# Master's Department of Engineering Sciences
## MSc in Automation Engineering and Robotics

**Name of the unit:** Medical Imaging

**Lecturer:** Daniel RACOCEANU (daniel.racoceanu@sorbonne-universite.fr)
**Course code:** UM5RBI36
**Student workload:** 14 h of lectures, 12 h of labs
**Credits:** 3 ECTS
**Specialization tracks:** ☐ ROBOT ☒ SI (elective) ☒ MeDH (elective)
**Semester offered:** ☐ S1 ☐ S2 ☒ S3 ☐ S4
**Language of instruction:** ☐ French ☒ English
**Targeted audience:** ☒ Engineering Sciences students ☐ Other (specify):
**Localization :** ☒ PMC Campus ☐ Other (specify):

### Course Overview

This course introduces the main medical-imaging modalities and modern methods for analyzing biomedical images. It covers the physical principles of acquisition, conventional image-processing methods and recent artificial-intelligence approaches applied to medical imaging. Students will learn to understand, manipulate and analyze multimodal medical data (MRI, CT, ultrasound, digital histopathology, PET/SPECT) and to implement modern segmentation, classification, reconstruction and quantitative-analysis methods. Students will acquire: - an understanding of the main medical-imaging modalities; - the physical and digital foundations of acquisition; - conventional processing and analysis methods; - an introduction to artificial-intelligence approaches applied to biomedical imaging. The course emphasizes: - the physical principles of medical-image generation; - segmentation, classification, registration and reconstruction; - quantitative analysis; - machine-learning and deep-learning approaches; - robustness, bias and interpretability issues.

*Keywords:* Medical imaging, MRI, CT, ultrasound, PET, SPECT, microscopy, digital histopathology, DICOM/NIfTI, segmentation, registration, radiomics, pathomics, omics imaging, multimodality, biomarkers, classification, reconstruction, deep learning, biomedical AI, explainable AI, biomedical foundation models.

### Prerequisites

Students should have previously acquired the following prerequisites to follow this course:

- Mathematics: matrix representation of data, linear algebra
- Mathematics: statistics and probability
- Mathematics: Fourier transform and filtering
- Mathematics: differential equations and optimization
- Programmation Python

### Intended Learning Outcomes

By the end of this course, students will be able to:

1. Understand the main medical-imaging modalities and their physical principles
2. Identify the characteristics and constraints of biomedical data
3. Analyze a medical-imaging problem and propose a suitable methodology
4. Manipulate and analyze 2D/3D medical images in standard DICOM and NIfTI formats
5. Implement segmentation and registration methods

6. Explore multimodal approaches combining images, omics and clinical data
7. Use Python libraries dedicated to biomedical imaging
8. Prepare data for biomedical machine learning
9. Implement deep-learning methods for medical imaging
10. Quantitatively evaluate the performance of a biomedical model
11. Understand issues of robustness, reproducibility, bias and clinical validation
12. Interpret results produced by biomedical AI models

## Indicative Teaching Sequence and Methods

| Week | C/TD/TP* | Content | Preparation | Learn. outc. |
|---|---|---|---|---|
| S1 | C1 | Introduction to medical imaging, biomedical data and metadata, DICOM/NIfTI formats, and medical-image storage and management (standards and clinical nomenclatures). | | |
| S2 | C2 | Imaging modalities: radiography, CT, MRI, ultrasound, PET/SPECT, biomedical microscopy and histology. | | |
| S3 | C3 | Physical foundations and principles of medical-image generation and reconstruction. Radiomics, pathomics and biomarkers. | Prerequisites 1-3 | |
| S4 | C4 | Preprocessing, filtering, denoising and enhancement of biomedical images. | | |
| S5 | C5 | 2D/3D/4D medical-image classification and segmentation: contours, regions, atlases and deep-learning models for classification and segmentation. | | |
| S6 | TP1 | Classification of multimodal images (PET/SPECT, functional MRI, etc.): feature extraction and classification of pathologies using machine-learning and deep-learning methods | Prerequisite 5 | |
| S7 | TP2 | Segmentation and quantification of medical images (PET/SPECT, functional MRI, etc.): detection, delineation and quantitative analysis of regions of interest in 2D/3D/4D data using conventional methods and AI-based approaches. | Prerequisite 5 | |
| S8 | C6 | Image registration. Multimodal analysis | | |
| S9 | TP3 | Multimodal imaging and foundation models in histology (structural imaging, immunohistochemistry, omics imaging and spatial transcriptomics). | | |
| S10 | C7 | AI in biomedical imaging, explainable/responsible AI, bias and clinical validation | | |
| S11 | TP4 | Complete AI pipeline for classifying multimodal ophthalmology images (OCT and fundus images). | | |
| S12 | Project | Project defenses (recent high-impact papers, SU laboratory projects with available medical images, or recent biomedical-imaging challenges) | | |

* C/TD/TP respectively corresponds to lectures, tutorials and lab sessions.

**Sequence of the unit:**
TP1 after C5, TP2 after C5, TP3 after C6 and TP4 after C7
Quiz at the end of TP3

## Indicative Assessment of Intended Learning Outcomes (1st session)

| Week | Individ./group | In-person/remote | Type of exam | Evaluated outcomes | Scale % |
|---|---|---|---|---|---|
| S8 | Group | In-person | Quiz | AAV1-6,8 | 30 % |
| S14 | Individual | Remote | Project | AAV1-12 | 30 % |
| S15 | Group | In-person | Written exam | AAV 1-12 | 40 % |

## 2nde session of exam

| Session | Individ./group | In-person/remote | Type of exam | Evaluated outcomes | Scale % |
|---|---|---|---|---|---|
| 2 | Group | In-person | Written exam | AAV 1-10 | 40 % |
| 1 | Group | In-person | Quiz | AAV1-6,8 | 30 % |
| 1 | Individual | Remote | Project | AAV1-12 | 30 % |

**Date of generation of this unit description:** October 6, 2026