Assessing Directional Connectivity via Network Localized Granger Causality Extracted from MEG Data

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1Identifying causal relationships between different cortical areas for understanding mechanisms behind sensory processing
2Connectivity characterized by the temporal predictability of activity across brain regions via Granger causality (GC)
3Challenges with Magnetoencephalography (MEG): the data are low-dimensional, noisy, and linearly mixed versions of underlying source activities
4Conventional methods (two-stage procedures): NLGC
5Drawbacks: bias propagation, spatial leakage

### Model

- **Observation model:**
  \[ y_t = Cx_t + e_t, \quad t = 1, 2, \ldots, T \]
  \( e_t \) is MEG observation, \( C \) is MEG lead matrix, \( e_t \) is source activity, \( e_t \) is measurement noise
- **Source dynamic model (auto-regressive):**
  \[ x_t = \sum_{k=1}^{p} A_k x_{t-k} + w_t, \quad t = 1, 2, \ldots, T \]
  \( A_k \) is coefficient matrix, \( e_t \) is noise process

### Parameter Estimation

- **Goal:** directly localize GC influences without an intermediate source localization step
- **Method:** Network Localized Granger Causality (NLGC)

### Results: Simulation

#### NLGC performance/other methods
- **Hit Rate**
  \[ \text{Hit Rate} = \frac{\text{Number of true positives}}{\text{Total number of true positives} + \text{False negatives}} \]
- **False Alarm Rate**
  \[ \text{False Alarm Rate} = \frac{\text{Number of false positives}}{\text{Total number of false positives} + \text{True negatives}} \]

#### Results: Synthetic Data

- **Simulation means squared error (MSE)**
  \[ \text{MSE} = \frac{1}{n} \sum_{i=1}^{n} (y_i - \hat{y}_i)^2 \]

### Results: Processing vs. Resting State

- **13 younger and 9 older adults**
- **100 repetitions of tone pips presented at the end of resting state recordings**
- **20 40-second trials per subject/condition**
- **Connectivity in auditory cortex is investigated**

### Reference

Paper:

Python Package:

For details and more explanations, please check the paper.