EN.580.694: Statistical Connectomics
Final Project Proposal

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Predicting epileptic brain network response to electrical stimuli and mathematical problem solving

Opportunity Epilepsy is considered a network phenomenon characterized by "hypersynchronous" atypical activity during seizure, at both the single neuron level and higher neural populations [1][2]. Seizure cessation in epileptic patients is often attempted through local electrical stimulation or mathematical problem solving [3], but it is not fully understood how these work and how to predict when they will work.

Challenge A number of tools can be applied to understand epileptic networks, e.g. neuroimaging (MRI, fMRI), and electromagnetic recordings (ECoG, MEG) [4]. ECoG data are localized, instantaneous, gridded measurements of brain electrographic activity and useful for monitoring epileptic patients prior to resection surgery and for real-time stimuli testing of seizure cessation [5]. However, the complexity of the brain electrical activity and the high-dimensionality of the ECoG time series data are challenging from a network modeling perspective.

Action We propose to test a connectivity feature derivable from ECoG data that can be used to predict a patient's response (positive/negative) to stimuli at the onset of abnormal brain activity. Specifically, we will implement a particular approach [5][6] leveraging connectivity features (centralities) that have shown promise in correctly located seizure foci based on ECoG data over time, but adapt to our problem. We will train on extensive ECoG data collected on patients prior to resection surgery, with and without electrical and problem solving stimuli. Noting potential trends in the calculated features, we will develop a classifier and test on a testing ECoG dataset. The hypothesis is that the external stimuli - electrical or mathematical problem solving - globally affects strength of region connectivity over time, which is the primary feature of the applied approach [5].

1. Code up current approach [5] for calculating strength of region connectivity over time for an ECoG dataset, using several different centralities.

2. Apply to the training set of ECoG data with known outcomes (seizure or other abnormal brain activity stopped/not stopped) following application of stimuli (electrical pulse stimulation or the patient is posed a math problem to solve)

3. Note trends in the features calculated above (e.g., strength of region connectivity over time) for cases of positive or negative outcome, that can be used to predict positive or negative outcome. Essentially build a "classifier."

4. Apply classifier to a test dataset, i.e., an ECoG dataset not used in the training above, and assess performance.

Resolution We will gain insight into the utility of connectivity features (centralities) used in other seizure studies for the prediction of epileptic brain network responses to local electrical stimuli and mathematical problem solving.

Future Work One likely difficulty of this project will be the high dimensionality of the datasets. Additional graph classification approaches, e.g. using signal-subgraphs [7], may provide a more intuitive approach to deal with the data dimensionality and learning aspect of the problem.

Statistical Decision Theoretic

Each subject has a value s, where m is the total number of subjects, meaning that $2 \times m$ is the total number of graphs. The large graph for each subject, G_s, with nodes V_s and edges E_s is parcellated by an atlas, k_i, and produces the resulting small graph with labels Y_S. The decision rule class, for which the several methods have yet to be set, will determine the similarity between graphs. The loss is determined by incorrect matching of a graph to the same subject, and the risk is the expected loss over the space of all graphs.

Sample Space $G = (V, E, Y)$ Graphs of ECoG data, where V is each electrode (node), E is the region connectivity as calculated by approach in [5][6], and $Y \in \{0, 1\}$, where 0 is negative effect (no seizure cessation) and 1 is positive effective (seizure cessation).

Model $H = (V, E) \in \mathscr{H}$ Graphs of the raw ECoG data without the known classifications.

Action Space $\hat{Y} \in \mathscr{Y}$ Outcomes of classifier, i.e. $\{0, 1\}$, where 0 is negative effect (no seizure cessation) and 1 is positive effective (seizure cessation).

Decision Rule Class $f : \mathscr{H} \to \mathscr{Y}$; $f = thresh[cluster[rank(x(i) = \sum_{i=1}^{n} H_{ij} x(j)]]$ this is a mapping of the graph or connectivity matrix H_{ij} to the classes $\mathscr{Y}$ by a thresholding of a ranked and k-clustered centrality feature derived from the centrality vector which is a function of the eigenvector $\vec{x}$ [5].

Loss Function Loss functional: (TBD) $\ell(\hat{Y}, Y) =$ a ROC curve comparison of some kind between our sample space classes, and our action space classes.

Risk Function Risk functional: $R = E[L]$.

References

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