Nonlinear Granger Causality Analysis of Local Field Potentials

Discovering Connectivity in the Brain

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Problem

In order to understand how the brain as a whole functions, one has to reveal how different functional regions in the brain communicate. To this end the causal relations between brain regions need to be identified, i.e. identify whether an activation in one part of the brain causes activation in a different part of the brain with a certain small delay. Activity in the brain is mainly characterized by rhythmic activity and transients. This rhythmic activity is often divided in various frequency bands (alpha, beta, delta, gamma, theta), which have different interpretations. These frequency bands each have their own relevance and interpretation and connectivity might exist between different frequency bands.

The goal of this project is to investigate the causal relations between different brain regions and frequency bands.

Available data

For this project 2100 independent trials of two subjects are available. During each trial, test subjects are provided with an external stimulus in the form of changes on the display in front of the test subject. Parameters of this test are orientation of the stimulus on the screen, reward, and contrast of the artefact. For stabilizing the measurements, trials can be grouped according to the contrast for each test subject. The sampling frequency for all trials is 1000 Hz. For each trial, recordings from the V1, V2 and V4 areas in the visual cortex are done by a single depth probe per visual area with 16 recording channels.

Methods

The temporal relationships between signals can be typically assessed using Granger causality [1]. A nonlinear extension of that approach is available [2]. However, the question is how well this will work in the specific setting where signals might have different frequencies. To that end the frequencies in the signals need to be separated in terms of the relevant frequency bands. This could be done using Fourier transforms, but that might cause problems for non-linear and non-stationary data. One possible solution for that is to use Singular Spectrum Decomposition [3].

References

[1] Granger, C. W. J. (1969). Investigating causal relations by econometric models and cross-spectral methods. Econometrica.

[2] L. Faes, A. Porta, G. Nollo (2011). Information- based detection of nonlinear granger causality in multivariate processes via a nonuniform embedding technique. Phys. Rev., Vol. E 83, No. 051112.

[3] P. Bonizzi, O. Meste R.L.M. Peeters, J.M.H. Karel (2014). Singular spectrum decomposition: A new method for time series decomposition. Adv. Adapt. Data Anal.