Introduction

Continuous long-term EEG monitoring is the gold standard for recording epileptic seizures and assisting in the diagnosis and treatment of patients with epilepsy.

The task of automating the detection of epochs of EEG having seizure activity is non-trivial due to several factors, including the differences in seizure morphologies within and across patients, and the presence of movement and other recording artifacts.

We developed and tested a seizure detection algorithm based on two measures of nonlinear and linear dynamics, that is, the adaptive short-term maximum Lyapunov exponent ($\text{ASTL}_{\text{max}}$) and the adaptive Teager energy (ATE). The developed seizure detection algorithm is data-adaptive, training-free, and patient-independent.

Patient Data

Data from intracranial EEG (3 patients) and scalp EEG (2 patients) recordings were collected.

Intracranial EEG recordings were obtained from epilepsy patients with bilaterally, surgically implanted intracranial electrodes in the hippocampus, temporal and frontal lobe cortices.

Scalp EEG recordings with 22 recording electrodes, placed according to the International 10-20 system, were obtained from 2 epilepsy patients.

Patient Data Table

<table>
<thead>
<tr>
<th>Patient Number</th>
<th>Type</th>
<th>Duration (hrs)</th>
<th>Seizures</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>Intracranial</td>
<td>281</td>
<td>7</td>
</tr>
<tr>
<td>D2</td>
<td>Intracranial</td>
<td>217</td>
<td>24</td>
</tr>
<tr>
<td>D3</td>
<td>Intracranial</td>
<td>145</td>
<td>20</td>
</tr>
<tr>
<td>S1</td>
<td>Scalp</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>S2</td>
<td>Scalp</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>666</td>
<td>56</td>
</tr>
</tbody>
</table>

Flow Chart

Features Used

a) ATE:

$$\psi_k(x[n]) = x_k^2 - x_{n-k}x_{n+k}$$

b) $\text{ASTL}_{\text{max}}$:

$$\text{ASTL}_{\text{max}} = \frac{1}{\Delta t} \log_2 \frac{[X(t_{ik} + \Delta t) - X(t_{jk} + \Delta t)]}{[X(t_{ik}) - X(t_{jk})]}$$

Conclusion

The sensitivity ranged from 85.71% to 100%, while the false positives per hour ranged from 0 to 1 every 6.5 hours.

The average sensitivity across all five patients was 91.81% with an average specificity of 0.14 false positives per hour.

Two of the missed seizures in intracranial recordings (in patients D1 and D3) were subclinical events of smaller duration (< 10 sec) than the pre-determined algorithm's resolution.

Three of four seizures missed in patient D2 were localized to a specific region of the brain and also lasted less than 10 sec.

References
