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Brain-machine interfaces for seizure detection leveraging information theory

Stanford inventors have developed an information theoretic, seizure detection algorithm for electroencephalography (EEG) towards improving diagnosis, management, and treatment of patients with epilepsy.

Epilepsy affects approximately 1% of the world's population, and when inadequately treated, it carries a lifetime risk of mortality of approximately 25%. About a fifth to a third of epilepsy patients are refractory to treatment, and many patients undergo intracranial neuromonitoring studies, involving surgically implanted electrodes in the brain, to localize their seizure source. Treatment options for patients with refractory focal epilepsy include surgical resection, laser ablation, vagal nerve stimulation, and responsive neurostimulation. However, there is no guarantee that a patient will become seizure-free with most of these treatments. Better diagnostic tools are needed to guide clinical interventions and management of patients with epilepsy.

Stanford researchers, therefore, developed an algorithm that informs seizure activity to better diagnose, manage, and treat patients with epilepsy. The method detects seizures using information theoretic estimates of joint entropy by leveraging data compression. It is purely an algorithm (transformation) that requires no supervised learning, model fitting, or training data. Automatic seizure detection based on objective measures can speed up and improve manual EEG reviews. Reliable biomarkers for seizure activity enable device-based therapies that programmatically stimulate and disrupt seizures once detected. This approach has been reduced to practice on intracortical data and also has been preliminarily confirmed on ECoG and surface EEG recordings.

Stage of Development

Proof of concept & reduced to practice on intracortical data

Applications

- Clinical monitoring for patients with epilepsy.
- Automated seizure detection
- Validation/verification of manual review of EEG data

Advantages

- Higher performance than existing model-free methods. Provides a better understanding of the location, nature, and quality of seizures.
- No need for electrode selection, which requires expert interpretation, because the algorithm supports aggregate (multichannel/multielectrode) data.
- Model-free algorithm makes no assumptions about the structure of neural data and requires no training data.
- Manual EEG reviews can be augmented with robust quantitative measures.
- Can create opportunities to improve the diagnosis and treatment for people with epilepsy.

Publications

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- Yamada L, Oskotsky T, Nuyujukian P. 2021. Seizure detection and localization using human intracranial electrophysiology via information theoretic methods. *COSYNE.*
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Patents

- Published Application: 20230310857

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