Unveiling Epileptic Networks: Motif Synchronization for Interictal Spike and Foci Localization

Scalp EEG analysis is a primary diagnostic tool for epilepsy, particularly for identifying interictal epileptiform discharges (IEDs) that may indicate potential epileptogenic foci (EF).

This study explores Motifs Synchronization (MS), a functional connectivity (FC) technique, for automatically detecting EF laterality and IED occurrences. With MS, a motif is one of the $n!$ ordinal patterns of n sequential points within the time series (here we take $n = 3$). The time series of each individual EEG channel is transformed into a motif series, and connectivity is measured by pairwise comparing each channel's motif series within short time windows, introducing a small delay (1-3 samples) between them to capture directionality.

We used 63-channel EEG signals obtained from EEG-fMRI sessions of 10 patients (3 male, mean age 35 ± 12 years, epilepsy duration 30 ± 10 years) with mesial temporal lobe epilepsy who were evaluated for EF resection surgery. After artifact removal, downsampling to 250Hz and filtering, the IEDs were visually marked by a clinician. MS was applied to different EEG referencing montages (common reference to FCz, median and average) with time windows of 80ms with 50% overlap and an edge threshold of 95% correspondence.

Two key findings emerged. First, the number of connections in the MS-generated Time Varying Graph (TVG) seemed to increase significantly during IED segments across all montages/patients. Second, using the median referencing, the summed across time TVG revealed clusters of highly synchronized (exceeding the top 1% in strength) edges localized primarily in or near IED-marked regions for 8 out of 10 patients. We believe these results suggest MS as a promising tool for both IED and EF detection.