GRAPH NEURAL NETWORKS TO ANALYZE BRAIN CONNECTIVITY IN NEUROLOGICAL DISORDERS

1 Supervising staff

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This project will be performed in collaboration and with the help of the Department of Neurology at the CUB Hôpital Erasme.

2 Context

Epilepsy is one of the most common collection of neurological disorders, affecting nearly 1% of the global population[1]. It is characterized by an enduring risk of spontaneous seizures and profoundly impacts patients' lives due to its neurobiological, cognitive, psychological, and social consequences[2]. This work addresses two specific epileptic pathologies that have rarely been explored. The first disorder pertains to **patients admitted to an Intensive Care Unit** (ICU), where up to 20% will experience nonconvulsive seizures, either because of the acute decompensation of a chronic seizure disorder or as a complication of an acute brain injury or systemic illness[3,4]. The second concerns **children with Spike-Wave Activation during Sleep** (SWAS), a pediatric Epileptic Encephalopathy (EE) characterized by massive cognitive-behavioral regression[5]. This condition is one extreme of the spectrum of Self-Limited Focal Epilepsy with Centro-Temporal Spikes (SeLECTS), which is the most common epilepsy syndrome in the pediatric population. In both cases, classical diagnostic approaches based on electroencephalography (EEG) are hampered by several limitations that delay and complicate treatment, which has a highly detrimental impact on patient care[6,7].

Brain connectivity recently emerged as a promising approach to diagnose neurological disorders, alleviating the shortcomings of traditional EEG analysis. Brain connectivity represents the systemic operation of brain activity via a network depicting the interaction between anatomical areas. Its suitability to study neurological disorders relies on their shared functioning as dysconnectivity syndromes, originating from a reorganization of the neural activity[8]. In particular, it was shown that brain connectivity significantly changes between ICU patients at risk of seizures and controls[9] and from EE-SWAS to typical SeLECTS[10].

Satisfactory performances in diagnosing the pathological cases in the two patient populations have been achieved using logistic regression models fed by connectivity metrics. However, using **machine learning** models could further improve classification accuracy and thus provide even greater support for diagnosis. This was investigated in previous work at BEAMS, where several machine learning models leveraging functional connectivity were implemented and evaluated on the ICU patient cohort. The models considered explored varying levels of complexity and input formats; from the SVM and Random Forest, fed with connectivity features extracted from the graphs, to the Graph Neural Networks (GNN), taking as input de connectivity matrices directly. Strikingly, it was shown that model performances consistently decreased with complexity, as presented in Table 1.

Model	F1-score
SVM	75 %
Random Forest	74 %
Graph Convolutional Network	64 %
Graph Attention Network	61 %

Table 1. Model performances assessed via the weighted F1-score

This preliminary work shows the potential of machine learning methods to identify ICU patients at risk of seizures and prompts to take the analyses further to gain better accuracy and extend the investigation to the SeLECTS cohort. Especially, the performance of the GNNs could be significantly improved, which would give confidence in a completely different way of analyzing connectivity and pave the way for a whole new area of research. Indeed, GNNs preserve the topological properties of graphs, unlike traditional neural networks, which ignore the structural information inherently encoded in graph representations[11].

3 Work

This work aims to investigate and assess machine-learning methods based on brain connectivity to predict subsequent seizures in ICU patients and cognitive regression in SeLECTS. The goal would be to compare the performance of machine learning models to the traditional feature-based classification methods. Recording of EEG signals from patients in the ICU and the SeLECTS children will be provided (retrospective data already available).

4 References

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