School of Engineering
Institute Electrical & Micro Engineering
Embedded Systems Laboratory

Master or Semester Project

Electroencephalography based epileptic seizure detection

Epilepsy is one of the most common severely disabling brain conditions, affecting over 46 million people worldwide. It is characterized by abnormal electrical activity in the brain that manifests as recurring, sudden, excessive, synchronous electrical activity in neuronal networks that disrupt ongoing brain activity and causes clinical seizures. These seizures cause stereotyped behaviors or sensations that can include alteration of consciousness, depending on the part of the brain that is affected. Epilepsy accounts for a high proportion of the global disease burden, with 13 million disability-adjusted life years. Every year, more than five million new cases are diagnosed, and the number of people with epilepsy is expected to increase in future years [1].

The diagnosis of epilepsy is based on clinical history, neuroimaging and electroencephalography (EEG). Scalp EEG is an electrophysiological measurement technique. It records the electrical field of the brain cortex non-invasively by placing a number of surface electrodes onto the scalp, typically about 20 in routine clinical practice. The recordings obtained from EEG can provide information on the brain's overall electrical activity and help identify patterns of abnormal activity associated with seizures. During the last decade several public EEG seizure datasets have been made available. This has allowed for researchers all over the world to develop algorithms for automated analysis of EEG.

Automated EEG-based seizure detection algorithms have a long history, dating back to the 1970s. The development of these algorithms is driven by the need to reduce the workload of epileptologists in analyzing EEG recordings. Recently, there has been a significant increase in the development of machine learning algorithms. Some of these algorithms use a variety of features extracted from EEG signals, including time-domain, frequency-domain, and non-linear measures, to classify seizure and non-seizure segments as input to a classifier. Others use novel deep learning techniques that leverage advances in computational power to improve the accuracy and reliability of automated seizure detection [2]. Despite the progress made in the field of machine learning, automated EEG-based seizure detection algorithms are still not yet widely used in the clinic [3]. This is due to a high false positive rate along with poor standardization in reporting and validation of these algorithms [4, 5].

In the Embedded Systems Laboratory, we are actively contributing to several innovative seizure detection algorithms that leverage different fields of machine learning including, hyperdimensional computing, multi-modal signal processing, knowledge distillation, transfer learning, and other deep learning techniques. We are also working on a framework to validate seizure detection algorithms. This framework will allow to objectively compare and benchmark different seizure detection algorithms in order to validate them for use in the clinic.

In this project, you will help build the framework for the validation of EEG-based seizure detection algorithms. For this you will be writing scripts that standardize the format of

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several public EEG datasets. You will then select the best state-of-the-art algorithms for EEG-based seizure detection and reimplement them to evaluate them on the public datasets. This will allow for a fair and consistent comparison of algorithms. For the comparison you will select evaluation metrics and run the benchmark on the state-of-the-art algorithms. This will allow you to build a leaderboard of the best algorithms by benchmarking them with the framework.

Tasks:

- Write scripts to standardize data input and output of EEG-based seizure detection algorithms.
- Re-implement state-of-the-art algorithms for EEG-based seizure detection.
- Co-design evaluation metrics to benchmark EEG-based seizure detection algorithms and write scripts that compute algorithm performance.
- Perform analysis of state-of-the-art algorithms using the previously developed benchmark.
- Optional: Build a website to display a leaderboard of best algorithms
- If previous objectives are fulfilled, this work could lead to a peer-reviewed conference or journal submission.

Requirements:

- Basic knowledge of signal processing.
- Basic knowledge of machine learning tools and methods.
- Basic knowledge of MATLAB.
- Good programming skills in Python.
- Interest in biomedical applications.

References:

[1] V. L. Feigin, E. Nichols, T. Alam, et al. (2019), “Global, regional, and national burden of neurological disorders, 1990-2016: A systematic analysis for the global burden of disease study 2016”, The Lancet. Neurology, vol. 18, pp. 459–480.

[2] A. Shoeibi, M. Khodatars, N. Ghassemi, et al. (2021), “Epileptic seizures detection using deep learning techniques: A review”, International Journal of Environmental Research and Public Health, vol. 18, p. 5780.

[3] Reus, E. E. M., et al. (2022) "Automated seizure detection in an EMU setting: Are software packages ready for implementation?". Seizure

[4] Una Pale, Tomas Teijeiro & David Atienza (2023). “Importance of methodological choices in data manipulation for validating epileptic seizure detection models’’ ARXIV

[5] Shah, V., Golmohammadi, M., Obeid, I., Picone, J. (2021). “Objective Evaluation Metrics for Automatic Classification of EEG Events” In: Obeid, I., Selesnick, I., Picone, J. (eds) Biomedical Signal Processing. Springer

Lab: ESL

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