Neural Communications

Partners:

Télécom Bretagne/Lab-STICC

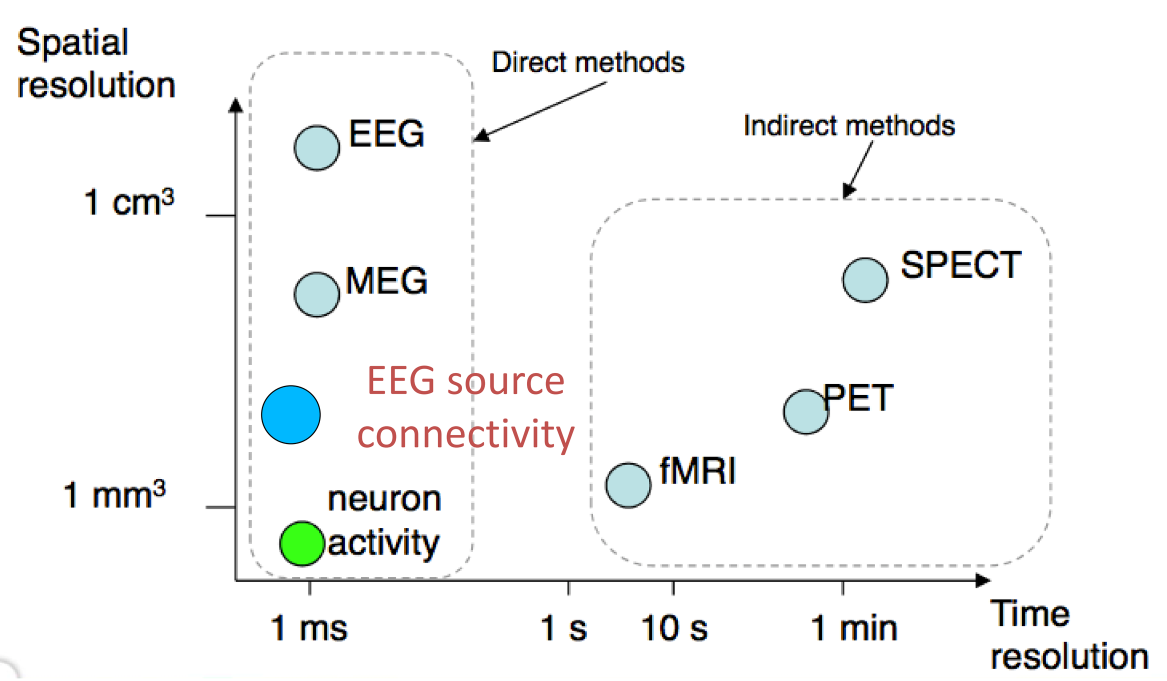
Université de Rennes 1/LTSI

Orange-Labs Lannion

1. Outline of the project

1.1 Context

High Resolution ElectroEncephalloGraphy (HR-EEG) is an imaging technique that allows to reach both high time resolution (about 1ms) and high spatial resolution (about 10dm^3). In this context, it becomes possible to track the dynamic processes of brain activity during resting state or cognitive tasks. **Neural Communications** aims at taking benefit of this fact to inspire and stress abstract mathematical models of mental information processing. Its central tool is graph theory.



1.2 Organization

Neural Communication groups three partners:

- Télécom Bretagne/Lab-STICC
- Université de Rennes 1/LTSI
- Orange-Labs Lannion

The process is as follows:

- **Collect** neuroimaging data
- **Use** the existing expertise to process it
- **Develop** novel tools to analyze it
- **Exploit** the results
- **Propose** models

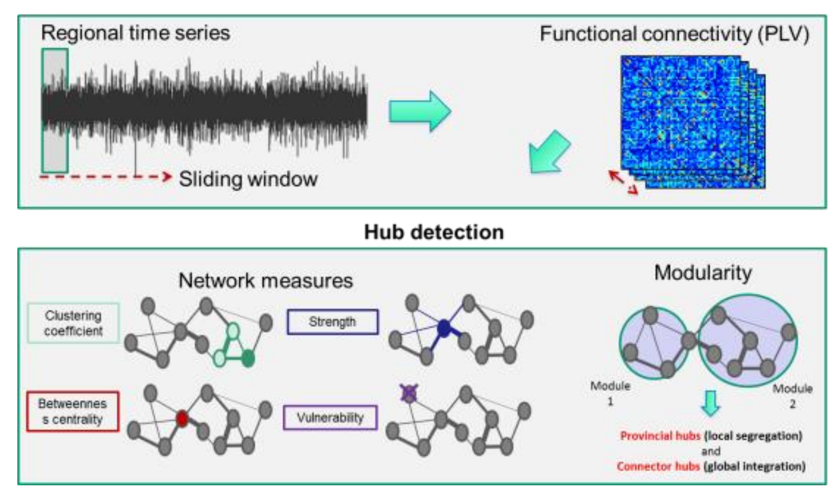
1.3 Valorizations

- Consolidated Hebbian learning and parsimonious energy consumption, resulting in large capacity associative memories, Eliott Coyac, Vincent Gripon, Charlotte Langlais and Claude Berrou, ICMNS 2015
- Neural clique networks in an unreliable environment, Eliott Coyac, Vincent Gripon, Charlotte Langlais and Claude Berrou, ICMNS 2015
- Impact du bruit synaptique sur les performances des réseaux de cliques neurales, Eliott Coyac, Vincent Gripon, Charlotte Langlais and Claude Berrou, Gretsi 2015
- Distributed Coding and Synaptic Pruning, Eliott Coyac, Vincent Gripon, Charlotte Langlais and Claude Berrou, ISTC 2016
- Performance of Neural Clique Networks subject to synaptic noise, Eliott Coyac, Vincent Gripon, Charlotte Langlais and Claude Berrou, COGNITIVE 2017 (submitted)
- Neighborhood-Preserving Translations on Graphs, Nicolas Grelier, Bastien Pasdeloup, Jean-Charles Vialatte and Vincent Gripon, GlobalSip 2016.
- Identifying Spatiotemporal patterns of functional connectivity using dictionary learning, Nicolas Farrugia, Julia Huntenburg, Daniel Margulies and Vincent Gripon, OHBM 2016.
- An intrinsic difference between vanilla RNNs and GRU models, Tristan Stérin, Nicolas Farrugia and Vincent Gripon, Cognitive 2017.
- Evaluating Graph Signal Processing for Neuroimaging Through Classification and Dimensionality Reduction, Mathilde Ménoret, Bastien Pasdeloup, Nicolas Farrugia and Vincent Gripon, EUSIPCO 2017.
- Gait improvement via rhythmic stimulation in Parkinson's disease is linked to rhythmic skills, Nature Scientific Reports, 2017.
- Electroencephalography Source Connectivity: Aiming for High Resolution of Brain Networks in Time and Space, Hassan M., Wendling F., IEEE Signal Processing Magazine, Vol. 35, issue 3, pages:81-96, 2018.
- SimNet: A Novel Method for Quantifying Brain Network Similarity, Mheich A., Hassan M., Khalil M., Gripon V., Dufor O. and Wendling F., IEEE Transactions on Pattern Analysis and Machine Intelligence (TPAMI), 2017.
- The dynamic functional core network of the human brain at rest, Kabbara A., El Falou W., Khalil M., Wendling F., Hassan M., Scientific Reports, 2017.

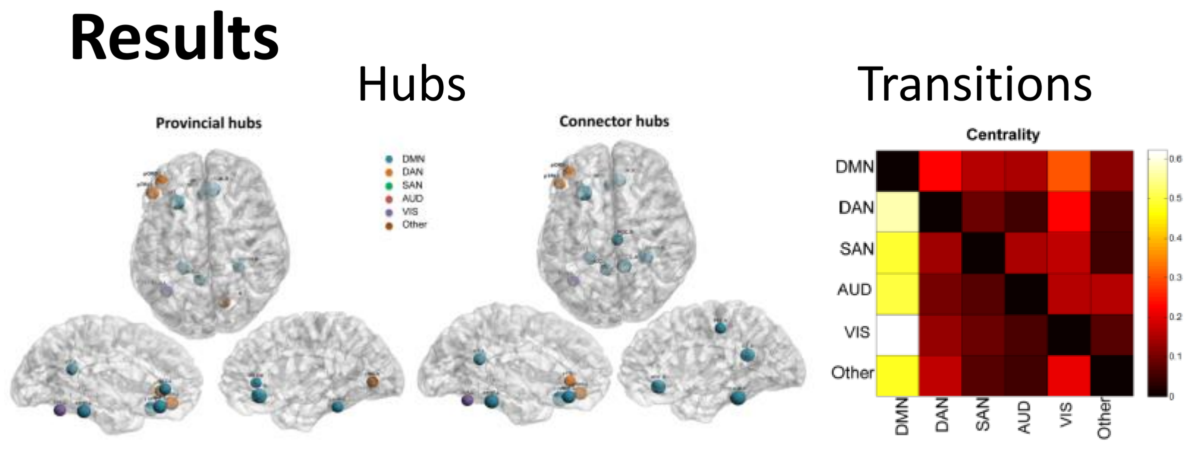
2. Obtained results

2.1 Spatio-temporal dynamics of brain networks at rest

Method



Results

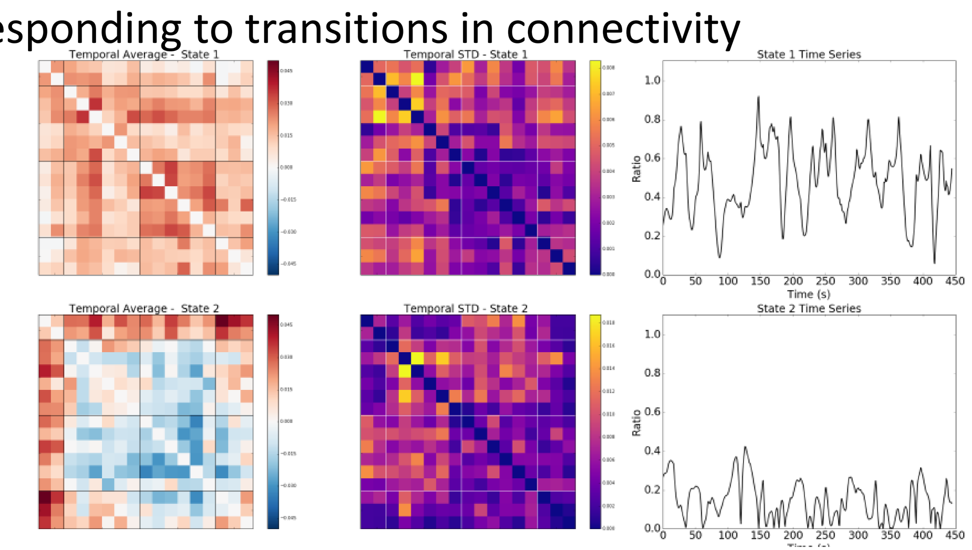


2.2 Dynamics of cognitive activity

New method for dynamic functional connectivity:

- We consider temporal sequences of connectivity matrices
- We use sparse dictionary learning to decompose these sequences

We obtain spatiotemporal patterns (and their time series) corresponding to transitions in connectivity



2.3 Models of brain communications

We established how point-to-point communications between two regions of the brain is biologically plausible.
Noise generated by failing synapses and external interferences has been modeled. For any neural network, external noise can simply be generalized and modeled by insertion and erasure parameters.
We showed that Neural clique networks can be used as hubs of local associative memories in the brains, for communications with other regions of the brain.

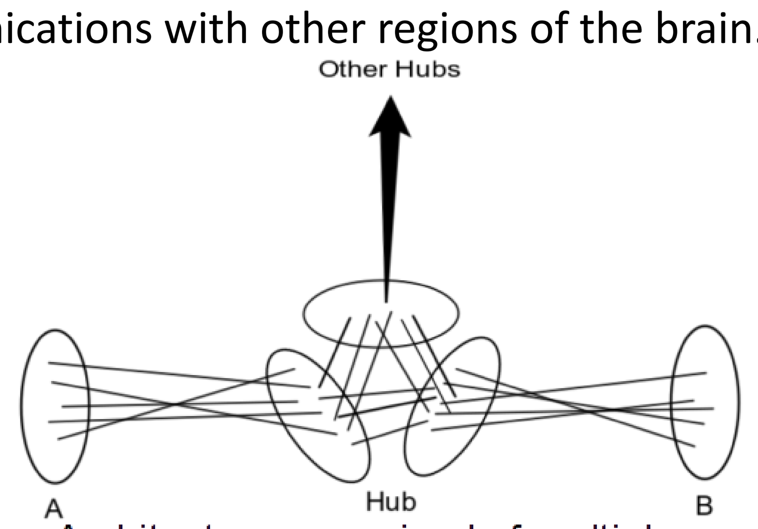
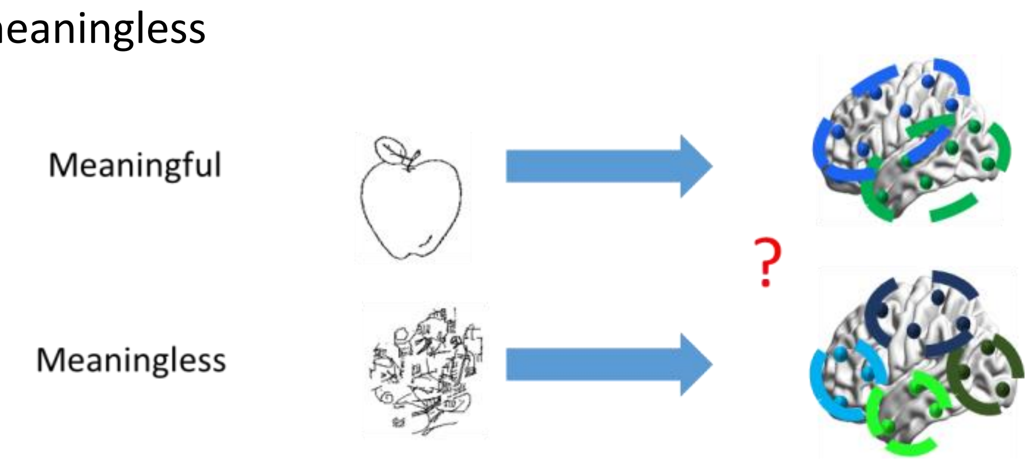


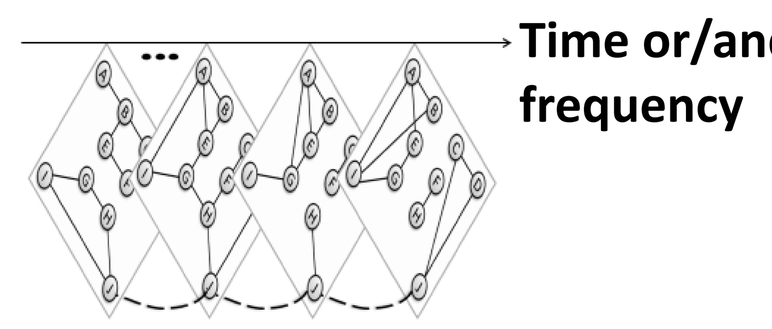
Figure: Architecture comprised of multiple neural clique networks, able to perform associations between elements of networks A and B and communicate with other hubs.

3.1 Stimuli-dependant and frequency-dependant networks

➔ Tracking the dynamic of brain netowrks for two different category of visual stimuli: meaningful vs. meaningless



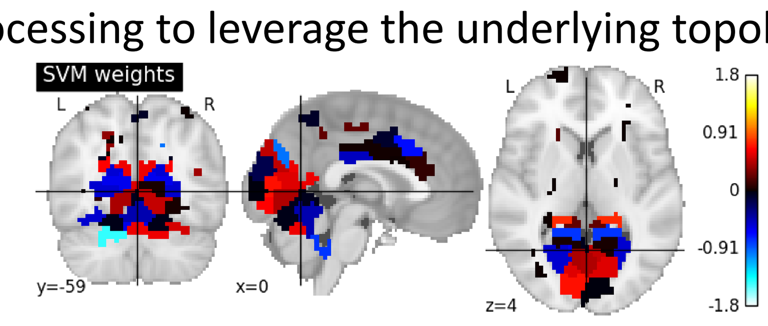
➔ Multilayer (time/frequency) functional networks approach



3.2 Graph signal processing for fMRI decoding

Graph signal processing has been used to improve classification by taking into account spatial properties:

- We build graphs using both information about the geometrical coordinates of regions of interest in the brain and statistical similarities,
- We use graph sampling techniques to reduce dimension of signals while preserving the bandwidth of these signals on the graph,
- We demonstrate the interest of graph signal processing to leverage the underlying topology



2.5 Collect neuroimaging data on source localization in binaural setting

In partnership with Orange laboratories in Lannion, this part of the project is devoted to the testing of the methods previously developed on visual tasks. Indeed, if resting state analysis offers the best substrate for brain connectivity analysis, we also developed methodological tools and processing pipelines for task-related signals. Thanks to this new analysis on binaural sounds, we want to assess and extend experimentally the method validity to any kind of sensory input.
We also want to pave the way to use connectivity graphs (static and dynamic) as valid, reproducible and sensitive biomarkers of the functioning brain. Binaural sounds will indeed be qualified according to the feelings of people (pleasant vs. unpleasant) and their spatial location.