Dynamical recurrence analysis for modeling neural activity during epilepsy seizures

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Problem Formulation

- Absence Seizures

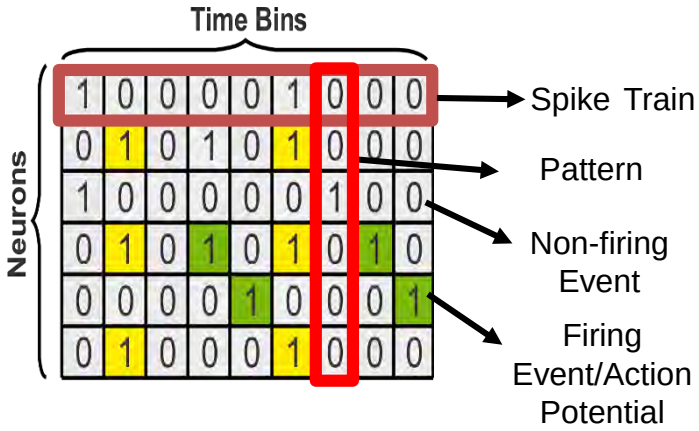
Between Seizures:
Patient is normal

During Seizure:
- Vacant stare
- Eyes roll upward
- Cease activity
- Lack of response

- Goal: Modeling Brain Neuronal Activity during Absence Seizures
  - Identify Patterns
  - Temporal Correlations among neurons
  - Dimensionality Reduction

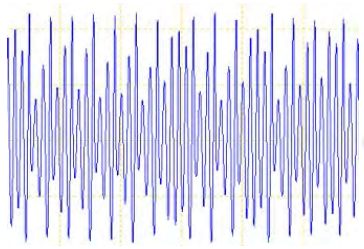
Challenges - Motivation

- Real Dataset:
  - Background Noise (Unmodeled)
  - Extremely rare firing within thousand time bins



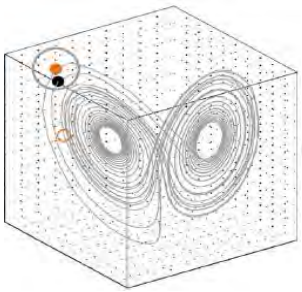
- Solution: Recurrence Quantification Analysis (RQA)!
  - Can be applied to rather short and even nonstationary data
  - Does not make any assumption about the model that governs the system or the data (e.g., linearity, convexity, stationarity)
  - Is robust to outliers

Methodology – Experimental Results



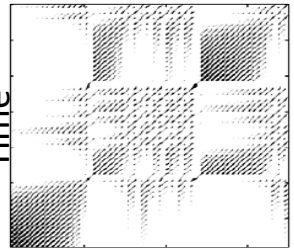
Original time series

Time-Delay Embedding



Phase Space (States x_k)

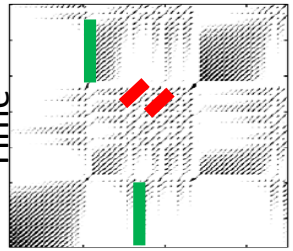
Binary Recurrence Matrix

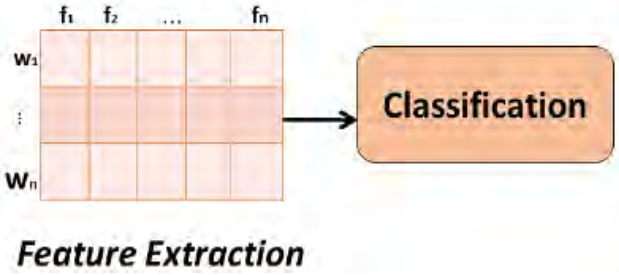


Recurrence Plot

Critical Parameters
Embedding dimension m
Time Delay τ

$$R_{i,j}(\varepsilon) = \begin{cases} 1, & d(x_i, x_j) \le \varepsilon \\ 0, & \text{otherwise} \end{cases}$$





Mean ± Standard Deviation	Seizure	Non-seizure
Precision	68.93±0.99	57.46±0.41
Recall	38.12±0.99	82.95±0.77
Specificity	82.95±0.77	38.12±0.99
F-score	49.08±0.93	67.89±0.44