Point of Care Device for Proactive Epileptic Seizure Alert

Ngan Le, Matthew Aguirre, Kaitlynn Graham, Shayok Dutta, Natalie Nguyen, Evan Garcia

Mentors: Dr. Satish T. S. Bukkapatnam (satish@tamu.edu), Dr. Trung Q. Le (trung.le@tamu.edu), Dr. Samba Reddy (reddy@medicine.tamhsc.edu)

Introduction

Epilepsy

- Epilepsy is a neurological disorder.
  - Neurons deviate from normal functions by firing rapidly and asynchronously.
  - Current treatments for epilepsy:
    - Surgeries
    - Implantable devices
    - Antiepileptic drugs

Point of Care (POC) Devices

- Devices for diagnosis and/or intervention at the source of the problem.
- Currently being used in a variety of settings such as doctors’ offices, hospitals, and in patients’ homes.
- Benefits:
  - Quick diagnosis of the patient’s health
  - Generally light, portable, fast and relatively inexpensive

Motivation

- Epilepsy affects 1 in 100 adults and 1 in 20 children.
- In the U.S. alone, there are more than 2.2 million people with epilepsy.
- The sudden nature of epilepsy causes a great deal of lifestyle changes:
  - Increased mortality risk
  - Expensive medical care
  - Physical and emotional stress and anxiety.
- No present POC device can serve as an early seizure warning system.

Problem Description

- We aim to develop a wearable, non-invasive POC device to provide a reliable seizure warning system.
- Benefits of this device include:
  - Early proactive control of epileptic seizures
  - Decrease risk of injury during episodes
  - Potentially reduce progression of seizures
  - Help users live healthy lifestyles.

Research Methodology

Data Analysis

1. **Training phase**
   - Feature extraction
2. **Testing phase**
   - Classification

Data Source: PhysioNet Database

- Seizure annotations
- Physiological data
- Feature extraction: Normalized power spectrum density, Recurrence Quantification Analysis, Frequency spectrum of the signal

Feature Prediction

- Diriichlet process based mixed Gaussian Process
- Epileptic Seizure classifer: Support Vector Machine

Seizure Episode Prediction

- Multi-step ahead prediction

**Step 1: Feature Extraction**
- Utilize Recurrence Quantification and Power Spectral Analysis to extract 13 features.

**Step 2: Feature Selection**
- Select significant seizure features out of 13 extracted features.
- ANOVA finds consistency of features between multiple patients.
- Principal Component Analysis converts highly correlated features into a set of linearly uncorrelated features.

**Step 3: Classification**
- Consistent features will be utilized as the inputs of the support vector machine classification model.
- Support vector machine for classification and prediction.

**Step 3: Prediction**
- Dirichlet process based mixed Gaussian model will be utilized to predict the features future states.
- Predicted value can then be classified into seizure and non-seizure states.

System Design

- Front end analog circuit collects and processes the EEG signal on board.
- Feedback mechanism is used to alert the patient of an impending seizure.

Hardware

- EEG signal processing circuit involves multiple stages of amplifiers and filters to prepare the collected signal for feature extraction.

Implementation

- The EEG headset design:
  - Discrete, long
  - Quick diagnosis of the patient’s health
  - Generally light, portable, fast and relatively inexpensive

Embodiment

- The EEG headset design:
  - Discrete, long-term use
  - Multi-channel EEG support.
  - Form fitting cloth for outer layer.
  - 3D printed flexible for inner shell.

Preliminary Results

- Normalized power spectral density features of EEG signals have been utilized to classify between seizure and non-seizure events.
- Channel 16 of 10-20 system shows significant differences between seizure and non-seizure state across patients.
- SVM classification results 89.22% total classification accuracy.

Confusion matrix of the seizure classifier

<table>
<thead>
<tr>
<th>Prediction</th>
<th>Seizure</th>
<th>Nonseizure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Seizure</td>
<td>86.66%</td>
<td>13.34%</td>
</tr>
<tr>
<td>Actual Nonseizure</td>
<td>91.78%</td>
<td>8.22%</td>
</tr>
</tbody>
</table>

Ongoing and Future Work

- Utilize ANOVA for feature selection, support vector machine for classification and prediction.
- Compare EEG signals with verified EEG system.
- Integrate the software and the hardware.
- Validate the devices in vivo settings.

Proposed Ex Vivo Validation of Device

Acknowledgements & References

We would like to acknowledge the Aggie-Challenge program for their funding and the Engineering Innovations Center (EIC) for help with device fabrication.

References:
- Wieser. 8.22% Neurons deviate from normal functions.
- Garcia. An increased mortality risk.
- Antiepileptic drugs.
- Generally light, portable, fast and relatively inexpensive.
- Principal Component Analysis converts highly correlated features into 91.78%.
- Implantable devices.
- Physical and emotional stress and anxiety.
- These predicted value can then be 86.66%.
- Expensive medical care.
- ANOVA 13.34%.
- No present POC device can serve as an early seizure warning system.
- Invasive POC device to provide a reliable seizure warning system.
- In the U.S. alone, there are more than 2.2 million people with epilepsy.
- The sudden nature of epilepsy causes a great deal of lifestyle changes.
- Expensive medical care.
- Physical and emotional stress and anxiety.
- No present POC device can serve as an early seizure warning system.
- We aim to develop a wearable, non-invasive POC device to provide a reliable seizure warning system.
- Benefits of this device include:
  - Early proactive control of epileptic seizures
  - Decrease risk of injury during episodes
  - Potentially reduce progression of seizures
  - Help users live healthy lifestyles.
- Data analysis:
  - Data extraction
  - Classification model
  - Prediction model
- System design:
  - Hardware design
  - Software design
- Product development:
  - System design
  - Testing and validation
  - Design refinement
- Online clinical databases
  - Data collection
  - Data analysis
  - Classification model
  - Prediction model
- System design
  - Hardware design
  - Software design
- Product development:
  - System design
  - Testing and validation
  - Design refinement
- Online clinical databases
  - Data collection
  - Data analysis
  - Classification model
  - Prediction model
- System design:
  - Hardware design
  - Software design
- Product development:
  - System design
  - Testing and validation
  - Design refinement
- Online clinical databases
  - Data collection
  - Data analysis
  - Classification model
  - Prediction model
- System design:
  - Hardware design
  - Software design
- Product development:
  - System design
  - Testing and validation
  - Design refinement
- 944 hours of continuous EEG from 24 pediatric epilepsy patients.
- 23 EEG channels were collected from 21 electrodes located at the site of the international 10-20 System.