Non-convulsive status epilepticus detection

YING WANG

PROMOTORS:
PROF. RICHARD VAN WEZEL; PROF. RONALD AARTS

CO-SUPERVISOR: DR. MIKE X COHEN; DR. XI LONG
Nonconvulsive Status Epilepticus (NCSE)

- **Nonconvulsive status epilepticus** is a term used to denote a range of conditions in which electrographic seizure activity is prolonged and results in non-convulsive clinical symptoms. [1]

- NCSE temporal criteria: Seizures persisting or continuing over 10 minutes. [2]

- Long-term NCSE with high degree of unresponsiveness:
  - Structural brain damage (increase risks of death) for people at ICU;
  - Unknown for chronic patients, need to be monitored.

BrainWave Project

- Brainwave: a project aiming at developing a 24/7 wearable brainwave processing alarm platform ("Brain Wave chip") for epilepsy and Parkinson’s patients;

- Cooperation research project between Eindhoven University of Technology (SPS, TU/e), Radboud University Nijmegen (Donders) and Kempenhaeghe research center;

- Development of algorithms for **online seizure detections in epilepsy (Non-convulsive seizures)** & **freezing of gait (FOG) prediction in Parkinson’s Disease**;

  - **Oral presentation about FOG part:**
    - *Day 2, Session “Neuromuscular lower extremities 1”: EEG Analysis of Freezing of Gait in Local-Moving Experiment;*

  - **Relevant Posters about FOG part:**
    - *Poster Session 1:*
      - #23 Eye Blinks Related to Freezing of Gait in Parkinson’s Patients;
      - #28 Improvement of Fog Detection in Parkinson’s Disease Patients Via Multimodal Data Analysis;
    - *Poster Session 2: #1 Analyzing Freezing of Gait Using Foot Switch Data;*
Electroencephalographic (EEG)

- “EEG signal reflects the activity of millions of neurons located in a multitude of brain structures.” [1]

- Scalp EEG:
  - A non-invasive technique;
  - Electrodes placed on the scalp;

- Intracranial EEG:
  - Electrodes placed directly on the exposed surface of the brain.


Subject Demography

• 16 subjects with NCSE were mainly analyzed;
• Age of 21 +/- 10 years; 13 males and 3 females;
• With heterogeneous clinical backgrounds;
• With different types of seizure history;
• With varied IQ level:
  • 7 subjects with normal IQ;
  • 4 subjects with light IQ;
  • 1 subject with moderate IQ;
  • 4 subjects with severe IQ.
NCSE dataset

- The data recordings were archived at Kempenhaeghe Research Center;
- 21 common electrodes;
- The length of data recordings are from ca. 14 minutes to ca. 22 hours;
- NCSE dataset were annotated by two independent raters:
  - focal or generalized discharges;
  - four patterns of the discharges: fast spike, spike wave, wave and EMG-like discharge;
  - Minimal 20-second length.
Statistics about Ictal discharges in NCSE dataset

14 of 16 NCSE subjects show discharges in the EEG recordings.

Agreement:
- Cohen Kappa: 0.499 (Moderate agreement [0.4 0.6]);
- Fleiss Kappa: 0.3773

Total number of ictal discharges: 331

Ictal Proportion (the seconds of ictals/ the seconds of all EDF duration): ca. 7.9%

Ictal Distribution:
- Focal: 47 (14.2%)
- Generalized: 284 (85.8%)

Ictal definite/possible:
- Definite: 168
- Possible: 163

Ictal number of patterns:
- Spike Wave: 254 (76.7%);
- Wave: 78 (23.6%);
- Fast Spike: 34 (10.3%);
- Unknown: 12 (3.6%)
- EMG-Like discharges: 2 (0.6%);

Ictal onset:
- Clear: 187 (56.5%)
- Blurry: 144 (43.5%)
NCSE Discharge (EEG) Example: Spike Waves

- Classic Spike Waves
- Not classic Spike Waves (wave pattern merged)
Workflow of NCSE detection

Segment into 50% overlapped windows (via Hamming window):
2.56 second window

Filtering:
0.5 Hz to 45 Hz

Re-Reference to the average of channels

Feature Extraction:
PSD, Peak2Peak, Wavelet coefficients, etc.

Classification: RUSBoost

Post-processing

Workflow of 3-class classification + Post-Processing

2-Class Features Table

Binary Classifier: “Yes” or “No”

Find misclassified points

Set these points as “Gray”

3-Class Features Table

Train 3-Class Classifier

Build 3-Class dataset & Train its classifier

2-Class Features Table

3-Class Classifier: “Yes” or “No” or “Gray”

Predicted values ("Yes"=1, "No"=0, "Gray"=tuning value for individual subject)

A smooth window: 20-second long vector

≥ a threshold value?

Y
“Yes”

N
“No”
Performance on average

<table>
<thead>
<tr>
<th>2-Class Classifier</th>
<th>3-Class Classifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPR</td>
<td>PPV</td>
</tr>
<tr>
<td>86%</td>
<td>23%</td>
</tr>
</tbody>
</table>

TPR (sensitivity) = \( \frac{TP}{TP+FN} \);

PPV (precision) = \( \frac{TP}{TP+FP} \);

TNR (specificity) = \( \frac{TN}{TN+FP} \);

TP \rightarrow True Positive Events;  
TN \rightarrow True Negative Events;
FP \rightarrow False Positive Events;  
FN \rightarrow False Negative Events;
Avoid pitfalls in NCSE detection?

- Too many inter-ictals or short ictal discharges (less than 20 seconds) in EEG recordings;

- Our Current algorithm cannot distinguish the three types well:
  - Inter-ictal;
  - Slow activities (caused by drowsiness or slow activities shown by some damage brains);
  - Ictal;

Potential solutions:

- Visibility Graph (VG) method and its extension

(Oral presentation at 14:30 by Hui Du

“Visibility Graph methods in Nonconvulsive Seizure Detection”)

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