MAIA Booklet

2020/2022

UdG
UB
UNICLAM

COURSE MODULES

60 ECTS

Semester 1 (30 ECTS at UB)

Image Processing I — *6 ECTS*
Coordinator: F. Mériaudeau

Digital Signal Processing — *6 ECTS*
Coordinator: J.M. Bilbault

Software Engineering — *5 ECTS*
Coordinator: Y. Fougerolle

Applied Mathematics — *6 ECTS*
Coordinator: D. Fofi

Sensors and Digitization — *5 ECTS*
Coordinator: A. Lalande

French Culture — *2 ECTS*
Coordinator: Y. Golder

Semester 2 (30 ECTS at UNICLAM)

Machine and Deep Learning — *6 ECTS*
Coordinator: C. Marrocco

Introduction to Robotics — *5 ECTS*
Coordinator: G. Antonelli

Statistical Learning and Data Mining — *6 ECTS*
Coordinator: A.I. D'Enza

Distributed Programming and Networking — *6 ECTS*
Coordinator: M. Molinara

Advanced Image Analysis — *5 ECTS*
Coordinator: A. Bria

Italian Culture — *2 ECTS*
Coordinator: A. Cedola

COURSE MODULES

60 ECTS

Semester 3 (30 ECTS at UdG)

Medical Image Registration and Applications — *6 ECTS*
Coordinator: R. Martí

Medical Image Segmentation and Applications — *6 ECTS*
Coordinator: X. Lladó

Computed Aided Surgery and Medical Robotics — *6 ECTS*
Coordinator: X. Cufí

Computer Aided Diagnosis — *5 ECTS*
Coordinator: A. Oliver

eHealth — *5 ECTS*
Coordinator: J. Freixenet

Local Culture — *2 ECTS*
Coordinator: M. Anton

Semester 4 (30 ECTS)

Research training — *30 ECTS*
Coordinator: Student supervisor(s)

COURSE MODULES - Semester 1

Image Processing 1

Module coordinator
Fabrice MÉRIAUDEAU

6 ECTS

1. Syllabus

- Introduction to digital image processing: image presentation, human perception, light & colour.
- Signals in 2 and more dimensions: discrete signal processing in 2D, concepts of frequency domain analysis, Fourier analysis, sampling.
- Image formats: computer applications and storage of images.
- Image enhancement – spatial domain: basic image enhancement techniques, image histogram, histogram equalisation, and histogram modification.
- Image enhancement – filtering: convolution and correlation; spatial domain filters and masks; frequency domain filters…

2. Learning outcome

- Critical understanding of the principle theories and concepts of image analysis, modelling, enhancement and coding.
- Critical awareness of current issues in image processing.
- Critical awareness of a range of techniques and application of image processing.

COURSE MODULES - Semester 1

Digital Signal Processing

Module coordinator
Jean-Marie BILBAULT

6 ECTS

1. Syllabus

- Discrete-time signals: sampling, Nyquist frequency and aliasing. Decimation, rate conversion and oversampling.
- Linear systems and digital filtering: revision of Z-transform, time and frequency responses. Digital filters, fir and iir filters, window functions, bilinear transforms.
- Design of Butterworth, Tchebychev, etc. filters. Frequency transformation.
- Random signals: random signals, probability density functions, auto and cross-correlation functions for complex sequences, relation between correlation and convolution.
- Fourier Transformation: Fourier transform properties, sampling and the discrete transform for periodic functions, aliasing, line spectra, symmetry, anti-alias filters. The Fast Fourier Transform (FFT), decimation, twiddle functions and butterflies (DIF & DIT). Spectral resolution and side lobes, leakage and weighting functions.
- Hardware and software structures for FFT implementation, FFT processing rates.

2. Learning outcome

- Knowledge & skills to tackle significant signal processing tasks.
- Critically analyse a range of Digital Signal Processing problems.

COURSE MODULES - Semester 1

Software Engineering

Module coordinator
Yohan FOUGEROLLE

5 ECTS

1. Syllabus

- C++ programming.
- Basics: data types, variables, constants and operators; control structures; functions; arrays and pointers; input & output.
- Oriented object programming.
- Standard template library.
- Image and 3D processing algorithms.
- Algorithms and code optimization.

2. Learning outcome

- Provide the necessary background in software engineering, ranging from problem analysis to the implementation using Oriented Object Programming paradigms, template data structures, and Image/3D standard rendering and processing libraries.

COURSE MODULES - Semester 1

Applied Mathematics (for Medical Imaging)

Module coordinator
David FOFI

6 ECTS

1. Syllabus

- Linear Algebra:
  - Linear spaces and subspaces.
  - Matrix factorization.
  - Solution of linear equations: A x = b.
  - Eigen decomposition and SVD.
  - PCA.
- Probability and Statistics:
  - Probability space.
  - Random variables.
  - Estimation.
  - Stochastic processes.
- Optimization:
  - Functions optimization.
  - Constrained optimization.

2. Learning outcome

- Review of the necessary mathematical tools needed to follow the rest of the Masters' courses.
- Introduction to the key techniques useful in image processing and machine learning.

COURSE MODULES - Semester 1

Sensors and Digitization

Module coordinator
Alain Lalande

5 ECTS

1. Syllabus

- Fundamental concepts:
  - X-ray and g-ray physics applied in medicine.
  - Ultrasound and Doppler effect.
  - Spin physics and basic imaging concepts.
- Introduction to imaging reconstruction:
  - Projections, filtered back-projection, Fast Fourier Transform.
- Magnetic Resonance Imaging.
  - Advanced technical considerations.
  - Segmented k-space, Echo-Planar Imaging, Parallel Imaging.
- Advanced imaging techniques in medicine:
  - Angiography, Flow Quantification, Diffusion and Perfusion.

2. Learning outcome

- To develop a basic knowledge of the physics of X-ray and g-ray based imaging techniques.
- To acquire a basic knowledge of the physics of ultrasound imaging.
- To develop an understanding of image reconstruction techniques.
- To develop an extensive and detailed knowledge of the principal theories and application of magnetic.

COURSE MODULES – Semester 1

French Culture

Module coordinator
Yves Golder

2 ECTS

1. Syllabus

- Burgundy: historical background.
- Administration, financing.
- Spiritual /Religious heritage: Cluny, Citeaux, Taizé, Tournus, Vézelay, les Mille Bouddhas…
- Architecture, especially the Romanesque architecture, medieval villages, castles, churches…
- Wine growing and its traditions: grape picking, St Vincent Tournante, Confrérie des Chevaliers du Taste Vin, vente des Hospices de Beaune
- Gastronomy: meat markets (Charolais), poultry markets (Bresse), specialties and traditional fare.
- Industrial heritage: Le Creusot/ Montceau, la vallée de l'image and the development of photography.
- Cultural events: festivals, carnival, music, and famous writers (Lamartine, Sand, and C. Bobin, a contemporary writer born at Le Creusot).
- French classes.

2. Learning outcome

- Cultural and historical knowledge of the visited country.
- French language (beginner level).

COURSE MODULES - Semester 2

Machine and Deep Learning

Module coordinator
Claudio Marrocco

6 ECTS

1. Syllabus

- Bayes decision theory.
- Learning – parametric and non-parametric classification.
- Feature selection and extraction.
- Margins and Kernel based algorithms.
- Ensemble classification and learning.
- Deep learning: CNNs, RNNs, GANs.

2. Learning outcome

- Introduce the fundamental concepts of pattern recognition.
- Introduce methods and algorithms the students can use for practical pattern recognition problems.
- Provide the students with techniques for assessing the performance of a pattern recognition system.

COURSE MODULES - Semester 2

Introduction to Robotics

Module coordinator
Gianluca Antonelli

5 ECTS

1. Syllabus

- Introduction.
- Direct kinematics.
- Differential kinematics.
- Algorithms for Inverse kinematics.
- Trajectory planning.
- Sensors and actuators.
- Dynamics.

2. Learning outcome

- To provide the necessary skills to understand the basic kinematic and dynamic concepts regulating the movement of robots (serial chain of links).
- To be able to implement and simulate inverse kinematics algorithms.
- To understand the main differences among sensors and actuators for robotic applications.
- To be able to generate trajectories both in the joint and operative spaces.

COURSE MODULES - Semester 2

Statistical Learning and Data Mining

Module coordinator
Alfonso Iodice D'Enza

6 ECTS

1. Syllabus

- Regression and classification problems.
- Linear models for regression, from simple to multiple regression, qualitative predictors, interactions and common issues.
- Classification problems, from linear ones, e.g. logistic regression and linear discriminant analysis, to non-linear ones, e.g. quadratic discriminant analysis.
- Model selection and regularization. Resampling methods for the estimate of the test error (cross validation) and for assessing the accuracy of an estimator (bootstrap).

2. Learning outcome

- Develop an understanding of the statistical learning framework, with general concepts for model building, selection and evaluation.
- Study the theoretical foundation of the basic (linear) methods for regression and classification.
- Study the computational approaches that support the effective application of the studied methods.
- Interpret the results and identify the most effective way to analyze the available data.

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COURSE MODULES - Semester 2

Distributed Programming and Networking

Module coordinator
Mario Molinara

6 ECTS

1. Syllabus

- Network programming paradigms (client-server, peer-to-peer, N-tier, cloud, etc.).
- Network programming: socket with Java, remote services (RPC, RMI, etc.).
- Web applications: scripting languages (client side and server side), frameworks MVC.
- Mobile programming.
- Cloud programming: Software as a Service (SaaS) for web application and Backend as a Service (BaaS) for mobile application.

2. Learning outcome

- Describe the introductory concepts in the implementation of software systems to be run on distributed systems.
- Introduce the main technologies for programming mobile systems.
- Introduce the main technologies for designing software systems accessing cloud computing resources.
- Describe the techniques needed for designing a medical image analysis application for mobile systems and/or accessing cloud computing resources.

COURSE MODULES - Semester 2

Advance Image Analysis

Module coordinator
Alessandro Bria

5 ECTS

1. Syllabus

- Elements of digital geometry.
- Mathematical morphology: basic operators and algorithms.
- Grayscale morphology.
- Basic segmentation techniques.
- Feature extraction.

2. Learning outcome

- Introduce advanced topics of image processing
- Introduce methods and algorithms for morphological operations on digital images
- Introduce techniques for defining image descriptors aimed at being used by a classification system

COURSE MODULES - Semester 2

Italian Culture

Module coordinator
Andrea Cedola

2 ECTS

1. Syllabus

- Lazio: historical background.
- Administration, financing.
- Spiritual /Religious heritage: Roma, Montecassino, Casamari, …
- Architecture: from Roman art to Contemporary art.
- Gastronomy: specialities and traditional fare.
- Industrial heritage: “la valle delle cartiere” (the valley of paper mills).
- Cultural events: festivals, carnival, music…

2. Learning outcome

- Improve the linguistic abilities and the knowledge of the Italian culture.

COURSE MODULES - Semester 3

Medical Image Registration and Applications

Module coordinator
Robert Martí

6 ECTS

1. Syllabus

- Similarity between images.
- Image preprocessing.
- Image matching and registration. Basics.
- Advanced image registration techniques.
- Applications of image registration.
- Evaluating image registration for medical applications.

2. Learning outcome

- To understand image similarity and registration.
- To analyse the state of the art registration algorithms used in medical image analysis, from the perspective of the computer vision engineer.
- To be able to evaluate a detection algorithm and asses is usability for daily clinical usage. Estimate the crucial factors for it to be successful.
- To learn what algorithm(s) could fit better for a particular application.

COURSE MODULES - Semester 3

Medical Image Segmentation and Applications

Module coordinator
Xavier Lladó

6 ECTS

1. Syllabus

- Introduction to Computer Aided Detection (CADe).
- Image preprocessing.
- Clustering segmentation techniques.
- Region-based segmentation in 2D and 3D images.
- Free-form segmentation and active contours.
- Deformable template matching and active shape models.
- Evaluation of detection algorithms for medical applications.

2. Learning outcome

- To have a good knowledge of the field of Computer Aided Detection (CADe).
- To analyse the state of the art segmentation algorithms used in medical image analysis, from the perspective of the computer vision engineer.
- To be able to evaluate a segmentation algorithm and asses is usability for daily clinical usage. Estimate the crucial factors for it to be successful.
- To learn what algorithm(s) could fit better for a particular application.

COURSE MODULES - Semester 3

Computer Aided Surgery and Medical Robotics

Module coordinator
Xavier Cufí

6 ECTS

1. Syllabus

- Characteristics of medical robotics. Applications.
- Sensors and image registration.
- Introduction to augmented reality.
- Principles of design of medical robots.
- Vision-based control and force control.
- Tele-manipulation and comanipulation.
- Introduction to intracorporal robotics.

2. Learning outcome

- To have an overview of the application domain and the potential contributions of a robot to the achievement of a medico-surgical operation.
- To analyse the constraints of clinical operation and determining the added value of the robot. Regulatory framework useful for engineers or scientists.
- To analyse the relationship between the different reference frames in image-guided robotics.
- To have on overview of the use of Augmented Reality techniques in medical robotic systems.
- To analyse the architecture of most usual medical robotics systems. Design approaches.
- To have an overview of the use of intra-operating imaging for controlling the robot and the mechanical interaction with living tissues.
- To be able to analyse tele-operation techniques and co-manipulation.

COURSE MODULES - Semester 3

Computer Aided Diagnosis

Module coordinator
Arnau Oliver

5 ECTS

1. Syllabus

- Introduction to diagnosis and CADx.
- Object and image characterization.
- Morphological, texture, and shape descriptors.
- Interest point detectors and descriptors.
- Classification and diagnosis.
- CADx evaluation.
- Applications.

2. Learning outcome

- To have a good knowledge of the field of Computer Aided Diagnosis (CADx).
- To have an overview of general image characterization.
- Applying pattern recognition techniques to the field of medical imaging.
- To learn what characteristics and what classifiers are more useful to the different medical images.
- To be able to evaluate a previously developed algorithm and asses is usability for medical images and daily clinical usage. Estimate the crucial factors for it to be successful.
- To learn what algorithm(s) could fit better for a particular application.

COURSE MODULES - Semester 3

eHealth

Module coordinator
Jordi Freixenet

5 ECTS

1. Syllabus

- Introduction to eHealth.
- The digital hospital.
- Electronic patient record.
- Storage of the information: PACS system.
- Transmission of information: the DICOM protocol.
- Displaying information and visualization of images.
- Automatic and semi-automatic annotation tools.
- Learning platforms for medical applications.

2. Learning outcome

- To have an overview of the different informatics aspects being currently used in everyday clinical practice.
- To have a good knowledge of the field of digital storage and PACS systems.
- To learn exchanging information techniques through different medical protocols.
- To have a good knowledge on automatic and semiautomatic tools designed as annotation tools for experts and how this annotations can be fully integrated in a learning platform. Understand the design of such tools.

COURSE MODULES - Semester 3

Local Culture

Module coordinator
Mar Anton

2 ECTS

1. Syllabus

- Aspects of the Catalan and Spanish culture.
- Cultural interchange: periodic informal meetings with local students.
- Cultural visits to Girona and surrounding area.
- Catalan and Spanish Language classes.
- Topics: Personal relationships, leisure, University and work, and cultural environment.

2. Learning outcome

- To give a cultural dimension to the language.
- To question what is culture, the distinction between cultures, the shaping of collective identities, the creation of stereotypes.
- To give cultural tips to facilitate the adaptation to the country of destination.
- To facilitate cultural exchanges between students of different countries and promote a closer and more realistic approach to the complexity of intercultural communication.