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A new method of self-similarity signal analysis applied to electroencephalograms recorded from animal model of epilepsy

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Background, Motivation and Objective. The epilepsy is the most common neurological disorder characterized mainly by a predisposition for recurrent seizures events (FISHER et al., 2014; World Health Organization, 2017). The electroencephalographic (EEG) activities are essential in clinics to identify epileptogenic zone and other features, because it provides the evolution of brain's electrical activity over time. Despite the information analyzed in EEG, other electrophysiological biomarkers can be extracted from these signals with specific metrics, aiming a better understanding of the underlying physiopathological mechanisms. Here we propose a new method for an electrophysiological characterization of seizures in an epileptic animal model using Kullback-Leibler Divergence (DKL) and network analysis in order to study and recognize hidden biomarkers along their patterns and dynamics. It is expected a better elucidation on the temporal dynamics of the different states presented during epileptic seizures and to reveal possible physiological modulatory mechanisms associated with these states.

Methods. It was recorded neural electrophysiological activities from cortex of control and experimental (epilepsy model) animal groups. The main objective is to evaluate how each temporal period of these recordings is correlated with another one, along the entire signal. To perform this analysis, the signal is divided into *n* equal intervals of size *m*, where, it is evaluated the degree of correlation between each instant of time and to infer irregularities associated with the signal over the time. The correlations are calculated by using Kullback-Leibler divergence (DKL), since it evaluates temporal asymmetries with a nonlinear metric, allowing a quantification and distinguishing of possible modulatory processes underlying seizures progress. Furthermore, DKL provides a natural thermodynamic interpretation, associated with the hyper synchronization of the neural activities during the seizures. The method works by extracting features from neuronal oscillations as amplitude, frequency, and phase in order to produce a matrix of states transition associated with each instant of time along the recordings. In these matrixes it is applied a principal component analysis (PCA) to reduce the redundancies and evaluate a profile trend of the states with clusters, as well used as adjacent matrixes for a network analysis. The use of graph theory provides a new perspective on how each instance of the signal are related or not with the precipitation of an event. All procedures were approved by the Institutional Animal Care and Use Committee of the Federal University of Rio de Janeiro (protocol #052/2017).

Results. The results obtained so far shows the consistency and sensitivity of DKL to present structures of different instances of the signal dynamics, figure 1, allowing a good resolution of the transitions among all events (baseline, seizures and after seizure stages). It is also observed that the DKL favored the detection of variations of signal complexity in the frequency and phase domain, allowing the study of the modulation associated with specific brain rhythms. Through the application of PCA, it was possible to verify the presence of clusters representing seizure events (black dots in figure 2), enabling to study the transients along seizures.

Discussion and Conclusions. This technique provide a new method to characterize epileptiform electrophysiological signals and may help to construct a new interpretation on neural dynamics during epilepsy. It is expected that with the use of DKL it will be possible to identify the main epileptogenic stages, their main characteristics, as well as which instances are most correlated with a certain brain region. Since DKL measures the cost to map a given distribution of probability onto another one, the values of DKL are causality markers along the activity, allowing to point out a direction to the event occurrences. The network analysis using the state transition matrices is still in development, and it will provide a new approach for the electrophysiological characterization, providing, for instance, new ideas on the temporal information flow and on the set of features related to some event precipitation, like a seizure.

Figures and Tables.

Figure 1: Transition States Matrix with signals from experimental animal group

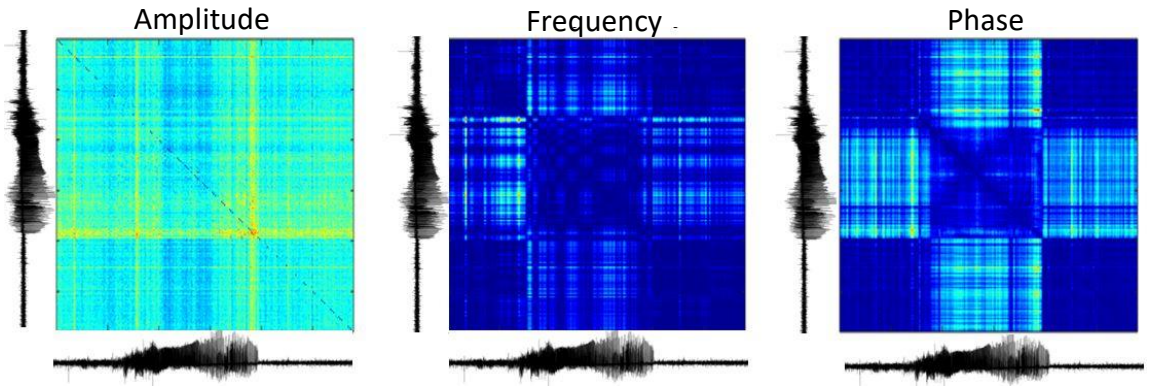
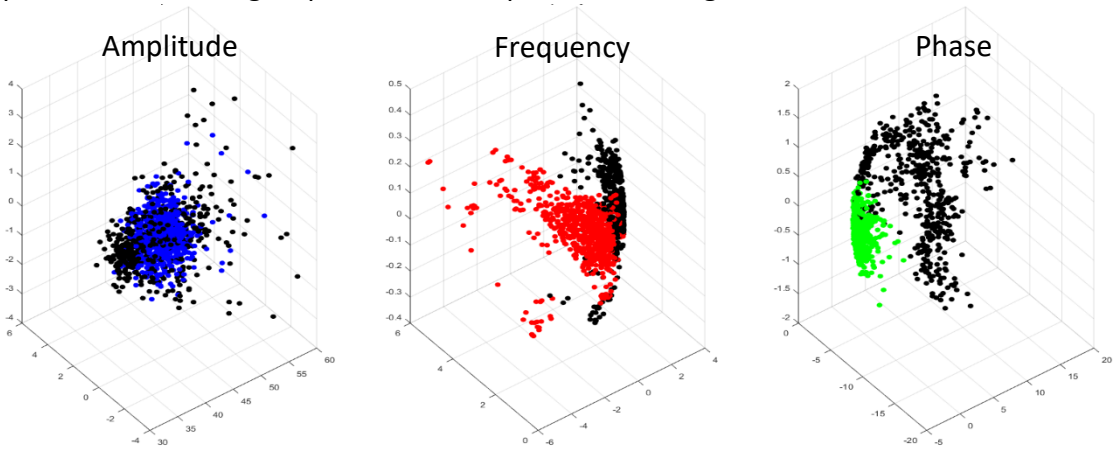


Figure 2: Principal component analysis of the transition state matrices yielded with signals recorded from experimental animal group. Black dots represent the stages related to seizure occurrence.



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Keywords. Self-similarity; electrophysiological biomarkers; epilepsy; animal models; network analysis.