precursors of epileptic seizures. An integrated system that incorporates RGB-D motion detection cameras, wrist accelerometers and RFID systems connected through the IoT can fulfill a significant need in home healthcare. The integrated systems will simultaneously monitor behavior and detect precursors to epileptic seizures. Based on machine learning algorithms, warning signals can be sent to devices of caregivers. Such a system will support independent living of individuals with epilepsy and provide comfort for family and caregivers.

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