Point of Care Device for Proactive Epileptic Seizure Alert

AggiE Challenge Team – Fall 2015
Introduction

Epilepsy

Point of Care (POC) Devices

➢ Benefits:
  ○ Quick diagnosis of the patient’s health
  ○ Generally **light, portable, fast** and relatively **inexpensive**. [3]

*Source: Children’s Healthcare of Atlanta. [1]*
*Link: https://www.youtube.com/watch?v=O8TVgxm-9Cc*
The sudden nature of epilepsy causes a great deal of lifestyle changes:

- An increased mortality risk
- Expensive medical care
- Physical and emotional stress and anxiety

No present POC device can serve as an early seizure warning system. [5]
Impacts
Problem Description

➢ We aim to develop a **wearable** and **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 Description

- Physionet Online Database
- 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.
Research Methodology

Data Analysis
Two Methods of Prediction

- **Forecasting**: “the ability to determine in advance the time of its occurrence with a certain precision”
- **Anticipation**: “implies more of an uncertainty as to when exactly an event will occur”

**Our Methodology: Anticipation**

- Simplicity
- High sensitivity and accuracy [4]
Classification to Predict

- **Early Seizure Detection**: Detect when a patient is having a seizure (*Classify the ictal state*)
- **Seizure Prediction**: Detect the state before seizure onset so you have confidence to say seizure is coming (*Classify the preictal state*)

**Goal of our device: Seizure Prediction**

- Detect the Preictal State.
- Identifying the preictal state will allow for long term prediction.
Anticipation

Pre-ictal period starts => Seizure is coming!

• This method involves classification between inter-ictal and pre-ictal state.

• Newest frontier yet; not much is known about the pre-ictal stage
Contribution

● New need for classification of Interictal vs. Preictal States.
● Literature Review on Preictal State:
  o Best Channel: Temporal Lobe [4]
  o Preictal State range: 10-30 min before Seizure State [4,5,6]

Our Methodology: Anticipation

● Preictal State = 15 min before seizure
● Interictal State = 40+ min before seizure
● Channel needed = T7-FT9 (Temporal Lobe)
Step 1: Feature Extraction

- Utilized **Recurrence Quantification** and **Power Spectral Analysis** to extract 13 features via MATLAB [8]

![Channel 16: Real time EEG signal](image)
Step 2: Feature Selection

- Utilized **Pairwise T-Tests** to select significant features out of 13 extracted features
- Good features held p-values < 0.05

```
<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>StDev</th>
<th>SE Mean</th>
<th>95% CI</th>
<th>T</th>
<th>P</th>
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<tr>
<td>1</td>
<td>20</td>
<td>0.000150</td>
<td>0.003061</td>
<td>0.000685</td>
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<td>0.03491</td>
<td>0.00781</td>
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<td>4.52</td>
<td>1.01</td>
<td>(-6.16, -1.92)</td>
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<td>4</td>
<td>20</td>
<td>10.9</td>
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<td>0.4022</td>
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<td>20</td>
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<td>5.84</td>
<td>1.31</td>
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<td>0.17</td>
<td>0.863</td>
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<td>9</td>
<td>20</td>
<td>1.681</td>
<td>2.371</td>
<td>0.530</td>
<td>(0.571, 2.791)</td>
<td>3.17</td>
<td>0.005</td>
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<tr>
<td>10</td>
<td>20</td>
<td>3.63</td>
<td>11.27</td>
<td>2.52</td>
<td>(-1.64, 8.90)</td>
<td>1.44</td>
<td>0.166</td>
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<td>20</td>
<td>-0.0822</td>
<td>0.0980</td>
<td>0.0219</td>
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<td>-3.75</td>
<td>0.001</td>
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<td>(-0.1118, -0.0337)</td>
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</tbody>
</table>
```
Step 2: Feature Selection

**Good features:**
2) Determinism
3) Avg. Diagonal Length
5) Entropy
9) Recurrence Time of 1st Type
12) Clustering Coefficient
13) Transitivity
Step 3: Classification

- Consistent features were utilized as the inputs of the Random Forest classification model

- Classified the difference between interictal and preictal states
Step 3: Classification

Ensemble Learning

- Backed by Normal Theory by Leo Brieman
- Creates an ensemble of one decision tree algorithm
- Captures variation better than single model

Each tree sees part of the training sets and captures part of the information it contains.
Current Results

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>95% Confidence Interval</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>89.82 ± 1.74</td>
<td>How often correct?</td>
</tr>
<tr>
<td>Missclassification Rate</td>
<td>10.18 ± 1.74</td>
<td>How often wrong?</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>89.77 ± 1.39</td>
<td>How often predict yes when its actually a preseizure state?</td>
</tr>
<tr>
<td>False Positive Rate</td>
<td>10.12 ± 2.46</td>
<td>How often predict no when its actually a preseizure state?</td>
</tr>
<tr>
<td>Specificity</td>
<td>89.88 ± 2.46</td>
<td>How often predict no when there is no preseizure state?</td>
</tr>
<tr>
<td>Precision</td>
<td>89.95 ± 2.34</td>
<td>How often predict yes correctly?</td>
</tr>
<tr>
<td>Prevalence</td>
<td>50.00 ± 0.00</td>
<td>How often does yes occur in the sample?</td>
</tr>
</tbody>
</table>

When using a small amount of patients (five patients), our classification model appeared to:

- **Almost 90% accuracy!**
Future Work

1. Evaluate the classification model’s performance from patient to patient.

1. Intensive testing to build a robust model
Research Methodology

System Design
System Design

Glasses with embedded electrodes
- non-invasively, autonomously collect EEG signals

Processor - Raspberry Pi
- process EEG signals on a processor
- wirelessly send analyzed data to our phone app

Android App
- Alert patients about impending seizures
Device Requirements

- Ease of upgrade
- Aesthetically inconspicuous
- Comfortable
- Lightweight
- Noise reduction while data collection
- Size Adjustable
- Minimal Wiring
- Reliable
Happy Customer :)
Future Work

1. Research optimal building materials
2. 3D print the design
3. Test system setup
User Interface

• With creation of a Point-of-Care device
  – There need to be a way for the user to know how they are being taking care of

• Something that is
  – Easy accessible
  – Remote monitor
  – Access data
  – Notification Method
User Interface

Have a device?
Let's get you set up

Don’t have a device?
Learn more about Android Wear

Connect to your device
On your device, swipe to see your device code. Then tap this code when it appears in the list below.

Bluetooth Connectivity

Store User Profile
User Interface

1. Monitoring
   - Notify User Seizure Incidences
     - Start, save, and send data

3. Contact
   - Accessibility to your physician
   - Personalized contacts

2. History
   - Analyze monthly, daily, and historical records

4. Location
   - Locate family & friends, near by hospitals
   - Save designated location
User Interface

Access Current Logs
Contact Your Physician
Send Current Location
Alert Contacts

Seizures
Warnings
False Positives
Accuracy

Features show percentages on pie chart
Research Methodology

Human subject testing
Human Subject Testing

• Institutional Review Board (IRB)

• Monitor scientific researches by setting specific guidelines and standards.

• An IRB proposal approval is required before any human subject testing can occur.
Overview

• Institutional Review Board Submission
  – Confidential
  – Three phases:
    1. Preliminary Information and Assessment
       - Consent form and number assignment
    1. Testing of Point of Care Device
       - Collecting EEG
    1. Conclusion of Study
       - Post questionnaire

– Cooperating with Dr.______ from ______ hospital
Testing Methodology

• Participants will be asked to perform a set of simple exercises:
  • blink rapidly for 1 minute,
  • breath deeply 10 times,
  • lie down for 15 minutes with eyes closed,
  • stare at an object for 2 minutes with minimal blinking,
  • walk around room for 3 minutes,
  • relax for 10 minutes.

• Participants have the right to withdraw their participation at any time.
Ongoing and Future Work

1. Submit IRB
2. Continue working on invention disclosure
3. Submit invention disclosure
Acknowledgement

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

• [1] https://www.youtube.com/watch?v=O8TVgxm-9Cc
• [2] https://www.google.com