UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

Course guide
240318 - 240NR025 - Neuroimage

Last modified: 13/03/2025

Unit in charge: Barcelona School of Industrial Engineering
Teaching unit: 707 - ESAII - Department of Automatic Control.

Degree: MASTER'S DEGREE IN NEUROENGINEERING AND REHABILITATION (Syllabus 2020). (Compulsory subject).

Academic year: 2025 **ECTS Credits:** 4.5 **Languages:** English

LECTURER

Coordinating lecturer: Benitez Iglesias, Raul

Others: Bachiller Matarranz, Alejandro
Alonso López, Joan Francesc

PRIOR SKILLS

Ability with python programming, basic signal and image processing, mathematical and statistical theory.

REQUIREMENTS

The student must have passed the subjects “Medical Images” and “Biomedical Signals”. The student must also pass or take simultaneously the subject “Data Analysis in Rehabilitation”.

TEACHING METHODOLOGY

The course is divided into three parts:
- Theory classes
- Laboratory guided activities class
- Self-study for doing exercises and activities.

In the theory sessions at the classroom, students will learn the theoretical basis of the concepts, methods and results which will be illustrated with examples appropriate to facilitate their understanding.
In the laboratory guided classes, students will review the concepts covered in the theory sessions. Teachers guide students in applying theoretical concepts to solve problems, always using critical reasoning.
Finally, several self-study activities to be developed in groups will be proposed in where teachers will introduce a clinical issue and students will revise the state-of-the-art, will propose a methodology, will apply it and will extract results. Students will present orally to the rest of their partners, will discuss their results and will answer several questions from the teacher and/or their partners.

LEARNING OBJECTIVES OF THE SUBJECT

The subject of “Neuroimage” covers the fundamental physical principles underlying various brain imaging techniques. Students will acquire theoretical and practical experience with common analysis approaches and software packages used for the analysis of different kind of neuroimages (including MRI, fMRI, DTI, EEG or MEG). They also investigate the role of neuroimaging as biomarkers in the clinical diagnosis of neurodegenerative disorders, in disease progression and in drug development.
Other complementary/specific objectives includes:
- To understand the utility of neuroimage information neurorehabilitation
- To know basic clinical applications of neuroimage in neurorehabilitation
- To learn how to apply mathematical algorithms oriented to neuroimage analysis.
- To present results in an attractive way to extract conclusions.
- To learn the most relevant neuroimage techniques to evaluate the brain activity and neurorehabilitation

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STUDY LOAD

Type	Hours	Percentage
Hours small group	9,0	8.00
Self study	72,0	64.00
Hours large group	31,5	28.00

Total learning time: 112.5 h

CONTENTS

INTRODUCTION TO NEUROIMAGING

Description:
- What is neuroimaging?
- Structural neuroimaging (MRI, CT, DTI/DWI, others)
- Functional neuroimaging (EEG, MEG, fMRI, PET, fNIRS)
- Neuroimaging in neurorehabilitation

Specific objectives:
- To explain the different modalities of structural and functional neuroimaging
- To understand the role of neuroimaging in neurorehabilitation in recent studies

Related activities:
Lectures of theoretical explanations and Laboratory

Full-or-part-time: 9h
Theory classes: 1h 30m
Laboratory classes: 1h 30m
Self study : 6h

STRUCTURAL NEUROIMAGE I: MRI

Description:
- Introduction to brain anatomy
- Preprocessing: Conversion, anonymization (deface)
- Segmentation & brain atlases
- Template registration
- Anatomical measurements
- Hands-on lab

Specific objectives:
- To understand the brain anatomy and the ways to obtain anatomical measures
- To depict the obtained measures on representations of the human brain

Related activities:
- Lectures of theoretical explanations and Laboratory

Full-or-part-time: 9h
Theory classes: 1h 30m
Laboratory classes: 1h 30m
Self study : 6h

STRUCTURAL NEUROIMAGE II: DWI

Description:
- Diffusion modelling (DTI, etc)
- Tractography
- Connectivity measures
- Graph analysis
- Hands-on lab

Specific objectives:
- To obtain a basic knowledge of magnetic fields and their application to neuroimaging
- To calculate and to assess connectivity and graph theory based measures

Related activities:
- Lectures of theoretical explanations and Laboratory

Full-or-part-time: 9h
Theory classes: 1h 30m
Laboratory classes: 1h 30m
Self study : 6h

FUNCTIONAL NEUROIMAGE I: fMRI

Description:
- Preprocessing: artifact reduction techniques for fMRI
- Resting state (rsfMRI)
- Task fMRI
- Hands-on lab

Specific objectives:
- To identify the differences between structural and functional MRI
- To explore relevant tools for the representation of functional MRI

Related activities:
- Lectures of theoretical explanations and Laboratory

Full-or-part-time: 13h 30m
Theory classes: 2h 15m
Laboratory classes: 2h 15m
Self study : 9h

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FUNCTIONAL NEUROIMAGE II: EEG, MEG

Description:
- Preprocessing: artifact reduction techniques for EEG/MEG source localization
- Forward modelling
- Source modelling
- Source analysis
- Hands-on lab

Specific objectives:
- To explore the most common artifacts on electrophysiological signal and the main strategies to reduce their effect.
- To compare different algorithms and methodologies for forward and source modelling

Related activities:
- Lectures of theoretical explanations and Laboratory

Full-or-part-time: 13h 30m
Theory classes: 2h 15m
Laboratory classes: 2h 15m
Self study : 9h

ARTIFICIAL INTELLIGENCE IN NEUROIMAGING

Description:
Application of pattern recognitiion, image processing and artificial intelligence in neuroimaging

Specific objectives:
Segmentation methods
Feature extraction and selection
Supervised classification of images

Related activities:
Practical exercises and hands-on project

Full-or-part-time: 27h
Theory classes: 4h 30m
Laboratory classes: 4h 30m
Self study : 18h

FINAL PROJECT

Description:
In groups, the students choose one of the open neuroimaging databases proposed by the professors of the subject, that include one or two image modalities. They analyze them and extract some conclusions. They will present these conclusions in a research paper and an oral presentation.

Specific objectives:
- To apply the knowledge obtained in the whole course in a real application
- To explore the combination of different algorithms to obtain the better representation of neural images
- To develop work-in-group and oral communication skills

Related activities:
- Group work with the teachers supervision.

Full-or-part-time: 30h
Theory classes: 6h
Laboratory classes: 6h
Self study : 18h

GRADING SYSTEM

The final mark is the weighted sum of the following marks:
Nfe: Final exam mark
Ncw: Mark of the continuous working. It includes theory and laboratory sessions (attendance, participation, reports, short proposed exercices ...)
NpNI: Mark obtained in the group project (work and oral dissemination).
Nfinal = 0.4 Nfe + 0.2 Ncw + 0.4 NpNI
Students who do not submit the final exam or do not perform the Neuroimaging project will be denoted as “Not taken”.
The reevaluation mark will replace the mark Nfe

EXAMINATION RULES.

The final exam will evaluate the theoretical aspects of the subject. The laboratory sessions will be evaluated with short reports or questions delivered at the end of the sessions. The final group project will be different for each one of the groups. The students will present their methodology and results to the rest of the class and teachers.

BIBLIOGRAPHY

Basic:
- Filippi, Massimo (ed.). Oxford textbook of neuroimaging. Oxford: Oxford University Press, 2015. ISBN 9780199664092.
- Hari, Riitta ; Aina Puce. MEG-EEG Primer [on line]. New York: Oxford University Press, 2017 [Consultation: 21/07/2022]. Available on: https://oxfordmedicine-com.recursos.biblioteca.upc.edu/view/10.1093/med/9780190497774.001.0001/med-9780190497774. ISBN 0190497793.

Complementary:
- Jenkinson, Mark ; Michael Chappell. Introduction to neuroimaging analysis [on line]. Oxford: Oxford University Press, 2018 [Consultation: 29/03/2023]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?docID=5891746. ISBN 9780192548276.
- Abraham Alexandre, Pedregosa Fabian, Eickenberg Michael, Gervais Philippe, Mueller Andreas, Kossaifi Jean, Gramfort Alexandre, Thirion Bertrand, Varoquaux Gael. "Machine learning for neuroimaging with scikit-learn". Frontiers in neuroinformatics [on line]. Vol. 8 núm 14 (2014) [Consultation: 21/04/2023]. Available on: https://doi.org/10.3389/fninf.2014.00014.

RESOURCES

Computer material:
- scikit-learn: Machine Learning in Python. https://scikit-learn.org/stable/- Sckit-image: Image processing in Python. https://scikit-image.org/- Nilearn: Statistics for NeuroImaging in Python. https://nilearn.github.io/stable/index.html- Open-source Python package for exploring, visualizing, and analyzing human neurophysiological data: MEG, EEG, sEEG, ECoG, NIRS, and more. https://mne.tools/stable/index.html