EE-629

Network Neuroscience: Methods & Applications

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Cursus	Sem.	Type
Electrical Engineering		Opt.

Language of teaching	English
Credits	2
Session	
Exam	Oral presentation
Workload	60h
Hours	**28**
Courses	17
Exercises	7
TP	2
Project	2
Number of positions	**60**

Frequency

Every year

Remark

Next time: Spring 2027

Summary

This course provides students with a solid background on theory and applications for brain network analysis. It involves concepts from signal processing and graph theory, applied to neuroimaging data to construct and analyse brain networks and their dynamics.

Content

Lecture 1 - Introduction to Network Neuroscience (2 hours)

- Motivation: the brain as a complex network
- Historical overview and key concepts
- Nodes, edges, and multiscale organization (neurons â## brain regions)
- Structural vs. functional networks

Lecture 2 - Graph Theory Fundamentals (1 hour + 1 hour exercise)

- Graph types (binary, weighted, directed, dynamic)
- Basic measures: degree, strength, path length, clustering, centrality
- Community structure and modularity

Lecture 3 â## Structural Brain Connectivity (2 hours)

- Diffusion MRI and tractography principles
- Building structural connectomes
- Issues: parcellation choice, tractography biases, thresholding

Lecture 4 - Functional Connectivity (1 hour + 1 hour exercise)

- MRI principles: resting-state vs task
- Correlation-based FC from fMRI
- Alternative measures: partial correlation, coherence, mutual information

- Confounds: motion, global signal, preprocessing impact

Lecture 5 - Functional Connectivity (1 hour + 1 hour exercise)
- Seed based FC, ICA
- Resting-state networks in healthy and disease

Lecture 6 - Dynamic and Time-Varying Connectivity (1 hour + 1 hour exercise)
- Sliding-window correlation
- Coactivation patterns, Hidden Markov Models, dynamic graph measures
- Interpretation and controversies

Lecture 7 - Multimodal Networks: Intro to Graph Signal Processing (GSP) (1 hour + 1 hour exercise)
- Introduction of GSP theory
- Application of GSP to neuroimaging
- Integration of structural and functional connectivity

Lecture 8 - Midterm exam
Lecture 9 - Network Neuroscience of Cognition (2 hours)
- Brain network reconfiguration during cognitive tasks
- Network flexibility and efficiency
- Linking networks to behavior and cognitive performance

Lecture 10 - Translational Applications: Connectome Fingerprinting (2 hours)
- Connectome fingerprinting to identify individuals
- Signal processing and machine learning perspectives
- Cognitive and clinical relevance

Lecture 11 - Clinical Applications (2 hours)
- Network alterations in neurological and psychiatric disorders
- Biomarker discovery and predictive models

Lecture 12 - Network Neuroscience in Alzheimerâ##s Disease (1 hour + 1 hour exercise)
- Network alterations in AD
- Brain GSP methods to find new biomarkers

Lecture 13 - Investigating high resolution (1 hour + 1 hour exercise)
- Increasing the field to increase spatial resolution: 7T MRI
- Principles of Layer fMRI
- Connectivity at super high resolution: Future promises and challenges

Lecture 14 - Final Exam
- Presentation of student projects

Keywords

Brain Networks, Functional Connectivity, fMRI, Neuroimaging, Network Neuroscience.

Learning Outcomes

By the end of the course, the student must be able to:

• Exploit functional and structural brain graphs from neuroimaging data, to master and extract advanced network science methodologies on brain networks, and to in-terpret the results.

Resources

Bibliography

Bassett, D., Sporns, O. Network neuroscience. Nat Neurosci 20, 353â##364 (2017). https://doi.org/10.1038/nn.4502.
Fornito, Alex, Andrew Zalesky, and Edward Bullmore. Fundamentals of brain network analysis. Academic Press, 2016.

Ressources en bibliothèque

- Find the references at the Library
- Bassett, D., Sporns, O. Network neuroscience. Nat Neurosci 20, 353â##364 (2017)

Moodle Link

- https://go.epfl.ch/EE-629