XGBoost-based Method for Seizure Detection in Mouse Models of Epilepsy

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Background

- Epilepsy is the second most common neurological disorder behind stroke, according to the World Health Organization (WHO).
- Epilepsy is caused by the disruption of the finely tuned inhibitory and excitatory balance in brain networks, manifesting clinically as seizures.
- Electroencephalographic (EEG) monitoring in rodent disease models of epilepsy is critical in the understanding of disease mechanisms and the development of anti-seizure drugs.
- Seizure detection with EEG requires a direct examination by a physician and substantial amount of time and effort.
- Automated detection is a powerful method to devote to this task which can reduce the annotation time of experts.
- Research on seizure detection methods applicable to multiple mouse models has been limited to date.
- In this study, an automated method for seizure detection in EEGs from different mouse models of epilepsy is proposed.

Data

Mouse model I : Intra-amygdala kainic acid (IAKA) Adult male SV129
EEG signals were recorded in each mouse for 14 days, with 20 minutes of baseline on the first day. 40 mins later, the intraperitoneal lorazepam (8 mg/kg) was injected to reduce morbidity and mortality. Following a latent period of 3-5 days, spontaneous recurrent seizures started to develop.

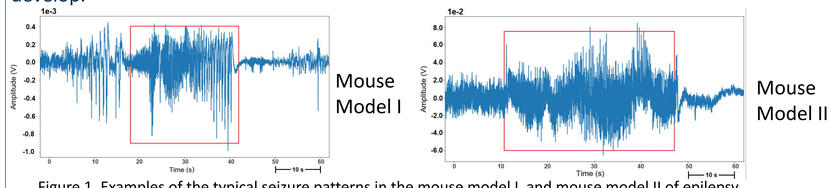

Figure 1. Examples of the typical seizure patterns in the mouse model I and mouse model II of epilepsy (the signal in the red block indicates the presence of seizure event).

Mouse model II : Dravet Syndrome (DS) F1.*Scn1a(+/-)tm1Kea*
Mice were bred with a mutation which mimics DS, a rare and severe epileptic encephalopathy. DS, F1.*Scn1a(+/-)tm1Kea* experience recurrent spontaneous seizures. These were recorded using tethered EEG monitoring from 12:30 to 6:30 pm between postnatal days p21-p28.

Table 1. Number and duration of seizures labelled by experts

	IAKA	DS
Number of mice	4	5
Average number of seizures	14	2
Total seizures number	54	11
Seizure duration (seconds)	2,212	398
Non-seizure duration (seconds)	4,053,284	278,758

Method

- Teager-Kaiser energy operator (TKEO)-based method

The discrete TKEO is defined

$$\varphi[x_t] = x^2 - x_{t-1} * x_{t+1}$$

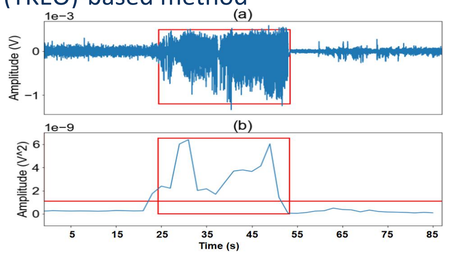

Figure 2. TKEO applied to the IAKA mouse EEG signal (a) the original signal (b) the signal after the TKEO approach wasapplied (the red line is the threshold)

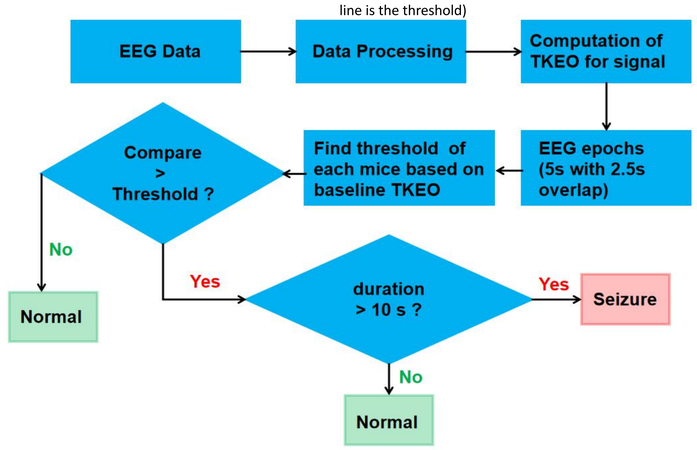

Figure 3. Structure of the TKEO-based method

- XGBoost-based method

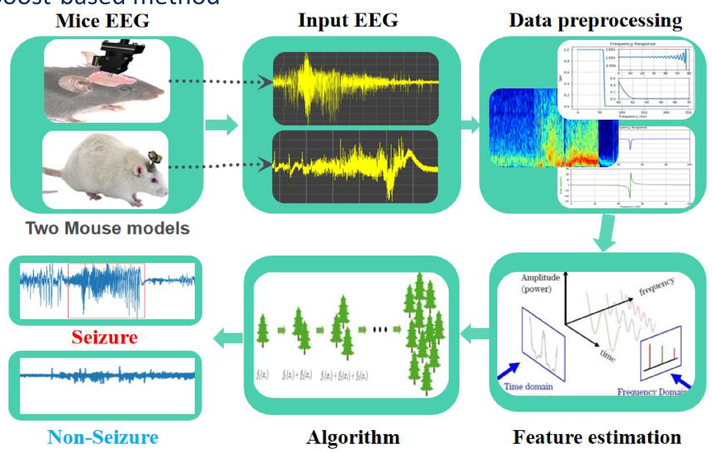

Figure 4. Structure of the XGBoost-based method

Results

Table 2. Performance of the TKEO-based seizure detection method on the independent test set.

	Sens (+/- std) (%)	Spec (+/- std) (%)	Acc (+/- std) (%)
IAKA Test (N=3)	72.1 (+/-12.0)	97.5 (+/- 0.1)	98.0 (+/- 0.7)
DS Test (N=4)	73.5 (+/-24.9)	62.4(+/-25.8)	62.3(+/-25.7)

Table 3. Performance of the XGBoost-based seizure detection method on the independent test set.

	Sens (+/- std) (%)	Spec (+/- std) (%)	Acc (+/- std) (%)
IAKA Test (N=3)	93.0 (+/-20.6)	99.3 (+/- 1.4)	99.3 (+/- 1.4)
DS Test (N=4)	99.5 (+/- 1.1)	98.0 (+/- 1.4)	98.0 (+/- 1.4)

std: standard deviation

Conclusion

- ✓ XGBoost-based method performed better than TKEO-based method in both mouse models of epilepsy
- ✓ A novel XGBoost-based method to detect seizures
- ✓ Assist researchers in the automated analysis of seizures in mouse model of epilepsy
- ✓ Single-channel, multi-type seizures in long mice EEG recordings
- ✓ Removes user bias when detecting seizures
- ✓ Fast, reliable, reproducible

Future work

The method need to be validated in data sets from :

- ☐ Larger numbers of mice
- ☐ Different mouse models of epilepsy

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