CENTRALE NANTES

MASTER OF SCIENCE, TECHNOLOGY AND HEALTH

2024-2025

YEAR 2

CONTROL AND ROBOTICS

SIGNAL AND IMAGE PROCESSING

PROGRAMME SUPERVISOR(S):
Sébastien BOURGUIGNON

YEAR 2 - Autumn Semester

CORE COURSES

Course code	Title	ECTS Credits
BIOSIM	Biomedical Signals, Images and Methods	4
DESIRE	Design of Signal and Image Representations	4
LEARN	Machine Learning, Data Analysis and Information Retrieval	4
MATSIP	Mathematical Tools for Signal and Image Processing	4
PROJECTSIP	Bibliographical research project	4
SIRIM	Signal and Image Restoration, Inversion Methods	4
STOMET	Stochastic Methods	4

LANGUAGE COURSES

Course code	Title	ECTS Credits
CCE3	Cultural and Communication English	2
ESP3	Spanish Language	2
FLE3	French Language	2

YEAR 2 - Spring Semester

CORE COURSES

Course code	Title	ECTS Credits
THESIS	Master Thesis or Internship	30

Master Programme - Control and Robotics - Signal and Image Processing

YEAR 2 - Autumn Semester

Biomedical Signals, Images and Methods [BIOSIM]

LEAD PROFESSOR(S): Clement HUNEAU

Requirements

Objectives

These introductory lectures to biomedical imaging aim to prepare the students for today's challenges and growing opportunities in computer-aided biomedical solutions.

At the end of the course the students will be able to:

- Describe the functioning principles of different biomedical imaging systems such as: X-ray, electrophysiology, magnetic resonance imaging and ultrasound, etc.
- Recognize the fundamental problems in medical image analysis, including the need for filtering, segmentation and registration.
- Describe different methods to solve the problems above.
- Use Python and Matlab languages to implement and run such solutions.

Course contents

Introduction
- History of biomedical imaging
- Structural vs functional imaging and some physiology

Biomedical measurement techniques
- X-ray, positron emission tomography (PET)
- Ultrasound
- Electrophysiology
- Magnetic resonance imaging (MRI)

Biomedical image processing
- segmentation
- filtering
- registration
- tomography

Practical hands-on sessions with Python and Matlab

Course material

- N. Paragios, N. Ayache & J. Duncan. Biomedical Image Analysis: Methodologies and Applications, Springer, 2010.
- Jerry l. Prince: Medical imaging signals and systems textbook second edition 2014

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	4	12 hrs	8 hrs	12 hrs	0 hrs	null hrs

Master Programme - Control and Robotics - Signal and Image Processing

YEAR 2 - Autumn Semester

Design of Signal and Image Representations [DESIRE]

LEAD PROFESSOR(S): Sébastien BOURGUIGNON

Requirements

Basics of spectral analysis, repressentation of signals and data in the frequency domain. Manipulation of integral transforms. Linear algebra and matrix manipulations. Numerical optimization.

Objectives

Extracting relevant information from a data set is a key issue data processing. For example, the use of specific methods is crucial for the detection of events in noise, denoising, inpainting, data compression, extraction of characteristic features for machine learning and classification.

This course introduces a set of mathematical (both analytical and numerical) tools for representing a signal, an image or, more generally, a data set in one or several dimensions, in order to extract the meaningful and useful information contained within. Different tools are presented, both in their mathematical and informational foundations and in their practical implementation, through application examples taken from real data analysis problems.

Starting from Fourier-based representations, time-frequency and time-scale representations are introduced for the analysis of non-stationary data. Multiscale analysis (in particular, based on wavelet transforms) is detailed. Then, a second part is dedicated to the recent framework of sparse representations, which generalise the former representations to more complex problems, in particular adapted to big data processing. Both information theory and algorithms are studied (greedy methods, convex optimization, combinatorial optimization) in order to understand the main concepts and limitations, with applications ranging from denoising to inpainting, compressed sensing and dictionary learning.

Course contents

Time-scale analysis and wavelet transforms. Theory and practice of wavelet transforms. Orthogonal transforms, standard wavelet transforms. Har and soft thresholding. Lab: Discrete Wavelet Transform and multiscale analysis; application to signal denoising and image compression.

Sparse representations. Toward more general models. Interest of non-orthogonal transforms. Redundant dictionaries (unions of bases, wavelet packets). EStimation and the l_0 "norm". Convex optimization based on the l_1-norm. Greedy algorithms. Information theory, sparse recovery and compressed sensing. Towards dictionary learning.
Lab: Sparsity-aware denoising: different models and appropriate algorithms.

Course material

S. Mallat, A Wavelet Tour of Signal Processing: The Sparse Way, Academic Press, 2008.
M. Elad, Sparse and Redundant Representations, Springer, 2010.
Y. C. Eldar and G. Kutyniok, Compressed Sensing: Theory and Applications, Cambridge University Press, 2012.

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	4	12 hrs	12 hrs	6 hrs	0 hrs	2 hrs

Master Programme - Control and Robotics - Signal and Image Processing

YEAR 2 - Autumn Semester

Machine Learning, Data Analysis and Information Retrieval [LEARN]

LEAD PROFESSOR(S): Diana MATEUS LAMUS

Requirements

Objectives

The objective of this course is to address advanced concepts in machine learning, which have become essential to cope with the continuous growth of data collection in all fields of industry and research. The course will cover various supervised and unsupervised learning methods, with a particular focus on deep learning methods and their application in signal and image processing. The sessions will include lectures, reading research articles, as well as practical exercises in Python.

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

- Extract discriminative and compact data representations.
- Better understand research articles in the field of deep learning.
- Implement advanced learning algorithms on signal and image databases.
- Design an experimental evaluation protocol for assessing learning methods.

Course contents

- Review of main machine and deep learning concepts
- Linear and non-linear methods for dimensionality reduction
- Introduction to Neural networks
- Convolutional Neural Networks
- Modern neural network architectures
- Unsupervised deep learning methods
- Semantic segmentation
- Advanced deep learning methods
- Experimental protocols for machine learning

Course material

- Bishop C.: Pattern Recognition and Machine Learning. Springer, 2006.
- Kevin P. Murphy,"Probabilistic Machine Learning" MIT Press, 2022
- Francois Cholet. Deep Learning with Python. [2022]
- Francois Fleuret. The Lilttle Book of Deep Learning [2024]

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	4	12 hrs	6 hrs	12 hrs	0 hrs	2 hrs

Mathematical Tools for Signal and Image Processing [MATSIP]

LEAD PROFESSOR(S): Said MOUSSAOUI

Requirements

Objectives

This course focuses on scientific computing and numerical optimization methods that are used in signal and image processing. It firstly provides a theoretical description of the methods and then addresses some examples such as non-linear curve fitting, image restoration and applications in modern signal processing problems.

At the end of the course the students will be able to:
- Formalize an optimization problem
- Choose an appropriate algorithm to solve an optimization problem

Course contents

- Introduction to scientific computing tools: Matlab, Python
- Unconstrained optimization (basic concepts, differential calculus, mathematical properties, optimality conditions, iterative methods, descent direction, line search, trust region)
- Constrained optimization (exterior penalty methods, interior-point methods, applications to image restoration)
- Global optimization interval methods, evolutionary methods, Monte Carlo methods)

Course material

- J. Nocedal and S. J. Wright. Numerical Optimization. Springer series in operations research, Springer, 1999
- S. Boyd and L. Vendenberghe. Convex Optimization. Cambridge University Press, 2004
- P. Venkataraman. Applied Optimization with Matlab Programming, John Wiley and Sons, 2001

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	4	12 hrs	8 hrs	10 hrs	0 hrs	2 hrs

Master Programme - Control and Robotics - Signal and Image Processing

YEAR 2 - Autumn Semester

Bibliographical research project [PROJECTSIP]

LEAD PROFESSOR(S): Mira RIZKALLAH

Requirements

Objectives

The objective of the projects is to confront the students with real problems, using their technical knowledge and analytical skills. The main idea is to teach them to do a good bibliographic research, to understand and write a synthesis of scientific papers (journals or conferences).

Signal and image databases that can be processed: biomedical signals, audio signals, hyperspectral images, medical images. Processing objectives: detection, restoration, source separation, segmentation, classification. Advanced machine learning and deep learning methods are also considered.

Course contents

Examples of previously proposed projects;
- Deep-learning-based methods for prostate cancer segmentation and classification
- Survival analysis and graph representations
- Sparse decomposition of multivariate signals based on optimal transport
- Zero-Note Samba : Self-supervised machine listening

Course material

Keshav, S. (2007). How to read a paper. ACM SIGCOMM Computer Communication Review, 37(3), 83-84.

Assessment

Individual assessment: EVI 1 (coefficient 1)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	4	0 hrs	0 hrs	0 hrs	64 hrs	0 hrs

Master Programme - Control and Robotics - Signal and Image Processing

YEAR 2 - Autumn Semester

Signal and Image Restoration, Inversion Methods [SIRIM]

LEAD PROFESSOR(S): Jérome IDIER

Requirements

Basic knowledge of signal processing, linear algebra, statistics, and optimization

Objectives

Inverse methods are used when information about an object under study is acquired indirectly, by measuring the effects of a physical phenomenon from which the causes are searched. This measurement principle is encountered in many applications: optics, acoustics, medical imaging, oceanography, astronomy, nondesctructive control of materials, ... Such a methodology is used in most imaging methods, where a map of the physical properties inside an object is searched from measurements acquired from outside (e.g., X-ray tomography, or CT scan). This is also the case for methods aiming to restore a signal, an image, a data set from a version that was downgraded, noisy and filtered by the acquisition device (e.g., PSF of a microscope or of a telescope).

This course shows basic and more advanced tools which enable one to address an inversion problem, from the definition of the direct problem (physical modeling) and general information theory elements (incomplete data, ill-posed problem, stastistical inference), the resolution principle essentially based on regularization, up to the efficient numerical computation of the solution by dedicated algorithms.

Course contents

1. General points: ill-posed problems, regularization, a priori information

2. Deconvolution: standard (linear) methods, quadratic regularization

3. Non-linear methods, spike train deconvolution, sparsity

4. Image restoration and tomography

Course material

A. Tarantola,Inverse Problem Theory and Model Parameter Estimation,SIAM, 2005.
J. Idier (Ed.), Bayesian Approach to Inverse Problems, ISTE Ltd and John Wiley & Sons Inc, 2008.
M. Bertero, P. Boccacci, Introduction to Inverse Problems in Imaging, CRC Press, 1998
P.C. Hansen, Discrete Inverse Problems: Insight and Algorithms, SIAM, 2010
J. M. Mendel, Optimal Seismic Deconvolution, Academic Press, 1983.
A. C. Kak et M. Slaney, Principles of Computerized Tomographic Imaging, IEEE Press, 1988.

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	4	12 hrs	12 hrs	6 hrs	0 hrs	2 hrs

Master Programme - Control and Robotics - Signal and Image Processing

YEAR 2 - Autumn Semester

Stochastic Methods [STOMET]

LEAD PROFESSOR(S): Eric LE CARPENTIER

Requirements

MATOSS (M1-SIP)

Objectives

This course addresses the characterization and the processing of random signals by means of statistical tools. It provides the theoretical foundations used in practical problems to estimate a quantity of interest and to retrieve sought information.
Applications concern: biomedical signal and image processing (diagnosis, tools to assist the disabled), music signal processing (recording, restoration, coding), positioning systems, etc.
At the end of the course the students will be able to:

- Provide a probabilistic description of a stochastic process
- Propose a recursive estimation algorithm
- Derive a stochastic simulation algorithm to calculate an approximate solution to an estimation problem

Course contents

- Probability theory, estimation theory: reminders from M1-SIP-MATOSS.
- Monte-Carlo
- Stochastic simulation
- Expectation-Maximization algorithm (EM)
- Markov chains, Markov processes
- Monte-Carlo Markov Chain (MCMC)
- Monte-Carlo through rejection
- Statistical filtering: Bayes, Kalman, EKF, UKF, particle filter

Course material

- Probability, Random Variables and Stochastic Processes. A. Papoulis, S.U. Pillai. McGraw Hill.
- Fundamentals of Statistical Signal Processing, Vol.1: Estimation theory, S. Kay, Prentice Hall.

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	4	12 hrs	10 hrs	8 hrs	0 hrs	2 hrs

Master Programme - Control and Robotics - Signal and Image Processing

YEAR 2 - Autumn Semester

Cultural and Communication English [CCE3]

LEAD PROFESSOR(S): David TROYA

Requirements

Objectives

- Understand the fundamental principles of scientific writing and the importance of clarity and precision in communication.
- Structure scientific documents effectively, adhering to genre-specific conventions.
- Employ appropriate language and tone for diverse scientific audiences.
- Integrate and cite sources correctly to support research arguments and findings.
- Edit and revise their writing for coherence, style, and grammatical accuracy.
- Prepare and deliver scientific presentations, both written and oral.

Course contents

Introduction to Scientific Writing

Overview:

This course provides an essential foundation in scientific writing, equipping students with the skills necessary to effectively communicate research findings and scientific concepts. Through a combination of lectures, workshops, and practical assignments, students will learn the conventions of scientific writing, including structure, style, and clarity. The course will cover various types of scientific documents, such as research papers, literature reviews, grant proposals, and poster presentations.

Course Structure:

The course will be organized into weekly sessions that include lectures on theoretical concepts, hands-on writing exercises, peer review workshops, and discussions of exemplary scientific literature. Students will engage in collaborative projects and receive constructive feedback to enhance their writing skills.

Assessment:

Students will be assessed through a combination of assignments, including written documents, peer review participation, and presentations. Active participation in workshops and discussions is also required to foster a collaborative learning environment.

Course material

Hoogenboom BJ, Manske RC. How to write a scientific article. Int J Sports Phys Ther. 2012 Oct;7(5):512-7. PMID: 23091783; PMCID: PMC3474301.

Paré G, Kitsiou S. Chapter 9Methods for Literature Reviews. In: Lau F, Kuziemsky C, editors. Handbook of eHealth Evaluation: An Evidence-based Approach [Internet]. Victoria (BC): University of Victoria; 2017 Feb 27. Available from: https://www.ncbi.nlm.nih.gov/books/NBK481583/

How to Create a Research Poster. A guide fo creating a research poster. https://guides.nyu.edu/posters

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	2	0 hrs	32 hrs	0 hrs	0 hrs	0 hrs

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YEAR 2 - Autumn Semester

Spanish Language [ESP3]

LEAD PROFESSOR(S): Marta HERRERA

Requirements

N/A

Objectives

For beginners:
Practice and reinforcement of the five skills (oral and written expression and comprehension as well as interaction)
Acquisition of vocabulary and linguistic structures
Be able to talk about yourself and those around you
Be able to express oneself during daily activities
Know how to give your opinion

For advanced students:
Practice and reinforcement of the five skills (oral and written expression and comprehension as well as interaction)
Acquisition of specialised vocabulary
Be able to understand the essential content of concrete or abstract subjects including a technical discussion
Be able to communicate spontaneously and fluently
Be able to express oneself in a clear and detailed manner, to express an opinion on a topical subject

Course contents

For beginners:
Personal environment (introduce yourself, express yourself, your tastes, your character, your hobbies, etc.), your surroundings (friends, family, location, climate), your interests (sports, leisure)
Present tense (regular and irregular)
Language patterns to express habit, obligation, "gustar" and its equivalents,
Possessive adjectives
Differences between "es", "está", "hay"
Use of "por" and "para"
Adverbs and frequency patterns
Numeral adjectives

For advanced students:
Knowledge of the Hispanic world (economic, technical, cultural and social environment)
Present tense (regular and irregular)
Imperative
Past tenses
Direct / indirect style
Future tense
Conditional tense
Present and past subjunctive moods

Course material

Preparation manuals, our own tailor-made documents, written and internet press, general civilization documents, digital tools

Assessment

Individual assessment: EVI 1 (coefficient 1)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
Spanish	2	0 hrs	32 hrs	0 hrs	0 hrs	0 hrs

French Language [FLE3]

LEAD PROFESSOR(S): Silvia ERTL

Requirements

N/A

Objectives

The objective is to familiarize the learner with the French language and French culture through an entertaining task-based communicative language teaching, focused on speaking combined with:
▪ Phonetics
▪ Self-correcting exercises on our learning platform
▪ Learning Lab activities
▪ Project work
▪ Tutoring

Course objectives include the acquisition and reinforcement of vocabulary, syntax, and pronunciation by both traditional means and through the use of digital resources. Students will learn general French, develop language skills of oral and written comprehension and expression.

After completing this course (32 hours + personal work), the students will be able to communicate in spoken and written French, in a simple, but clear manner, on familiar topics in the context of study, hobbies etc. Another important goal of this course is to introduce the student to French culture.

At the end of the course, complete beginners can achieve an A1
level and some aspects of the A2 of The Common European Framework of Reference for Languages. More advanced students may aim for B1/B2 levels. Those who already completed the first year of the French course will be prepared for working in a French business environment.

Course contents

Two different tracks are proposed: track 1 for students newly arrived at Centrale Nantes and track 2 for students who have completed the first year of the French course. Track 1:
Full range of practical communication language exercises: reading comprehension, listening comprehension, written expression, oral expression.
Learners will be able to use the foreign language in a simple way for the following purposes:

1. Giving and obtaining factual information:
▪ personal information (e.g. name, address, place of origin, date of birth, education, occupation)
▪ non-personal information (e.g. about places and how to get there, time of day, various facilities and services, rules and regulations, opening hours, where and what to eat, etc.)

2. Establishing and maintaining social and professional contacts, particularly:
▪ meeting people and making acquaintances
▪ extending invitations and reacting to being invited
▪ proposing/arranging a course of action
▪ exchanging information, views, feelings, wishes, concerning matters of common interest, particularly those relating to personal life and circumstances, living conditions and environment, educational/occupational activities and interests, leisure activities and social life

3. Carrying out certain transactions:

- making arrangements (planning, tickets, reservations, etc.) for travel, accommodation, appointments, leisure activities
- making purchases
- ordering food and drink

Track 2:
This track follows on directly from the first-year French course, developing and completing the concepts studied thus far. The main themes are: housing, health and work. These topics will help prepare students for their future work environment. For example, housing is explored in the form of a search for accommodation upon arrival in a new city. Special workshops for CVs and cover letters, elevator pitches and job interviews.

Course material

Preparation manuals, our own tailor-made documents, written and televised press, internet, general civilization documents, digital tools, our own educational materials on Hippocampus (Moodle).

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	2	0 hrs	32 hrs	0 hrs	0 hrs	0 hrs

Master Thesis or Internship [THESIS]

LEAD PROFESSOR(S): Sébastien BOURGUIGNON

Requirements

Basics of signal and image processing and/or data science.

Objectives

- Be exposed to and adapt to an industrial or research environment
- Put in practice the scientific and technical skills acquired in the previous semesters
- Strengthen interpersonal and communication skills
- Be part of or manage a project
- Organize tasks, analyze results and build deliverables

Course contents

Students should be pro-active and career-oriented in the search for their thesis/internship. The topics are validated by the program supervisor to ensure an adequate Master level. The thesis/internship is evaluated through the submission of a written report and an oral defense.

Course material

- Turabian Kate Larimore, Booth Wayne Clayton, Colomb Gregory G., Williams Joseph M., & University of Chicago press. (2013). A manual for writers of research papers, theses, and dissertations: Chicago style for students and researchers (8th edition.). Chicago (Ill.) London: University of Chicago Press.
- Bui Yvonne N. How to Write a Master's Thesis. 2nd ed. Thousand Oaks, Calif: Sage, 2014.
- Evans David G., Gruba Paul, et Zobel Justin. How to Write a Better Thesis. 3rd edition. Carlton South, Vic: Melbourne University Press, 2011.

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	30	0 hrs	0 hrs	0 hrs	0 hrs	0 hrs