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Studying local topological features of neuronal network models for epileptogenic foci identification

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Abstract

Epileptic seizures vary in range and intensity among affected patients. In most of them, the identification of epileptogenic foci and its relevance is crucial for a successful recovery. Motivated by these facts, this project is aimed at representing the neuronal web as mathematical networks, where neurons are mapped into nodes and the anatomical ties between neurons as edges. Other networks are defined, local topological characteristics will determine their robustness, e.g. their ability to sustain or withstand random failures. In this sense, epileptogenic foci appear as localized features that might spread across the entire brain producing seizures of different intensity.

1. Introduction and Motivations

Epilepsy is a medical condition characterized by seizures or disruptions of the electrical communication between neurons. Some epileptic seizures can be controlled with medications while others require surgical interventions. In those cases, surgeons must decide how much of the brain to remove or disconnect. **Translational medicine ASPECT to this research.**

Epilepsy is the 4th most common neurological problem in the USA, followed by migraines, strokes and Alzheimer disease. The average incidence of this condition each year in the USA is estimated at 45 incidents for every 100,000 people.

Young children and older adults are the groups with the highest rates. In addition, the prevalence of this condition is estimated at 2.2 million people or 7.1 for every 1000 people in the USA.

EEG collects information from different electrodes, which in turn receive signals emerging from a large group of neurons. Patches of neurons are supposed to work in synchrony, when it is localized, localized failures may emerge and also spread over the entire brain.

Fig. 1 Evaluation of a seizure onset zone.

Fig. 2 Epileptic seizures are associated with disruptions within the brain networks (epileptogenic foci) [1,2], which emerge from 4 nodes in local communication failure and the breaking of coherence.

Fig. 3 The brain connectivity atlas is determined using both fMRI and EEG techniques. The former provides the spatial resolution while the latter the temporal resolution. Networks are identified via anatomical (structural) and functional (the state of brain networks) features in the study of mathematical networks with their topological measures [3].

2. Objectives

This project is aimed at:

- Mastering the concepts behind the Connectome project and the mapping of the problem of epilepsy onto a problem of measuring local topological features of networks.
- Using R (RStudio) to solve the above-mentioned problem.

3. Methodology

In order to accomplish the above-mentioned objectives, the following steps will be carried on:

1. Install the package "igraph" from the R-repository.
2. Create a batch of different networks, including random networks, hierarchical ones, and complex networks with power law distribution.
3. Compute the topological measures of the network and look for associations with those networks obtained from a joint analysis of fMRI and EEG signals.
4. Analyze topological measures to be used as mathematical markers for epileptogenic foci, and the imminent appearance of seizures.

4. Network Analysis

RStudio is a free and open-source integrated development environment (IDE) for R, a programming language for statistical computing and graphics.

Random Number Generation

First, using the "igraph" package [4], a random sample of numbers was created. The resulting sample was plotted using a command in "igraph": "layout_spring" as well as a histogram of the degrees of nodes, the connectivity of one node to another.

Histogram of node degree

Fig. 4 (left) The median numbers plotted in "igraph": Random sample labeled as g1. R studio plot(1). (middle) Random sample, "network_color", "network_order", (right) The histogram of node degrees using the random sample on the left.

If we change the algorithm of generating a random sample of numbers, either by changing the probability distribution or by doing bootstrapping, we might model local connectivity within the brain neuronal network. Epileptogenic foci seem to appear among nodes with high degree that function also as bridge points.

5. Conclusions

The results of this project can be summarized as:

1. We mastered Rstudio to analyze statistical properties of neuronal networks through the package "igraph".
2. Neuronal networks can be mapped into mathematical networks appealing to local topological measures and different probability distribution of nodes.
3. Epileptogenic foci seem to appear among nodes with large relative frequency in degree distributions and which are also bridge points. Besides that, these nodes are part of geodesic paths, meaning signals have the potential to propagate over the entire brain.

6. Acknowledgments

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7. References

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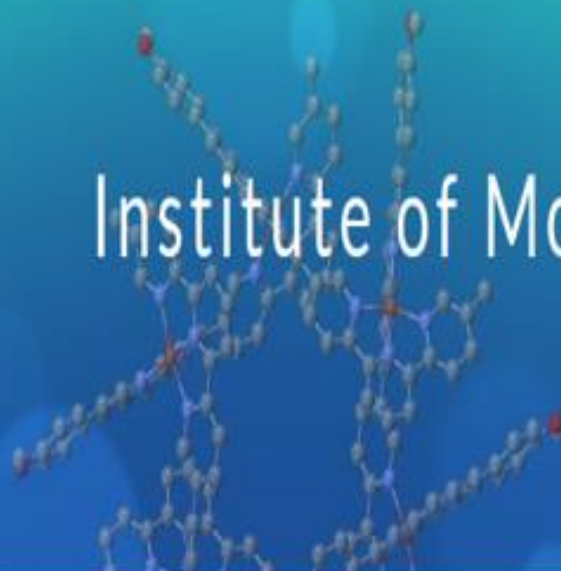
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