
ENGINEERING PROGRAMME

2025-2026

Year 2 / Year 3

Specialisation option

Data Analysis and Applications in
Signal and Image Processing

OD DATASIM

PROGRAMME SUPERVISOR

Said MOUSSAOUI



Autumn Semester

Course unit	ECTS Credits	Track	Course code	Title
UE 73	12	Core course	ARSIG ATRIM CSOPT MSTAT	Signal representation and analysis Image processing and analysis Scientific computing and numerical optimization Statistical data modelling and analysis
UE 74	13	Core course	APSTA FEBIO GRASP IMINV PRTS11	Machine learning theory and practice Filtering and biomedical signal processing Graph theory and time series analysis Imaging and Inverse Methods Project in signal and image processing

Spring Semester

Course unit	ECTS Credits	Track	Course code	Title
UE 83	14	Core course	AIMED AMULT APPLI AUDIO PRTSI 2	Advanced machine learning and medical imaging Multi-sensor data analysis R&D applications Audio content analysis and Information Retrieval Project in signal and image processing

ENGINEERING - OD DATASIM

Year 2 / Year 3 - Autumn Semester - Course Unit 73 / 93

Signal representation and analysis [ARSIG]

LEAD PROFESSOR(S): Sébastien BOURGUIGNON

Requirements

Mathematical foundations: linear algebra, integration, series, numerical optimization. Fourier series, Fourier transform.

Objectives

Extracting relevant information from a data set is a key step for efficient data processing. For example, the use of specific analysis methods is crucial for event detection 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 (analytical and numerical) tools for representing a signal, an image or, more generally, a data set, in order to extract its meaningful and useful information. Different analysis tools are presented, both in their mathematical and informational foundations and in their practical numerical implementation, through application examples taken from real data processing problems.

The first part of the course deals with the analysis of stationary signals, through Fourier analysis and high-resolution spectral analysis. Time-frequency and time-scale representations are studied for the analysis of non-stationary data. Finally, some elements concerning the more recent sparse representation framework are introduced, which generalise the former representations to more complex issues, in particular adapted to modern problems concerning big data processing.

Course contents

1. Spectral analysis for stationary signals: Fourier analysis, high-resolution methods. Lab work: detection of multiple oscillating components in noise; application to exoplanet detection from time series.
2. Time-frequency analysis: linear (short-term Fourier transform) and quadratic (spectrogram, Wigner-Ville) representations. Numerical tutored work: comparison of different time-frequency representations; time-frequency representations of piano instruments.
3. Non-stationary signals: time-scale representations and wavelet transforms. Lab work: Discrete Wavelet Transform and multiscale analysis; application to signal denoising and image compression.
4. Toward more general models: sparse representations. Lab work: denoising through projection into orthogonal bases and into redundant spaces ; denoising of piecewise constant signals.

Course material

A.V. Oppenheim and R.W. Schaffer. Discrete-time signal processing, Prentice Hall, 2010.

S. Marcos. Les méthodes à haute résolution : Traitement d'antenne et analyse spectrale, Hermès, 1998.

L. Cohen, Time-Frequency analysis, Prentice-Hall, 1995.

N. Martin et C. Doncarli, Décision dans le plan temps-fréquence, Hermes, 2004.

S. Mallat, A Wavelet Tour of Signal Processing: The Sparse Way, Academic Press, 2008.

M. Elad, Sparse and Redundant Representations, Springer, 2010.

Skills developed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
 - C2C3 : Think and act in an unpredictable and uncertain environments
 - Intermediate

Skills assessed through this course

No skill observed

Sustainable Development Goals (SDGs) covered by this course

Climate action / Good health and well-being / Industry, innovation and infrastructure / Quality education

Sustainable Development and Social Responsibility Positioning

Contribution to the training of engineers with mastery of digital tools in information and communication technologies, enabling them to address problems across multiple sectors. Enhancement of knowledge and know-how in data processing, leading to a better understanding of observable phenomena.

Assessment

Collective assessment: EVC 1 (coefficient 0.4)

Individual assessment: EVI 1 (coefficient 0.6)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	8 hrs	12 hrs	10 hrs	0 hrs	2 hrs

ENGINEERING - OD DATASIM

Year 2 / Year 3 - Autumn Semester - Course Unit 73 / 93

Image processing and analysis [ATRIM]

LEAD PROFESSOR(S): *Diana MATEUS LAMUS*

Objectives

This course is an introduction to the essential techniques for digital image processing. It covers how images are acquired, formed, stored, processed and used. We will review different types of image processing methods, including techniques for image transformation, enhancement, filtering, denoising, and some segmentation bricks. The course is composed of a series of lectures accompanied by significant hands-on experience to put into practice and analyse the taught techniques.

Course contents

Content:

- Introduction to digital images
- Quantitative image quality metrics
- Morphological operators
- Spatial filtering
- Spectral filtering
- Geometric transformations
- Segmentation methods

Course material

- [1] Digital Image Processing, 4th Ed. Gonzalez and Woods © 2018, ISBN: 9780133356724
- [2] Computer Vision: Algorithms and Applications (Texts in Computer Science). 2011th Edition. by Richard Szeliski
- [3] D. Forsyth, J. Ponce, Computer vision: a modern approach, Prentice Hall 2003.

Skills developed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
 - C2C3 : Think and act in an unpredictable and uncertain environments
 - Intermediate

Skills assessed through this course

No skill observed

Sustainable Development Goals (SDGs) covered by this course

Good health and well-being

Assessment

Collective assessment: EVC 1 (coefficient 0.5)

Individual assessment: EVI 1 (coefficient 0.5)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	8 hrs	12 hrs	10 hrs	0 hrs	2 hrs

ENGINEERING - OD DATASIM

Year 2 / Year 3 - Autumn Semester - Course Unit 73 / 93

Scientific computing and numerical optimization [CSOPT]

LEAD PROFESSOR(S): Said MOUSSAOUI

Objectives

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

Course contents

1. Scientific computing
 - Matlab
 - Python
2. Unconstrained optimization
 - basic concepts: differential calculus, mathematical properties, optimality conditions
 - iterative methods (first and second order methods, descent direction, line search, trust region)
 - applications (usual functions, parametric curve fitting, signal denoising)
3. Constrained optimization
 - exterior penalty methods
 - interior-point methods
 - applications to image restoration
4. Global optimization
 - interval methods
 - evolutionary methods
 - Monte Carlo methods

Course material

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

Skills developed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
 - C2C1 : Represent and model
 - Intermediate

Skills assessed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
 - Intermediate

Sustainable Development Goals (SDGs) covered by this course

Good health and well-being / Industry, innovation and infrastructure / Quality education

Sustainable Development and Social Responsibility Positioning

Contribute to educating engineers who are proficient in digital information and communication technology tools in order to understand engineering problems in several sectors.

Assessment

Collective assessment: EVC 1 (coefficient 0.4)

Individual assessment: EVI 1 (coefficient 0.6)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	8 hrs	12 hrs	10 hrs	0 hrs	2 hrs

ENGINEERING - OD DATASIM

Year 2 / Year 3 - Autumn Semester - Course Unit 73 / 93

Statistical data modelling and analysis [MSTAT]

LEAD PROFESSOR(S): 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, Bayesian estimation: maximum likelihood (ML) estimation, minimum mean square error (MMSE) estimator, maximum a posteriori (MAP) estimator, linear minimum mean square error (LMMSE).
- Markov chains, Markov processes.
- Statistical filtering: Bayes, Kalman, particles.

Course material

[1] Probability, Random Variables and Stochastic Processes. A. Papoulis, S.U. Pillai. Mc Graw Hill.

[2] Fundamentals of Statistical Signal Processing, Vol.1: Estimation theory, S. Kay, Prentice Hall.

Skills developed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
 - C2C1 : Represent and model
 - Intermediate

Skills assessed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
 - Intermediate

Sustainable Development Goals (SDGs) covered by this course

Good health and well-being / Industry, innovation and infrastructure / Quality education

Sustainable Development and Social Responsibility Positioning

The course is based on a document designed to provide students with long-term support in their studies and professional lives (SDG4). It provides a solid theoretical foundation for understanding the research work carried out at the school (SDG9), particularly in the medical field (SDG3), which most students will have to deal with during their end-of-study internship.

Assessment

Collective assessment: EVC 1 (coefficient 0.4)

Individual assessment: EVI 1 (coefficient 0.6)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	10 hrs	10 hrs	10 hrs	0 hrs	2 hrs

ENGINEERING - OD DATASIM

Year 2 / Year 3 - Autumn Semester - Course Unit 74 / 94

Machine learning theory and practice [APSTA]

LEAD PROFESSOR(S): *Diana MATEUS LAMUS*

Objectives

The aim of this course is to provide students with 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 and their applications in the context of signals and images. We will review the most influential methods for unsupervised and supervised learning. The sessions will alternate between lectures, practical exercises, and mini-projects in Python. Although the techniques will be presented from a broad and general perspective, the applications will focus on signal and images analysis, in particular from biomedical fields.

Course contents

- Introduction to machine learning
- Supervised and unsupervised methods
- Data representation, variable selection, and dimensionality reduction
- Evaluation measurements
- Probabilistic and linear classification methods
- Support Vector Machines (SVM)
- Decision trees and random forests
- Neural networks
- Introduction to deep learning
- Semantic Segmentation

Course material

- [1] Bishop C. : Pattern Recognition and Machine Learning. Springer, 2006.
[2] Kevin P. Murphy, Probabilistic Machine Learning: An Introduction, 2022

Skills developed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
 - C2C1 : Represent and model
 - Proficient

Skills assessed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
 - Proficient

Sustainable Development Goals (SDGs) covered by this course

Good health and well-being

Assessment

Collective assessment: EVC 1 (coefficient 0.5)

Individual assessment: EVI 1 (coefficient 0.5)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	10 hrs	10 hrs	10 hrs	0 hrs	2 hrs

ENGINEERING - OD DATASIM

Year 2 / Year 3 - Autumn Semester - Course Unit 74 / 94

Filtering and biomedical signal processing [FEBIO]

LEAD PROFESSOR(S): Said MOUSSAOUI

Objectives

- master analogue and digital filter synthesis techniques in line with application constraints
- implement digital filter applications for real signal processing
- be familiar with methods for acquiring and processing biomedical signals

Course contents

- 1/ Linear filtering
 - characterization of filters (specifications on frequency response)
 - linear filter synthesis methods
 - IIR and FIR filter synthesis
- 2/ Biomedical signal processing
 - Electrocardiography: acquisition principles and processing methods
 - Electromyography: acquisition principles and processing methods
 - Electroencephalography: acquisition principles and processing methods

Course material

- [1] M. Najim, Digital Filters Design for Signal and Image Processing, 2013, Wiley
 [2] A. Zverev, Handbook of Filter Synthesis, John Wiley and Sons, 1967
 [3] Naik Ganesh R., Santos Wellington Pinheiro Dos. Biomedical Signal Processing. A Modern Approach. Lavoisier, 2023

Skills developed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
 - C2C2 : Solve and arbitrate
 - Intermediate

Skills assessed through this course

No skill observed

Sustainable Development Goals (SDGs) covered by this course

Good health and well-being / Industry, innovation and infrastructure / Quality education

Sustainable Development and Social Responsibility Positioning

Contribute to educating engineers who are proficient in digital information and communication technology tools in order to understand engineering problems in several sectors.

Assessment

Collective assessment: EVC 1 (coefficient 0.4)

Individual assessment: EVI 1 (coefficient 0.6)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	10 hrs	12 hrs	8 hrs	0 hrs	2 hrs

ENGINEERING - OD DATASIM

Year 2 / Year 3 - Autumn Semester - Course Unit 74 / 94

Graph theory and time series analysis [GRASP]

LEAD PROFESSOR(S): Mira RIZKALLAH

Requirements

- Basics on statistics and probability
- Mathematical notions : complex numbers, integrals, linear regression, machine learning and deep learning

Objectives

At the end of this course, students will know:

- Estimate the parameters of time series models (AR, MA, ARMA, ARIMA, etc.)
- Prediction of future values and corresponding uncertainties from estimated models
- Know the basic principles of signal processing on graph: Fourier transform on graph, filtering, statistical and deep learning on graphs, convolutional networks on graphs.
- Apply signal processing and learning methods to a problem and data real (neuroscience, brain connectivity)

Course contents

The first part of the course focuses on experimental modeling of time series. It provides a detailed description of the time series forecasting and modeling chain, from data analysis to model validation. The second part covers the principles of graph signal processing and graph convolutional neural networks.

1. Time series analysis

- Basics of time series: important characteristics of a time series graph, auto-regressive (AR) model, autocorrelation function (ACF), moving average (MA) models, study of residuals.
- Moving average (MA) models, partial autocorrelation, useful notations (lag operators..)
- Identification and estimation of ARMA, ARIMA models; use of ARIMA models to forecast future values.
- Seasonal ARIMA models and exponential smoothing

2. Signal processing and learning on graphs

- Basic notions of graph-based modeling, signal on graphs, applications, the interest of representation, how to define a graph?
- Graph fourier transform, convolution and filtering of signals on graphs
- Neural networks on graphs, theory and applications in different fields

3. Practical applications

- Prediction of climate change with ARIMA, SARIMA models. In-depth analysis of models and data transformations.
- Node and Graph Classification. Applications on real data: social networks and neuroscience

Course material

- H. Kwakernaak and R. Sivan, Modern signals and systems, Prentice Hall, Englewood Cliffs, 1991
- C. Chatfield and H. Xing, The Analysis of Time Series An Introduction with R, by Chapman and Hall/CRC, 2019
- Antonio Ortega, Introduction to graph signal processing , Cambridge University Press.

Skills developed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
 - C2C1 : Represent and model
 - Proficient

Skills assessed through this course

No skill observed

Sustainable Development Goals (SDGs) covered by this course

Climate action / Good health and well-being / Industry, innovation and infrastructure / Responsible consumption and production

Sustainable Development and Social Responsibility Positioning

In this course, various practical exercises relate to sustainable development, including temperature prediction in a given location (climate change), simulations of epidemics on graphs, graphs in neuroscience...

Assessment

Collective assessment: EVC 1 (coefficient 0.4)

Individual assessment: EVI 1 (coefficient 0.6)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	10 hrs	10 hrs	10 hrs	0 hrs	2 hrs

ENGINEERING - OD DATASIM

Year 2 / Year 3 - Autumn Semester - Course Unit 74 / 94

Imaging and Inverse Methods [IMINV]

LEAD PROFESSOR(S): Sébastien BOURGUIGNON

Requirements

Basics of statistical analysis and probability theory. Linear algebra: matrix manipulation, matrix properties. Numerical optimization.

Objectives

Inverse methods are used when information about an object under study is acquired indirectly, by measuring the effects of a physical phenomenon whose causes are sought. This measurement principle can be found in many applications: optics, acoustics, medical imaging, oceanography, astronomy, non-destructive testing of materials, etc. This is the case for most imaging devices, where the aim is to map physical properties inside an object under study from measurements located at its periphery (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, distorted and filtered by the acquisition device (e.g., PSF of a microscope or of a telescope).

This course aims to introduce students to basic and more advanced tools to address an inversion problem, from the definition of the direct problem (physical modelling) and general information theory elements (incomplete data, ill-posed problem, statistical inference), to the resolution principle essentially based on regularization, up to the efficient numerical computation of the solution by means of specific 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.

Skills developed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
 - C2C3 : Think and act in an unpredictable and uncertain environments
 - Proficient

Skills assessed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
 - Intermediate

Sustainable Development Goals (SDGs) covered by this course

Good health and well-being / Industry, innovation and infrastructure / Quality education

Sustainable Development and Social Responsibility Positioning

Contribution to the training of engineers with mastery of digital tools in information and communication technologies, enabling them to address problems across multiple sectors. Enhancement of knowledge and know-how in data processing, leading to a better understanding of observable phenomena.

Assessment

Collective assessment: EVC 1 (coefficient 0.3)

Individual assessment: EVI 1 (coefficient 0.7)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	10 hrs	8 hrs	12 hrs	0 hrs	2 hrs

ENGINEERING - OD DATASIM

Year 2 / Year 3 - Autumn Semester - Course Unit 74 / 94

Project in signal and image processing [PRTSI1]

LEAD PROFESSOR(S): Mira RIZKALLAH

Requirements

- Write a report
- Prepare presentation materials

Objectives

The aim of this course is to undertake a project related to the processing of real data: audio signals, biomedical images or signals, hyperspectral images etc. This project begins in the autumn semester and is pursued in the spring semester.

Course contents

The projects concern the processing of real data such as:

1. Spectral data and hyperspectral images: deconvolution, decomposition and separation
2. Physiological signals: EEG, EMG for BCI and Prosthesis control
3. Audio signal: segmentation, speech recognition, content analysis
4. Medical image analysis: image segmentation, pattern recognition, etc

Course material

- [1] Fundamentals of statistical signal processing - Vol I. Estimation theory. S. KAY. Prentice Hall, 1993.
System identification, theory for the user. L. LJUNG Prentice Hall, Englewood Cliffs, New Jersey, 1987 (1st ed.) - 1999 (2nd ed.).
- [2] Approche bayésienne pour les problèmes inverses. J. IDIER. Traité IC2, Série traitement du signal et de l'image, Hermès, 2001.
- [3] Pattern Classification. R.O. DUDA, P.E. HART, D.G.STORK, Willey 2001.
Analyse d'images, filtrage et segmentation. Sous la direction de J.P. COQUEREZ et S. PHILIPP, Masson 1995

Skills developed through this course

- C1 : Design and prototype innovative systems that create value
 - C1C1 : Develop
 - Intermediate

Skills assessed through this course

- C1 : Design and prototype innovative systems that create value
 - Intermediate

Sustainable Development Goals (SDGs) covered by this course

Affordable and clean energy / Climate action / Good health and well-being / Industry, innovation and infrastructure / Partnerships for the goals / Quality education / Responsible consumption and production / Sustainable cities and communities

Sustainable Development and Social Responsibility Positioning

Various projects fall under the umbrella of sustainable development and social responsibility.

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	1	0 hrs	0 hrs	0 hrs	32 hrs	0 hrs

ENGINEERING - OD DATASIM

Year 2 / Year 3 - Spring Semester - Course Unit 103 / 83

Advanced machine learning and medical imaging [AIMED]

LEAD PROFESSOR(S): Diana MATEUS LAMUS

Objectives

This course will address advanced aspects of acquiring, reconstructing, and processing biomedical signals and images. The module aims to put in practice concepts acquired in previous periods (optimization approaches, data analysis algorithms, machine learning methods, etc.) in various practical application contexts. Several speakers from the industrial and research sectors will present real-world challenges they are working on and will propose mini-projects to be solved during practical sessions. These thematic sessions will be accompanied by additional lectures and practical sessions, providing alternative solutions

Course contents

Introduction to various medical imaging modalities such as ultrasound, computed tomography (CT), positron emission tomography (PET), or magnetic resonance imaging (MRI).

Practical implementation of algorithms for image formation/reconstruction, noise reduction, classification, segmentation, registration, and anomaly detection.

Course material

Medical Imaging Signals and Systems. Prince Links. Pearson Editions. 2015

Skills developed through this course

- C1 : Design and prototype innovative systems that create value
 - C1C2 : Dare
 - Intermediate

Skills assessed through this course

No skill observed

Sustainable Development Goals (SDGs) covered by this course

Good health and well-being

Assessment

Collective assessment: EVC 1 (coefficient 1)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	10 hrs	14 hrs	8 hrs	0 hrs	0 hrs

ENGINEERING - OD DATASIM

Year 2 / Year 3 - Spring Semester - Course Unit 103 / 83

Multi-sensor data analysis [AMULT]

LEAD PROFESSOR(S): Said MOUSSAOUI

Objectives

This course focuses on techniques for analysing multi-sensor data using so-called source separation methods. These recent methods - principal component analysis, independent component analysis and non-negative matrix factorization - exploit sensor redundancy to analyse data content by exploiting linear mixture models and adopting statistical assumptions about the sources.

The second part of the course addresses applications for signal and image processing in order to show how to adapt analysis methods to the constraints of the applications.

Course contents

1. Source separation methods
 - a) Algebraic methods
 - b) Iterative methods
 - c) Statistical approaches (maximum likelihood and Bayesian estimation)
2. Applications for signal analysis
 - a) Spectrometry
 - b) Biomedical signals
3. Applications for hyperspectral imaging
 - a) Concepts of remote sensing
 - b) Geometrical approaches
 - c) Hyperspectral image analysis by source separation

Course material

- [1] P. Comon and C. Jutten, Séparation de sources 1: concepts de base et analyse en composantes indépendantes, Traité IC2, série Signal et image, 03-2007
- [2] P. Comon and C. Jutten, Séparation de sources 2: au-delà de l'aveugle et applications, Traité IC2, série Signal et image, 03-2007
- [3] A. Hyvarinen, J. Karhunen, and E. Oja, Independent Component Analysis. Johns Willey & Sons., 2001.

Skills developed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
 - C2C2 : Solve and arbitrate
 - Proficient

Skills assessed through this course

No skill observed

Sustainable Development Goals (SDGs) covered by this course

Good health and well-being / Industry, innovation and infrastructure / Quality education

Sustainable Development and Social Responsibility Positioning

Contribute to educating engineers who are proficient in digital information and communication technology tools in order to understand engineering problems in several sectors.

Assessment

Collective assessment: EVC 1 (coefficient 0.4)

Individual assessment: EVI 1 (coefficient 0.6)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	10 hrs	10 hrs	10 hrs	0 hrs	2 hrs

ENGINEERING - OD DATASIM

Year 2 / Year 3 - Spring Semester - Course Unit 103 / 83

R&D applications [APPLI]

LEAD PROFESSOR(S): Sébastien BOURGUIGNON

Objectives

This course is composed of interventions given by R&D engineers and researchers working on data analysis and processing problems in various fields of science and engineering. It aims at presenting how different kinds of information processing problems (signal, image, data analysis) are tackled in several industrial or academic research activities, using modern methodologies, in particular using the various courses and tools seen in the first two periods of the year of the DATASIM track.

Course contents

Each course takes place over one day. The morning is dedicated to a presentation of the problem encountered, its methodological obstacles and the solutions that are proposed. The afternoon is dedicated to the practical implementation of the methods developed in the first part, on real data. Provisional program (subject to changes):

ONERA: Co-design approaches for the joint acquisition and processing of data, and applications in optical imaging

RENAULT: Introduction to Data Fusion for Driving Assistance and Autonomous Vehicles

DB-SAS: Ultrasound imaging for non-destructive testing

Université Gustave Eiffel : Image Processing using LBM: Anisotropic Diffusion and Segmentation

Lagrange Laboratory (Observatory of the Côte d'Azur): Introduction to detection and some applications in Astrophysics

CNES: Space imaging: from principles to applications

Course material

Ku, Jason, et al. "Joint 3d proposal generation and object detection from view aggregation." 2018 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). IEEE, 2018.

S. Steyer, G. Tanzmeister and D. Wollherr, "Object tracking based on evidential dynamic occupancy grids in urban environments," 2017 IEEE Intelligent Vehicles Symposium (IV), Los Angeles, CA, 2017, pp. 1064-1070, doi: 10.1109/IVS.2017.7995855.

"Fundamentals of Statistical Signal Processing, Volume II: Detection Theory", S. Kay, Prentice Hall, 1993, ISBN-10: 013504135X

Valorge C. and al., (2012) Satellite Imagery. From acquisition principles to processing of optical images for observing the Earth, Cépadues Edition

Baghdadi N. and al., (2016). Optical Remote Sensing of Land Surface: Techniques and Methods, ISTE Press Ltd - Elsevier Inc

Skills developed through this course

- C1 : Design and prototype innovative systems that create value
 - C1C2 : Dare
 - Intermediate

Skills assessed through this course

No skill observed

Sustainable Development Goals (SDGs) covered by this course

Climate action / Good health and well-being / Industry, innovation and infrastructure / Quality education

Sustainable Development and Social Responsibility Positioning

Contribution to the training of engineers with mastery of digital tools in information and communication technologies, enabling them to address problems across multiple sectors. Enhancement of knowledge and know-how in data processing, leading to a better understanding of observable phenomena.

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	16 hrs	16 hrs	0 hrs	0 hrs	0 hrs

ENGINEERING - OD DATASIM

Year 2 / Year 3 - Spring Semester - Course Unit 103 / 83

Audio content analysis and Information Retrieval [AUDIO]

LEAD PROFESSOR(S): Mathieu LAGRANGE

Requirements

Tools for audio signal processing

Objectives

This course aims to train students in:

- the principles of audio numerical representation (acoustic, encoding, processing)
- the principles of psycho acoustics (perception, cognition)
- modelling and learning of high level attributes (musical information retrieval)

Course contents

Basics of Acoustics

Representation of sounds

- spectrogramme, spectral analysis

Sound Processing and data analysis

- PCA, MDS

Perception and psychoacoustics

Auditory Scene Analysis

Source separation

Course material

Acoustique, Informatique et Musique. Outils scientifiques pour la musique. B. D'Andréa-Novel, B. Fabre, P. Jouvelot. Mines Paristech, 2012

Klapuri, A. and Davy, M. (Editors), Signal Processing Methods for Music Transcription, Springer-Verlag, New York, 2006

Auditory Scene Analysis, The Perceptual Organization of Sound, By Albert S. Bregman, MIT Press

Skills developed through this course

- C1 : Design and prototype innovative systems that create value
 - C1C1 : Develop
 - Intermediate

Skills assessed through this course

No skill observed

Sustainable Development Goals (SDGs) covered by this course

Good health and well-being / Responsible consumption and production / Sustainable cities and communities

Sustainable Development and Social Responsibility Positioning

This course allows students to train in digital audio signal processing for the following applications related to sustainable development: - monitoring of natural environments for biodiversity assessment - monitoring of urban environments and characterization of the acoustic quality of cities - training and raising students' awareness of the importance of perception,

particularly auditory perception, for improving well-being.

Assessment

Collective assessment: EVC 1 (coefficient 0.4)

Individual assessment: EVI 1 (coefficient 0.6)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	10 hrs	12 hrs	8 hrs	0 hrs	2 hrs

ENGINEERING - OD DATASIM

Year 2 / Year 3 - Spring Semester - Course Unit 103 / 83

Project in signal and image processing [PRTSI 2]

LEAD PROFESSOR(S): Mira RIZKALLAH

Objectives

The aim of this course is to undertake a project related to the processing of real data: audio signals, biomedical images or signals, hyperspectral images. This project begins in the autumn semester and is pursued in the spring semester.

Course contents

The projects involve the processing of real data such as:

1. Spectral data and hyperspectral images: deconvolution, decomposition and separation
2. Physiological signals: EEG, EMG for BCI and Prosthesis control
3. Audio signals: segmentation, speech recognition, content analysis
4. Medical image analysis: image segmentation, pattern recognition, etc

Course material

[1] Fundamentals of statistical signal processing - Vol I. Estimation theory. S. KAY. Prentice Hall, 1993.

System identification, theory for the user. L. LJUNG Prentice Hall, Englewood Cliffs, New Jersey, 1987 (1st ed.) - 1999 (2nd ed.).

[2] Approche bayésienne pour les problèmes inverses. J. IDIER. Traité IC2, Série traitement du signal et de l'image, Hermès, 2001.

[3] Pattern Classification. R.O. DUDA, P.E. HART, D.G.STORK, Willey 2001.

Analyse d'images, filtrage et segmentation. Sous la direction de J.P. COQUEREZ et S. PHILIPP, Masson 1995

Skills developed through this course

- C3 : Manage complex programmes or change responsibly
 - C3C3 : Finalise and leverage feedback
 - Intermediate

Skills assessed through this course

- C2 : Analyse a complex system from all angles (scientific, economic, human, social) and propose a solution
 - Proficient
- C3 : Manage complex programmes or change responsibly
 - Intermediate

Sustainable Development Goals (SDGs) covered by this course

Affordable and clean energy / Climate action / Good health and well-being / Industry, innovation and infrastructure / Partnerships for the goals / Quality education / Responsible consumption and production / Sustainable cities and communities

Sustainable Development and Social Responsibility Positioning

Various projects fall under the umbrella of sustainable development and social responsibility.

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	2	0 hrs	0 hrs	0 hrs	48 hrs	0 hrs