Seizure Detection System in Wearable Devices

A Project Work Synopsis

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Abstract

Sudden Unexpected Death in Epilepsy (SUDEP) is one of the most common syndromes shown by epileptic patients. SUDEP stands second in the mortality rate caused by neurological conditions. Studies show that companionship reduces the risk of SUDEP, and devices that can detect or predict seizures play a significant role in saving the lives of epileptic patients. Wearable devices that automatically detect and predict seizures could be life-changing technology for patients suffering from epileptic seizures. These devices can help in constant monitoring and detection of seizures.

This research aims to produce a Machine Learning model to detect seizures which can be used in seizure detection wearable devices. With the help of multimodal sensors like Electrodermal Activity (EDA) and Accelerometer (ACC) accurate detection of seizure can be obtained. The system can analyse skin resistance and irregular heartbeats that could indicate an impending seizure. In addition to seizure detection the model will include unique feature of real time location tracking, allowing the emergency contacts such as caregivers, guardians, and doctors to be notified of the patient's exact coordinates during an episode. The research also includes a comprehensive log system that records the frequency and details of the seizure, which can assist in patient monitoring and personalized treatment. Overall, the research paper aims to demonstrate the potential of wearable technology in enhancing seizure management and improving patient outcomes.

Keywords: Seizure, Electrodermal Activity (EDA), Accelerometer (ACC), Epilepsy, Machine Learning, Skin conductance, Frequency, Wearable devices.

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1. INTRODUCTION

1.1 Problem Definition

The problem is to develop a machine learning model that can accurately detect seizures in people with epilepsy using sensor data obtained from wearable devices. The system should be capable of collecting and storing physiological signals like EDA and ACC, which can help identify the occurrence of seizures. The model should be designed to provide real-time alerts when a seizure is detected, enabling timely intervention by caregivers or medical professionals.

The objective of the model is to improve the quality of life of people with epilepsy by facilitating early detection and intervention to prevent injury or other serious consequences. By providing a reliable and accurate seizure detection system, this technology can reduce the burden on caregivers and healthcare providers while providing greater independence and freedom for individuals with epilepsy.

The challenge in developing a machine learning model is to accurately differentiate between a seizure and other activities that may mimic a seizure, such as exercising, sleeping, or simply moving.

1.2 Problem Overview

This research aims to develop a machine learning model that can analyse the sensor data and accurately detect seizures in real-time. The model should be trained on a large dataset of labelled seizure and non-seizure data to enable it to learn the complex patterns and characteristics associated with seizures. The system should be designed to be highly sensitive and specific, to minimize false alarms and missed detections.

To ensure the model's reliability and accuracy, the system should be rigorously validated using independent datasets and tested in real-world scenarios. Additionally, the system should be designed to be user-friendly and accessible to individuals with epilepsy, so they can easily use and interact with it.

There are so many technical challenges associated with the development of a seizure detection system using a wearable device. These include:

- **Data collection:** Collecting high-quality data from sensors in a real-world setting can be difficult, as the sensors must be comfortable and unobtrusive while still accurately capturing relevant information.
- **Feature extraction:** Once the data is collected, it must be processed to extract relevant features that can be used to identify when a seizure is occurring. This process can be very complex and might require an advanced signal processing and machine learning techniques.
- **Classification:** The extracted features must then be used to classify whether a seizure is occurring or not. This is typically done using machine learning algorithms, but developing accurate and reliable classifiers can be challenging due to the variability in seizure patterns.
- **Real-time performance:** Finally, the system must be able to operate in real-time, providing alerts within seconds of a seizure onset. This requires efficient and optimized algorithms that can process data quickly and accurately.

Overall, developing a seizure detection model requires expertise in signal processing, machine learning, and real-time systems design. While significant progress has been made in recent years, there is still much work to be done to develop reliable and effective model that can improve the quality of life for individuals with epilepsy.

1.3 Hardware Specification

- 11th Gen Intel® i7-11800H @ 2.30GHz
  16 GB RAM. 256GB SSD 1TB HDD

1.4 Software Specification

- GitHub
- Proteus
- Empatica
- Google Colab

2. LITERATURE SURVEY

2.1 Literature Review Summary

Year and Citation	Article/ Author	Tools/ Software	Technique	Source	Evaluation Parameter
Regalia, G., Onorati, F., Lai, M., Caborni, C. and Picard, R.W., 2019. Multimodal wrist-worn devices for seizure detection and advancing research: focus on the Empatica wristbands. *Epilepsy research*, *153*, pp.79-82.	Regalia, G., Onorati, F., Lai, M., Caborni, C. and Picard	Multimodal Sensors (EDA, ACC)	Machine Learning	ScienceDirect	Furthermore, research is still needed to reduce the FAR and improve the accuracy of seizure detection using multimodal sensors.
Ortega, M.C., Bruno, E. and Richardson, M.P., 2022. Electrodermal activity response during seizures: A systematic review and meta-analysis. Epilepsy & Behaviour, 134, p.108864.	Ortega, M.C., Bruno, E. and Richardson	Electrodermal Activity Sensor	Machine Learning	ScienceDirect	Further research is indeed needed deeply understanding EDA response during epileptic seizures.
Tang, J., El Atrache, R., Yu, S., Asif, U., Jackson, M., Roy, S., Mirmomeni, M., Cantley, S., Sheehan, T., Schubach, S. and Ufongene, C., 2021. Seizure detection using wearable sensors and machine learning: Setting a benchmark. Epilepsia, 62(8), pp.1807-1819.	Tang, J., El Atrache, R., Yu, S., Asif, U., Jackson, M., Roy, S., Mirmomeni, M., Cantley, S., Sheehan, T., Schubach, S. and Ufongene	ACC, EDA, PCG	Machine Learning	Epilepsia	The use of ML algorithms and biosensors would be of great help in determining the type of seizure a patient is having.
Zangróniz, R., Martínez-Rodrigo, A., Pastor, J.M., López, M.T. and Fernández-Caballero, A., 2017. Electrodermal activity sensor for classification of calm/distress condition. Sensors, 17(10), p.2324.	Zangróniz, R., Martínez-Rodrigo, A., Pastor, J.M., López, M.T. and Fernández-Caballero	Electrodermal Activity Sensor	Machine Learning	MDPI	The usage of EDA sensors in wearable devices turned out to be of great importance in the health industry, notably in the epilepsy section.
Humairah Tabasum, Nikita Gill, Rahul Mishra and Saifullah Lone. Wearable microfluidic-based eskin sweat sensors – Article.	Humairah Tabasum, Nikita Gill, Rahul Mishra and Saifullah Lone	Electrodermal Activity Sensor (EDA)	Machine Learning	Royal Society of Chemistry	Developing new cell subtypes, organ-specific microbiomes and metabolites, biochemical and biophysical gradients across linked organs and mimicking physiological responses are crucial.

Xu Zeng, Hai-Tao Deng, Dan-Liang Wen, Yao-Yao Li, Li Xu and Xiao-Sheng Zhang. Wearable Multi-Functional Sensing Technology for Healthcare Smart Detection – Article.	Xu Zeng, Hai-Tao Deng, Dan-Liang Wen, Yao-Yao Li, Li Xu and Xiao-Sheng Zhang	Accelerometer (ACC)	Machine Learning	MDPI	Wearable sensors have made significant progress but still face challenges such as high integration, fitting human skin, achieving high resolution.
Rosales, M.A., Bandala, A.A., Vicerra, R.R. and Dadios, E.P., 2019, November. Physiological Based Smart Stress Detector using Machine Learning Algorithms. In 2019 IEEE 11th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM) (pp. 1-6). IEEE.	Rosales, M.A., Bandala, A.A., Vicerra, R.R. and Dadios	Galvanic Skin Response	Machine Learning, SVM classifiers	IEEE	The GSR sensor can detect changes in sweat gland activity that are reflective of the intensity of the person's emotional state.
Adwitiya, A.Y., Hareva, D.H. and Lazarusli, I.A., 2017, September. Epileptic Alert System on Smartphone. In 2017 International Conference on Soft Computing, Intelligent System and Information Technology (ICSIIT) (pp. 288-291). IEEE.	Adwitiya, A.Y., Hareva, D.H. and Lazarusli	Accelerometer (ACC)	Fall Detection Algorithm	IEEE	The research consists of negatives such as the placement of smartphones, as it is not convenient to place the device on the upper arm or the head.
Sarmast, S.T., Abdullahi, A.M. and Jahan, N., 2020. Current classification of seizures and epilepsies: scope, limitations and recommendations for future action. Cureus, 12(9).	Sarmast, S.T., Abdullahi, A.M. and Jahan	-	-	Cureus	The classification system can help patients understand their condition and describe their symptoms to healthcare providers very easily which helps in better communication.
Siddiqui, M.K., Morales-Menendez, R., Huang, X. and Hussain, N., 2020. A review of epileptic seizure detection using machine learning classifiers. Brain informatics, 7(1), pp.1-18.	Siddiqui, M.K., Morales-Menendez, R., Huang, X. and Hussain	Electroencephalogram (EEG), Electrocor-ticography (ECoG)	Machine Learning classifiers Blackbox and non-Blackbox methods	Brain Informatics	Black-box classifiers may achieve high predictive accuracy, but they ~~cannot~~ generate interpretable logic rules. Detecting seizures from large volumes of EEG data is a major challenge in epilepsy diagnosis.

2.2 Existing System

Wearable devices that automatically detect and predict seizures could be life-changing technology for patients suffering from epileptic seizures. Embrace E4 watches help detect seizures way before onset seizure. It uses advanced machine learning algorithms with electrodermal activity (EDA) and Accelerometer (ACC) sensors. These devices use machine learning algorithms that can recognize the EDA and ACC responses of a person. The data availability refined the EDA response, resulting in negligible false alarm rates. The Embrace E4 watches were successful in detecting GTCS with the help of EDA and ACC sensors. The success rate of the watches ranged from 92 % - 100 % while the false alarm rate ranged from 0.2–1 percentage. As the sensitivity is nearly 100 % this device can reduce the risk of SUDEP by predicting the seizure. It also has an added location feature that can alert the caregivers when the patients have a possible epileptic seizure. But still the False Alarm Rate (FRA) was higher than expected. Therefore, more machine learning algorithms can be used to differentiate between a seizure and a false seizure. This could help patients and could be used for monitoring and further understanding of epileptic seizures.

2.3 Problem Formulation

A seizure is a neurological condition developed by an abrupt burst of electrical activity in the brain. Epilepsy is a condition caused by frequent seizures due to unknown triggers. It affects about 50 million individuals, making it one of the most prevalent neurological conditions worldwide. Both the person having the seizure and others nearby find it frightening and unsettling. These are typically non-life-threatening, and, with proper care and assistance, many sufferers can have a healthy life.

There have been many approaches to developing systems that can monitor seizure patients and detect seizures. Seizures can be easily identified by ECG or EEG waves. But the sensors and systems that can detect ECG and EEG waves are not portable or convenient to use. Then came the idea of using a wrist-worn device like a watch, which is mobile and conveniently sized for this purpose.

To make the model viable, we need sensors that need to be attached to a device that can detect seizures. This cannot be made possible with any one sensor, thus the use multimodal sensor approach. The most practical sensors applicable for this are the ACC and EDA sensors. The Accelerometer (ACC) sensor can pinpoint the position of the device and track sudden movements. Electrodermal activity (EDA) sensor measures the variations in skin conductivity brought on by an increase in sweat gland activity.

Machine learning algorithms can be used to train the model using data acquired from the sensors, we can develop a model that can detect seizures. Further, we can improve this model and implement it on the wristwear device, which will have the functionality of alerting the connected carers when seizures are detected.

2.4 Proposed System

The proposed system is a machine learning model that can accurately detect seizures in individuals with epilepsy. The system involves using wearable sensors to collect data on movement, heart rate, and other physiological parameters.

The main goal of the system is to develop a highly sensitive and specific machine learning model that can accurately detect seizures in real-time. The model should be trained on a large dataset of labelled seizure and non-seizure data to enable it to learn the complex patterns and characteristics associated with seizures. Reducing the false alarm rate (FAR) will be a critical objective of the research, thereby increasing the model's accuracy.

By developing a machine learning model to detect seizures, individuals with epilepsy can benefit from timely interventions that reduce the risk of injury or other serious consequences. Additionally, this technology can provide caregivers and medical professionals with valuable information that can inform treatment decisions and improve the overall management of epilepsy.

3. OBJECTIVES

- To train a machine learning model and analyse the data from various multimodal sensors.
- To provide a reliable and accurate seizure detection machine learning model.
- To find the false alarm rate produced by the multimodal sensors.

4. METHODOLOGY

The paper mainly focuses on sensors like EDA and ACC to measures various aspects of a human body. EDA(Electro Dermal Activity) will measure the electrical activity of the skin. The EDA sensor will analyse the change in skin conductance and can give early indication of seizure. EDA combined with other psychological measures can improve the accuracy of the seizure detection system. The accelerometer (ACC) which are attached to body parts mainly wrists, will detect motion and changes in position of body. It will detect seizure by analysing change in movement patterns. Also, signal processing technique is used to extract features like amplitude, frequency of movement, from the accelerator data.

The paper also focuses on machine learning algorithm like SVM(Support Vector Machine), KNN(K-nearest neighbors). These machine learning algorithms can automatically detect seizure and classify them in real time which will help in better patient care.

SVM is supervised learning method and thus can be helpful in seizure detection by training the data collected from EDA, ACC, HRV(Heart rate variability). K-nearest neighbor (KNN) is a supervised machine learning algorithm which is very helpful in seizure detection system. This algorithm is used on the data collected by accelerometer which is attached to wrists of the patient's body. Then the data will be preprocessed by removing unwanted and noise data and thus normalizing the signals. The data will be split into the training and testing datasets. The KNN model will be trained on the training set using features like movement patterns. The performance of the model can be evaluated on the testing data using various metrics like precision, accuracy, etc. Thus, the trained model can be used to predict whether a movement pattern would correspond to a seizure or non-seizure event.

5. EXPERIMENTAL SETUP

The dataset used in this experiment consists of EDA and ACC signals collected from patients during seizure and non-seizure periods. Training data and testing data are separated into two parts of the dataset. The classifiers are trained using the training data, and their effectiveness is assessed using the testing data. The training data is used to train a variety of machine learning classifiers, such as the SVM classifier and the KNN classifier, which are then applied to the testing data.

We intend to segment the EDA and ACC signals into fixed-length windows in order to get them ready for categorization. Each window's features, such as mean, variance, skewness, kurtosis, and the signal's frequency distribution, would be retrieved. Then, these features are employed to train and evaluate the SVM and KNN classifiers.

A number of performance indicators, such as accuracy, sensitivity, specificity, and F1-score, will be used to assess the classifiers' effectiveness. The experiment's findings could demonstrate that EDA and ACC signals obtained from wearable sensors can be used to accurately detect seizures via SVM and KNN classifiers. This can be implemented by the following steps

- Use EDA and ACC signals collected from patients during seizure and non-seizure periods to train a machine learning model for seizure detection.
- Segment the EDA and ACC signals into fixed-length windows for categorization and retrieve features such as mean, variance, skewness, kurtosis, and signal frequency distribution.
- Train and evaluate the effectiveness of machine learning classifiers, such as SVM and KNN, using the extracted features..
- Determine whether EDA and ACC signals obtained from wearable sensors can accurately detect seizures through the SVM and KNN classifiers.
- Evaluate the model's performance in real-world scenarios to ensure its practicality and usefulness for detecting seizures in individuals with epilepsy.

6. CONCLUSION

The implementation of a machine learning model for detecting seizures using wearable devices has become a promising field of research in recent years. In this study, we reviewed various research papers, articles, and review papers related to seizure detection using machine learning algorithms. The majority of studies have focused on using wrist or ankle-worn devices that incorporate various sensors such as ACC, EDA, and PCG to detect seizures based on the signals they generate.

One of the main objectives of our study is to improve the accuracy of the system as much as possible. To achieve this, we will segment the EDA and ACC signals into fixed-length windows and extract relevant features such as mean, variance, skewness, kurtosis, and frequency distribution. We will then use these features to train and evaluate the performance of the SVM and KNN classifiers. The effectiveness of the classifiers will be measured using various performance indicators such as accuracy, sensitivity, specificity, and F1-score.

In addition, we plan to include a feature that logs the occurrence of seizures for future reference. This will make it easier for medical professionals to develop appropriate treatment plans for the patients. In situations where the carers or attendants are unaware of the patient’s location during a seizure, we intend to implement a feature that sends the patient’s location when an episode occurs. This feature would be useful not only for the patient’s treatment but also for patenting the device in the future.

7. TENTATIVE CHAPTER PLAN FOR THE PROPOSED WORK

CHAPTER 1: INTRODUCTION

- Problem Definition
- Problem Overview
- Hardware Specification
- Software Specification

CHAPTER 2: LITERATURE REVIEW

- Summary of Literature Review
- Existing System
- Problem Formulation
- Proposal System

CHAPTER 3: OBJECTIVE

- Research Objectives and Hypothesis
- Research Methodology
- Expected Contributions

CHAPTER 4: METHODOLOGIES

- Electrodermal Activity Sensor
- Accelerometer Sensor
- SVM Classification
- KNN Classification

CHAPTER 5: EXPERIMENTAL SETUP

- Sensors Used
- Machine Learning Algorithms
- Data Analysis
- Machine Learning Classifiers

CHAPTER 6: CONCLUSION AND FUTURE SCOPE

- Summary of the Proposed Work
- Achievements and Limitations
- Future Scope of the Proposed Method
- Concluding Remarks

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