Frites: A Python package for functional connectivity analysis and group-level statistics of neurophysiological data.

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Summary

The field of cognitive computational neuroscience addresses open questions regarding the complex relation between cognitive functions and the dynamic coordination of neural activity over large-scale and hierarchical brain networks. State-of-the-art approaches involve the characterization of brain regions and inter-areal interactions that participate in cognitive processes (Battaglia & Brovelli, 2020). More precisely, the study of cognitive brain networks underlies linking brain data to experimental variables, such as sensory stimuli or behavioral responses.

Information-based measures, such as information theoretic quantities, machine-learning models or measures of distances, currently provide ideal tools for quantifying the coupling between brain signals, and the link between brain network's activity and task variables. Nevertheless, progress is limited by the lack of neuroinformatics tools that combine methods for the estimate of information-based measures from neural data and the assessment of their statistical relevance at the population level. `Frites` provides such an integrated framework and it is optimally developed for the discovery of cognitive brain networks from multi-channel neurophysiological datasets.

Statement of need

`Frites` (*Framework for Information Theoretical analysis of Electrophysiological data and Statistics*) is a pure Python package for cognitive (task-related) brain network inference, which combines in a single framework information-based analyses of neurophysiological data and group-level statistical inference.

`Frites` is equipped with a set of information theoretic tools for the analysis of interactions between brain signals and their relation with experimental task-related variables. More precisely, this package can be used to study the relation between local brain activity, cross-frequency coupling (Combrisson et al., 2020) and inter-areal functional connectivity (FC) with experimental variables (i.e., cognitive tasks). For what concerns FC, the toolbox allows the estimate of dynamic (i.e., time-resolve), undirected (e.g., mutual information) and directed (e.g., Granger causality) functional connectivity (FC) on a single-trial basis (Brovelli et al., 2015). The core functions for information measures exploit a `NumPy` tensor-based implementation of the Gaussian Copula Mutual-Information (Ince et al., 2017). Nevertheless, the definition

39 of custom estimators, such as kernel methods (Wollstadt et al., 2019) and `scikit-learn`
40 cross-validated classifiers (Pedregosa et al., 2011), is also supported.

41 The package integrates a non-parametric permutation-based statistical framework to perform
42 group-level inferences on non-negative measures of information. The toolbox includes different
43 methods that cope with multiple-comparison correction problems, such as test- and cluster-
44 wise p-value corrections. The implemented framework supports both fixed- and random-effect
45 models to adapt to inter-individuals and inter-sessions variability (Combrisson et al., 2021).

46 `Frites` is optimally designed for the analysis of continuous and multi-channel neurophysiolog-
47 ical data, encompassing recordings with either uniform spatial sampling (e.g., M/EEG data)
48 and spatially sparse intracranial recordings, such as intracranial EEG or Local Field Potentials
49 (LFPs). The package supports standard `NumPy` array inputs (Harris et al., 2020), objects from
50 the `MNE-Python` software (Gramfort et al., 2013), but also multi-dimensional labelled `Xarray`
51 objects (Hoyer & Hamman, 2017).

52 In order to facilitate automated and efficient usage, `Frites` provides a set of high-level
53 workflows that integrate several analysis steps from information-based estimation to network-
54 level statistical inference.

55 Since several computations implemented in the workflows, such as permutation tests, are
56 computationally demanding, `Frites` natively supports parallel processing using the `Joblib`
57 package. In addition, some functions can further be accelerated using the `Numba` compiler
58 (Lam et al., 2015) as an optional dependency. Programming optimizations and external
59 dependencies allow to investigate large-scale datasets in a reasonable time.

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