SHAKE THE FUTURE.

CENTRALE NANTES

MASTER OF SCIENCE, TECHNOLOGY AND HEALTH

CONTROL AND ROBOTICS

SIGNAL AND IMAGE PROCESSING

YEAR 2

PROGRAMME SUPERVISORS:
SEBASTIEN BOURGUIGNON, OLIVIER-HENRI ROUX

CONTROL AND ROBOTICS – SIGNAL AND IMAGE PROCESSING

YEAR 2 - AUTUMN SEMESTER

Digital Signal and Image Representations

CONTROL AND ROBOTICS – SIGNAL AND IMAGE PROCESSING
YEAR 2 - AUTUMN SEMESTER

LEAD PROFESSOR: Sébastien BOURGUIGNON

Objectives

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

- Design and numerically implement time-frequency and wavelet analysis methods for time series and images
- Understand the basics of sparsity-aware signal processing, both from the theoretical and the algorithmic perspectives
- Develop specific methods based on dedicated signal and image representations to different objectives (denoising, compression, automatic classification and machine learning)

Course contents

Extracting relevant information from a data set is a key step for efficient data processing. For example, dedicated tools are necessary for efficient detection of significant information in a noisy environment, extraction of characteristic features for statistical learning and classification, noise reduction or data compression.

This course introduces a set of mathematical (both analytic 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. A last and important part concerns 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).

- From Fourier to time-frequency analysis: linear representations (short-term Fourier transforms) and quadratic representations (Wigner-Ville distribution, Cohen's class).
 Lab: Automatic music transcription.

- Time-scale analysis and wavelet transforms.
 Lab: Discrete Wavelet Transform and multiscale analysis; application to signal denoising and image compression.

- sparse representations.
Lab: sparse optimization algorithms. Application to Compressed Sensing.

Course material

A.V. Oppenheim and R.W. Schafer. Discrete-time signal processing, Prentice Hall, 2010.
L. Cohen, Time-Frequency analysis, Prentice-Hall, 1995.
S. Mallat, A Wavelet Tour of Signal Processing: The Sparse Way, Academic Press, 2008.
M. Elad, Sparse and Redundant Representations, Springer, 2010.

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

SIGNAL AND IMAGE RESTORATION, INVERSION METHODS

CONTROL AND ROBOTICS – SIGNAL AND IMAGE PROCESSING
YEAR 2 - AUTUMN SEMESTER

LEAD PROFESSOR: Jérome IDIER

Objectives

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

- Understand the notion of direct and inverse problems
- Identify data processing problems as inverse problems, and be aware of the intrinsic difficulty of inverse problems
- Make the distinction between naïve solutions and regularized solutions
- Design inverse methods in the context of signal and image restoration, and use Matlab to implement them

Course contents

Inverse methods are called for when knowledge 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 in optics, acoustics, medical imaging, oceanography, astronomy, or non-destructive control of materials, for instance. Such a methodology is used in most imaging methods, where a map of the physical properties inside the object is searched from measurements acquired outside of it (e.g., X-ray tomography, or CT scan). This is also the case for methods aiming at restoring a signal, an image, or a dataset from a version that was downgraded, corrupted by noise and filtered by the acquisition device (e.g., the impulse response of a microscope or of a telescope).
This course presents basic and more advanced tools that enable one to address inverse problems, including the notion of direct problem (physical modelling), general information theory elements (incomplete data, ill-posed problems, statistical inference), the design of solutions based on the concept of regularization, up to the numerically efficient computation of solutions in big data cases.

- Generalities: ill-posed problems, regularization, prior information
- Deconvolution: standard (linear) methods, quadratic regularization, statistical estimation
- Non-linear methods, spike train deconvolution, sparsity
- Image restoration and tomography

Course material

- 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
- C. Kak and M. Slaney, Principles of Computerized Tomographic Imaging, IEEE Press, 1988.

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

MACHINE LEARNING, DATA ANALYSIS AND INFORMATION RETRIEVAL

CONTROL AND ROBOTICS – SIGNAL AND IMAGE PROCESSING
YEAR 2 - AUTUMN SEMESTER

LEAD PROFESSOR: Mathieu LAGRANGE

Objectives

The aim of this course is to address the key notions of machine learning, essential today in dealing with the ubiquitous collection of increasing amounts of data. The course will introduce the different types of machine learning movements and their applications in the context of signals and images. We will review the most influential methods historically for unsupervised and supervised learning. The sessions will alternate between lectures, practical exercises in Python, seminars and projects. Although the techniques will be presented from a broad and general perspective, the applications will focus on images, biomedical data and sound processing.

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

- Extract relevant features from large databases
- Run machine learning algorithms for solving problems

Course contents

- Introduction to machine learning
- Probabilistic supervised classification
- Data representation and dimensionality reduction - Variable selection
- Linear classification
- Support Vector Machines (SVM)
- Trees and random forest algorithms
- Neural networks
- Deep learning

Course material

- Bishop C.: Pattern Recognition and Machine Learning. Springer, 2006.
- Kevin P. Murphy, "Machine Learning" MIT Press, 2013

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

PROJECT

CONTROL AND ROBOTICS – SIGNAL AND IMAGE PROCESSING
YEAR 2 - AUTUMN SEMESTER

LEAD PROFESSOR: Said MOUSSAOUI

Objectives

The purpose of this project is for the student to apply the theories and techniques studied during the courses, according to his/her career plan. It is, therefore, either a technical project for an industrial application, or an introduction to research to consider a research profession.

Course contents

This project can be either a technical project or an initiation to research: latest developments, proposals, experiments, analysis and prospects etc.
It is an extended individual project (including scientific support, bibliography, scientific study)

Course material

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

BIOMEDICAL SIGNALS, IMAGES AND METHODS

CONTROL AND ROBOTICS – SIGNAL AND IMAGE PROCESSING
YEAR 2 - AUTUMN SEMESTER

LEAD PROFESSOR: Diana MATEUS LAMUS

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 language 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
- Ultrasound
- Electrophysiology
- Magnetic resonance imaging

Biomedical image processing
- segmentation
- filtering
- registration
- tomography

Practical hands-on sessions

Course material

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

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

STATISTICAL SIGNAL PROCESSING AND ESTIMATION THEORY

CONTROL AND ROBOTICS – SIGNAL AND IMAGE PROCESSING
YEAR 2 - AUTUMN SEMESTER

LEAD PROFESSOR: Eric LE CARPENTIER

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 statistical description of a random process
- Solve a statistical estimation problem in a practical situation
- Derive a numerical algorithm to calculate and to characterize the solution

Course contents

- Probability theory: random vectors, density, mean, variance.
- Time analysis, frequency analysis: random signals, autocorrelation, power spectral density.
- Classical estimation Theory, Bayesian estimation: maximum likelihood (ML) estimation, minimum mean square error (MMSE) estimator, maximum a posteriori (MAP) estimator, linear minimum mean square error (LMMSE).
- Expectation-Maximization algorithm (EM)
- Markov chains, Markov processes
- Statistical filtering: Kalman

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.

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

MATHEMATICAL TOOLS FOR SIGNAL AND IMAGE PROCESSING

CONTROL AND ROBOTICS – SIGNAL AND IMAGE PROCESSING
YEAR 2 - AUTUMN SEMESTER

LEAD PROFESSOR: Said MOUSSAOUI

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

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

CULTURAL AND COMMUNICATION ENGLISH

CONTROL AND ROBOTICS – SIGNAL AND IMAGE PROCESSING
YEAR 2 – AUTUMN SEMESTER

LEAD PROFESSOR: Spencer HAWKRIDGE

Objectives

Team-building and Communicational English:

- Understand the general concepts of team-building
- Build a team-building project
- Understand and nurture the creative process
- Enhance self-belief and self-empowerment

Behavioral skills in an inter-cultural environment:
- Strengthen self-confidence and capacity for interaction
- Develop active listening and reformulation skills
- Develop networking skills

Course contents

Cultural and Communicational English: exercises to explore in practice the areas of culture and communication
Field-related or inter-cultural project (for example, construct content for inter-cultural teambuilding activities; example WIOBOX website etc).

Course material

Written and televised press, information and digital tools, general documents business environment and company strategies.
Internet conferences (Ted Talks, etc.), our own educational materials on Hippocampus (Moodle).

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	**EXAM**
English	4	0 hrs	32 hrs	0 hrs	0 hrs	0 hrs

French Language

CONTROL AND ROBOTICS – SIGNAL AND IMAGE PROCESSING

Year 2 – Autumn Semester

LEAD PROFESSOR: Silvia ERTL

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 (2 semesters), 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.

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).

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LABO	PROJECT	**EXAM**
French	4	0 hrs	32 hrs	0 hrs	0 hrs	0 hrs

YEAR 2 - SPRING SEMESTER

Master Thesis / Internship

Master Thesis / Internship

CONTROL AND ROBOTICS – SIGNAL AND IMAGE PROCESSING

Year 2 - Spring Semester

LEAD PROFESSOR: Said MOUSSAOUI

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.

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