

# Course guide 240318 - 240NR025 - Neuroimage

Unit in charge: Teaching unit:	Last modified: 16/04/2024       Barcelona School of Industrial Engineering       707 - ESAII - Department of Automatic Control.		
Degree:	MASTER'S DEGREE IN NEU	JROENGINEERING AND REHABILITATION (Syllabus 2020). (Compulsory subject).	
Academic year: 2024	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



# **STUDY LOAD**

Туре	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



### 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 recognition, 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).

N final = 0.4 N fe + 0.2 N cw + 0.4 N p N I

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: <a href="https://oxfordmedicine-com.recursos.biblioteca.upc.edu/view/10.1093/med/9780190497774.001.0001/med-9780190497774">https://oxfordmedicine-com.recursos.biblioteca.upc.edu/view/10.1093/med/9780190497774.001.0001/med-9780190497774</a>. 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: <a href="https://doi.org/10.3389/fninf.2014.00014">https://doi.org/10.3389/fninf.2014.00014</a>.

# RESOURCES

### **Computer material:**

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