PROGRAMME DÉTAILLÉ M2 IM

Année 2025-2026
RNCP : 34274

Détails des cours de M2 par option

- UE communes à toutes les options
  - Pour les FA :
    - PPR Alternance 1 - 9 ECTS
    - UE Management responsable et cadre juridique- 6 ECTS
    - UE PPR Alternance 2 – 24 ECTS
  - Pour les FI :
    - UE Management responsable et cadre juridique – 3 ECTS
    - PPR PFE Initial - 6 ECTS
    - UE PPR IM MDS initiale stage – 30 ECTS

Option Mathematics for Data Science (MDS)

- UE Mathématiques pour la modélisation (40h CM et 20h TD) 6 ECTS: Choix de 2 cours parmi les 3 suivants:
    - Statistical learning from and on Graphs
    - Geometric Statistics
    - Probabilistic Computational Methods
- UE Mathématiques appliquées (20h CM et 10h TD) - 3 ECTS: Choix de 1 cours parmi les 2 suivants:
    - Advanced optimization
    - Stochastic Calculus and Applications
- UE Numérique et informatique – 6 ECTS
    - Fundamentals of Machine Learning (20h CM et 10h TD)
    - Computational Optimal Transport (20h CM et 10h TD)
    - Technologies of Big Data (20h CM et 10h TD)
- UE Métiers - 6 ECTS

The professional courses are taught by professional speakers from outside the academic world. They aim to open students to new themes, issues and approaches, at the cutting edge of industrial research linked to artificial intelligence.

- Modeling and simulation in Medicine and Health (24h CM)
- AI Seminar in Environment, Neuroscience, Language (24h CM)
- AI Seminar in Ethic, Legal and Societal Issues (24h CM)
- Big Data and Analytics (24h CM)

Option Mathématiques et Modélisation du Vivant (MMV)

In the second year, part of the teaching is shared with life sciences masters programs (computational biology, computational neuroscience, etc.).

- UE Mathématiques pour la modélisation (40h CM et 20h TD) 6 ECTS: Choix de 2 cours parmi les 3 suivants:
    - Statistical learning from and on Graphs
    - Mixed Effects Models and Population Variability
    - Probabilistic Computational Methods
- UE Mathématiques appliquées (20h CM et 10h TD) - 3 ECTS: Choix de 1 cours parmi les 2 suivants:
    - Control Theory
    - Stochastic Calculus and Applications
- UE Numérique et informatique – 6 ECTS
    - Fundamentals of Machine Learning (20h CM et 10h TD)
    - AI for biological and medical data (20h CM et 10h TD)
    - Biomécanique de la cellule (14h CM et 14h TD)
- UE Métiers - 6 ECTS

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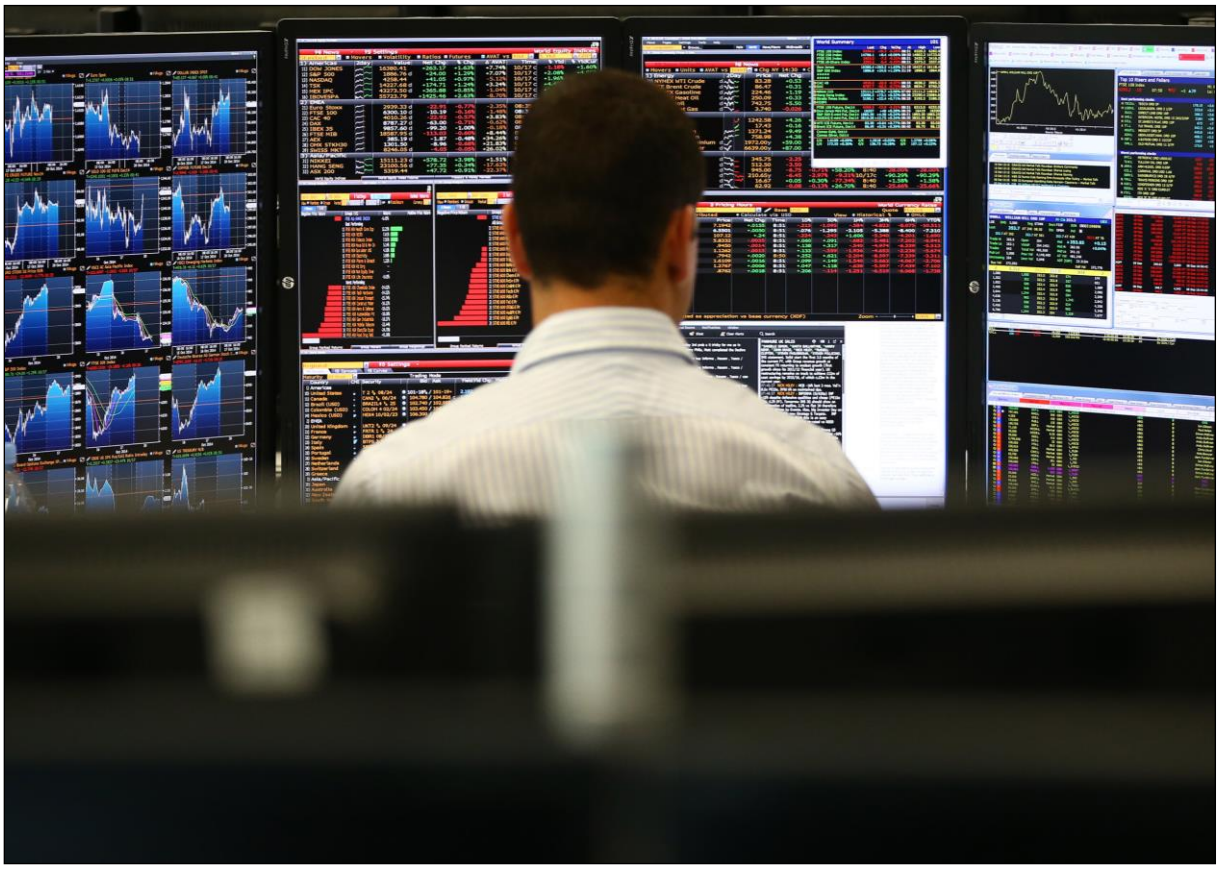
    - Modeling and simulation in Medicine and Health (24h CM)
    - AI Seminar in Environment, Neuroscience, Language (24h CM)
    - AI Seminar in Ethic, Legal and Societal Issues (24h CM)
    - Big Data and Analytics (24h CM)

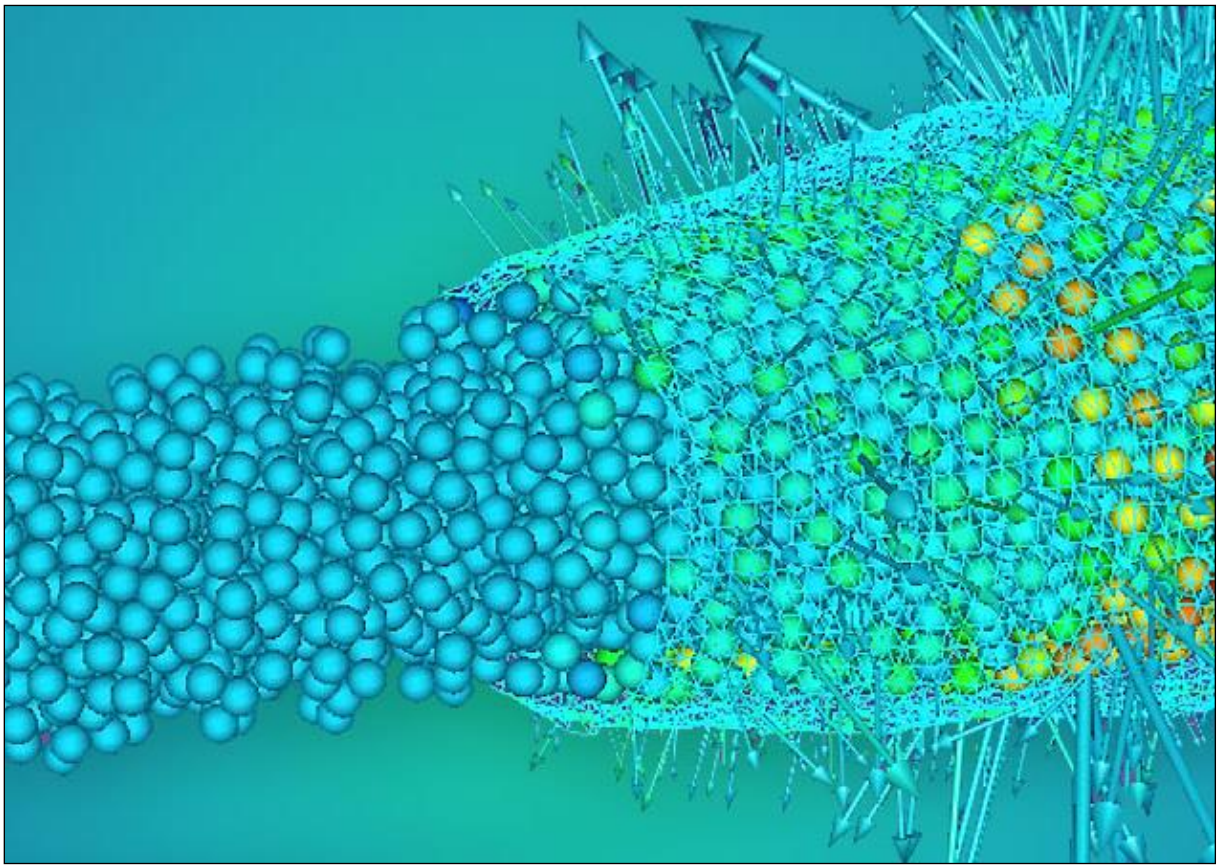
Option Informatique et Mathématiques Appliquées à la Finance et à l'Assurance (IMAFA)



The IMAFA option focuses on training high-level computer scientists with a perfect command of the mathematical concepts and tools needed to design and implement financial and banking information systems. At IMAFA, the aim is not to train financiers, but rather computer scientists with the mathematical and financial knowledge to bring real added value to the implementation of information systems in the banking, insurance and finance sectors.

- UE Mathématiques pour la modélisation
  - Modèles mathématiques pour la finance et l'assurance (27h CM et 27h TD)
  - Machine learning pour l'actuariat (24h CM)
  - Méthodes numériques pour le pricing d'options (15h CM et 15h TD)
- UE Mathématiques appliquées
  - Gestion de portefeuille (24h CM)
  - Calcul actuariel (36h CM)
- UE Numérique et informatique :
  - Applications distribuées en environnement hétérogène (15h CM et 15h TD)
  - Applications relationnelles pour le web (15h CM et 15h TD)
  - Génie logiciel (30h CM et 18h TD)
- UE Métiers 1 & 2
  - Marché de l'énergie (12h CM)
  - Finance de marché (27h CM)
  - Marché des taux (45h CM)

Option Ingénierie Numérique (INUM)



This option provides advanced skills in numerical analysis, applied mathematics and computer science. The "Trades" Unit is designed to introduce application problems using the knowledge base acquired during the course. Topics covered include modeling in the life sciences, materials, satellites and control systems. Finally, an end-of-study project unit enables students to tackle the mathematical or numerical modelling of a new subject. These projects are systematically supervised by one or more researchers or an industrial partner.

- UE Mathématiques pour la modélisation :
  - Commande optimale (20h CM et 10h TD)
  - Optimisation avancée (20h CM et 10h TD)
  - Réduction de modèles & Digital Twin (26h CM et 22h TD)
- UE Mathématiques appliquées :
  - Eléments finis (20h CM et 10h TD)
  - Volumes finis (16h CM et 8h TD)
- UE Numérique et informatique
  - Deep Learning (16h CM et 8h TD)
  - Machine learning en calcul scientifique (20h CM et 10h TD)
  - Calcul Haute Performance (15h CM et 15h TD)
- UE Métiers 1 & 2 :
  - Logiciels industriels (28h CM et 14h TD)
  - Systèmes satellitaires (16h CM et 8h TD)
  - Modélisation en biologie (12h CM et 12h TD)
  - Modélisation géométrique (12h CM et 12h TD)

Option Sciences des Données (SD)

This specialization offers advanced skills in data science and computer science. It requires a strong interest in computer science. The aim of the Business Unit is to introduce application problems using the knowledge base acquired during the course. Topics covered include Big Data technologies, deep learning, image analysis, natural language and more. Finally, an end-of-study project unit enables students to tackle the mathematical or numerical modeling of a new subject. These projects are systematically supervised by one or more researchers or an industrial partner.

- UE Mathématiques pour la modélisation
  - Big Data Technologies (18h CM et 18h TD)
  - Data Science (18h CM et 18h TD)
  - Artificial Intelligence Engineering (18h CM et 18h TD)
- UE Mathématiques appliquées
  - Deep Learning (18h CM et 18 TD)
  - Advanced Topics in Deep Learning ((18h CM et 18 TD)
- UE Numérique et informatique :
  - Text mining and Natural Language Processing (18h CM et 18 TD)
  - Advanced Data Mining (18h CM et 18 TD)
- UE Métiers 1 & 2
  - Machine Learning for Image Analysis (18h CM et 18 TD)
  - Applied Artificial Intelligence (18h CM et 18 TD)
  - Virtual Reality (18h CM et 18 TD)

Résumé des cours

UE Communes

UE Management responsable et cadre juridique

The module is designed to develop skills in legal reasoning and the analysis of practical management situations. The program integrates the following aspects in particular: Sociology of organizations, Labor law, Negotiation, Strategy.
The objectives are to complement the cross-disciplinary subjects studied during the first two years of the curriculum, to deepen certain economic and managerial concepts, and to broaden professional prospects.

UE Projet de Fin d'Etude

For Alternance students, this end-of-study project will consist of a mid-term presentation of their internships (9 ECTS).

UE Stage

This unit corresponds to the in-company work placement, which runs from the beginning of March to the end of August for full-time students (30 ECTS). Work experience for Alternance students is assessed for PPR Alternance 1 in S3 (3 ECTS) and PPR Alternance 2 (24 ECTS) in S4.

UE Mathématiques pour la Modélisation

Statistical learning from and on Graphs

This course explores in detail some areas in machine/statistical learning that either use graphs in order to learn from data leaving in Euclidean spaces (e.g. Bayesian networks, spectral clustering) or directly model graph data (e.g. social network analysis, graph neural networks). In all model-based approaches that we consider, maximum likelihood inference is adopted for the numerical estimation of the model parameters, with an important focus on EM and variational EM algorithms. Both R and Python will be employed to illustrate some implementations/applications of the proposed approaches and allow the student to become acquainted with the related libraries.

Mixed Effects Models and Population Variability

We introduce the population approach and mixed effects models and hierarchical models. We will explain the whole range from linear models to nonlinear mixed effects models.

The second part is devoted to the notion of a model via the joint probability distribution and the problem of the model selection. Several types of models will be considered (models for multidimensional continuous observations, models for count data, models for categorical data…). Independent observations and conditionally independent observations will be considered. Examples will be detailed. The main reference for this course will be the book Mixed Effects Models for the Population Approach, Models, Tasks, Methods and Tools, Marc Lavielle, Chapman and Hall/CRC, 2014.

Geometric Statistics

This course addresses some theory of random fields, spatial prediction, spatio-temporal processes, stationarity, isotropy, applications to topological Inference.
Some elements of random geometry are also given and associated set estimation theory is provided.

Probabilistic Computational Methods

This course addresses the basic methods used for simulating random variables and implementing Monte-Carlo and Quasi Monte-Carlo methods.
Simulation of stochastic processes used in neuroscience and mathematical finance, such as Brownian motion and solutions to stochastic differential equations, will be addressed.
The course will introduce sampling methods in finite dimension, discretization of diffusion processes, strong and weak errors.
Exercises will be done on paper and on the computer (using Python language).

Modèles mathématiques pour la finance et l'assurance

This course introduces the continuous mathematical models used in option pricing and risk analysis: Brownian motion, Itô's integral, stochastic differential equations and Girsanov's theorem. From a modeling point of view, these tools will be used to introduce the notion of strategy, arbitrage and risk-neutral probability, and to solve the problem of calculating premium and hedging in the Black-Scholes model.

Machine learning pour l'actuariat

This module looks at the application of machine learning (and artificial intelligence more generally) to actuarial science. For example, ML can be used to predict the calculation of premiums for a life insurance contract.

Méthodes numériques pour le pricing d'options

This course covers the numerical solution of elliptic and parabolic partial differential equations by finite differences, with application to European options, and the numerical solution of parabolic variational inequalities by finite differences, with application to American options. It also introduces random variable and Monte Carlo simulation methods, with a focus on the simulation of stochastic differential equations and the numerical calculation of option values.

Commande optimale

Optimal control of systems governed by partial differential equations (systems with distributed parameters): elliptic (Laplace) and parabolic (heat equation) systems. Distributed control, boundary control. Inverse problems: solution by optimal control with regularization. Sample applications.

Optimisation avancée

Parametric optimization in finite dimension (gradient method, evolutionary algorithms); taking constraints into account; calculus of variations, optimal control, shape optimization. The course includes supervised practical work on simplified optimization problems in aerodynamics and structural design..

Réduction de modèles & Digital Twin

Numerical simulation plays an important role in industry. For example, it can be used to help design or operate complex industrial systems. Often based on differential equations, these models can be time-consuming to compute. As a result, industry is increasingly turning to model reduction methods. These involve building a simplified model from complex models. The reduced model obtained, although less accurate, should retain a good representation of the initial model. Various model reduction methods will be presented in this class.
Digital twin
One of the challenges facing industry is to build digital twins capable of reproducing the complete operation of an object or process (e.g. an energy production line). The aim of this course is to introduce these digital tools, which combine digital simulation, data analysis and machine learning.

Big Data Technologies

This course focuses on the distributed storage and processing of massive data. In particular, it studies the Hadoop and Spark environments. Students will discover the Scala language and the main Spark libraries. They will learn how to use NoSQL databases and perform advanced data analysis in a distributed environment.

Data Science

This course provides an introduction to data science through various applications. In particular, it uses data analysis tools developed and employed by IBM. It also looks at the most relevant Python libraries in the field of data science.

Artificial Intelligence Engineering

The objective of this course is therefore to reinforce the knowledge of tomorrow's engineers around the issues of operationalizing AI in production, with regard to the needs, constraints and demanding processes of today's industry. The aim of this course is to provide students with: an awareness of MLOps and DataOps methodologies, so that they can apply them to simple examples; a better understanding of cloud-native environments and technologies; a good overview of the complete lifecycle of a Machine Learning application, including CI/CD, technical monitoring and business monitoring; and a few notions about sensitivity, security, encryption and data isolation.

UE Mathématiques appliquées

Advanced optimization

Stochastic gradient descent (Robbins-Monro, 1951) is the workhorse of many statistical and probabilistic procedures. In particular, it is widely used in machine learning for training artificial neural networks, support vector machines. This course is intended to provide a mathematical foundation to this algorithm and variants of it, along with a numerical intuition of its behavior on practical examples. It will be organized in three main blocks : a first one giving foundation on optimization, a second one dedicated introducing the stochastic gradient descent algorithm, and a third one discussing advanced topics in stochastic optimization.

Control Theory

Modeling, Control and Optimal Command of Biological Systems

Aims: To acquire mathematical techniques and develop efficient tools for the control of biological systems, with practical application to biochemical networks, bioprocesses and cell population control.

Contents:

- Part A.I. Introduction to Control Theory
- Part A.II. Optimal control, Pontryagin's maximum principle
- Part B.I. Modeling and control in systems biology
- Part B.II. Modeling, analysis and control of bioprocesses
- Part B.III. Modeling and control of cell population dynamics applied to cancer

References

[1] Lenhart, Suzanne, John T. Workman Optimal control applied to biological models.Chapman and Hall/CRC, 2007.

[2] Smith, Hal L., Paul Waltman. The theory of the chemostat: dynamics of microbial competition. Vol. 13. Cambridge university press, 1995.

[3] Tr´ elat, Emmanuel. Contr^ole optimal: th´ eorie & applications. Vol. 36. Paris: Vuibert,2005.

[4] Khalil, Hassan K. Nonlinear systems third edition. Patience Hall 115 (2002).

[5] Ingalls, Brian P. Mathematical modeling in systems biology: an introduction. MIT press,2013.

[6] Dochain, Denis, ed. Automatic control of bioprocesses. John Wiley & Sons, 2013.

[7] Bryson, A.E., 2018. Applied optimal control: optimization, estimation and control.

Routledge.

[8] Sch¨ attler, H. and Ledzewicz, U., 2012. Geometric optimal control: theory, methods and examples (Vol. 38). New York: Springer.

[9] Sch¨ attler, H. and Ledzewicz, U., 2015. Optimal control for mathematical models of cancer therapies. An application of geometric methods

[10] Faugeras, O. and Janin, J., 2012. Modeling in Computational Biology and Biomedicine: A Multidisciplinary Endeavor. Springer Science & Business Media

Stochastic Calculus and Applications

This course is devoted to the introduction of the basic concepts of continuous-time stochastic processes which are used in many fields : physics, finance, biology, medicine, filtering theory, decision theory. It will consist of a presentation of Brownian motion, Itô integral, stochastic differential equations and Girsanov theorem. Several applications will be given.

Gestion de portefeuille

The focus of this course is to provide an introduction to risk management for financial asset portfolios: Markowitz and Black-Litterman models; "Ex-post" risks, classic risk ratios (Sharpe, Beta, Information ratio, etc.) and their use; "Ex-ante" risks, multifactor modeling and variance-covariance matrix; Risk hedging, the futures, options and derivatives markets for hedging market and credit risks. This course includes Excel applications.

Calcul actuariel

The course aims to lay the foundations of actuarial calculation, by studying life and non-life insurance, the pricing of life insurance premiums and the valuation of profits.

Eléments finis

Mixed formulation of the Stokes problem; Speed-pressure compatibility; Convergence. Application to linear elasticity.

Volumes finis

Introduction of the limit conditions; practical implementation in the case of liquid flow in the cooling chamber of a gas generator. Pressure law for phase change. Application to liquid flow with phase change.

Deep Learning

This course provides an introduction to deep neural networks. It provides a comprehensive presentation of neural networks: deep, convolutional, recurrent, adversarial and generative. It also provides an introduction to the tools commonly used by practitioners. A significant part of the course is devoted to practical case studies on the computer, using Jupiter notebooks. More specifically, students will study image categorization, semantic image segmentation and speech recognition.

Advanced Topics in Deep Learning

This course focuses on the most advanced techniques in deep learning. In particular, it studies the ability of a neural network to model and estimate a multidimensional function. It looks at the convergence of the gradient algorithm for training a neural network, the structural properties of convolutional networks and neural networks applied to graphs. It also considers the statistical foundations of variational autoencoders. Finally, it examines the theoretical aspects of neural network explicability. Numerous applications with the Pytorch library put the theoretical concepts studied into practice.

UE Numérique et informatique

Fundamentals of Machine Learning

This course offers an in-depth look at some fundamental mathematical concepts driving recent advances in machine learning. Core topics encompass the theory of deep learning, large-scale and distributed optimization, causal inference, fairness, and safety in AI. Each topic will be explored through rigorous mathematical development complemented by practical Python-based experiments. For the final assessment, students must present a topic of their choice from a provided list and resources, following the same format of rigorous mathematical exploration and Python experimentation.

Computational Optimal Transport

Technologies of Big Data

The aim of this course is to learn how to install and how to use an architecture for Big Data. This course will present the various software used for Big Data treatment : Apache Pig, Hive, HBase, Spark …

AI for biological and medical data

Biomécanique de la cellule

Applications distribuées en environnement hétérogène

The focus of this course is to identify and understand the issues involved in programming in distributed and heterogeneous environments.

Applications relationnelles pour le web

The aim of this course is to:

- understand the need to manage data persistence; assess the suitability of a modeling tool;
- evaluate the relevance of localizing data processing on distributed architectures (client-server and multi-tier).

To achieve this, students will learn to design efficient (standardized) relational databases, use ORM and UML, program in SQL (Postgres DBMS), Java (JSP, JDBC, EJB) and use the Resin environment.

Génie logiciel

This module introduces the concept of software engineering and modeling using the UML language. It is divided into three parts: additional information on software engineering and development processes; an introduction to UML 1 and its use for modeling in all phases of software project development; and a section on testing methods.

Deep Learning

This course will present the theoretical foundations of Deep Learning and implement Deep Neural Networks (DNN) with Python. In particular, it will

- understand the limits of optimization algorithms for training DNNs,
- identify the mathematical approximation capabilities of DNNs,
- discover the advantages of DNNs for modeling a subvariety of a Euclidean space,

- know how to use the appropriate software tools to manipulate DNNs.

Machine learning en calcul scientifique

Machine learning, in particular Deep Learning (DL), is increasingly used to perform, improve and accelerate numerical simulations in scientific computing. This course aims to present a selection of current research topics in the general area of DL for scientific computing with an application to systems, modeled by partial differential equations. Emphasis will be placed on the design and implementation of algorithms, as well as on the underlying theory that guarantees the reliability of algorithms.

Calcul Haute Performance

Unix basics ; Optimizing algorithms in Fortran 90; Introduction to parallel programming; Message exchange programming (MPI). Dependency domains for numerical algorithms. Domain partitioning and communication structures.

Text mining and Natural Language Processing

This course focuses on the automatic processing and analysis of textual data and, more generally, on natural language processing. The most recent techniques are studied, with an emphasis on deep learning, recurrent neural networks and transformers. Numerous applications with the Pytorch language put the theoretical concepts studied into practice.

Advanced Data Mining

This course will present various multidimensional data mining techniques and dimensionality reduction methods for visualization. The course will also include an introduction to data visualization. As far as data mining methods are concerned, the focus will be on deterministic latent model methods, such as constrained matrix factorizations and tensor factorizations. The methods will be programmed by students in Python language during tutorials, and applied to data from a wide range of problems (image processing, chemometrics, recommender systems). The part of the course dealing with data visualization will include an introduction to the issues and history of data visualization. Several linear and non-linear dimension reduction methods will be presented in this part of the course and used in tutorials to analyze real data.

UE Métiers

Modeling and simulation in Medicine and Health

This professional course concerns more specifically the challenges of AI in medicine and health.

AI Seminar in Environment, Neuroscience, Language

This professional course concerns more specifically the challenges of AI in environment, neuroscience and language.

AI Seminar in Ethic, Legal and Societal Issues

This professional course concerns more specifically the challenges of AI in ethical, legal and societal issues.

Big Data and Analytics

This course offers an introduction to data science as well as various software tools. It provides a comprehensive presentation of neural networks : deep, convolutional, recurrent, adversarial and generative. It also provides an introduction to the tools routinely used by data analysis practitioners. An important part of the course is devoted to practical case studies on computers, using Jupiter notebooks. More specifically, we will study the categorization of images, semantic segmentation of images and speech recognition. Part of the evaluation will take the form of a Kaggle challenge.

Marché de l'énergie

The course introduces the principles of energy markets, particularly electricity and gas.

Finance de marché

This course provides an introduction to market finance. It covers the interest-rate market, the derivatives market, decision making and portfolio equilibrium models. A general overview of financial markets and how they work is given, and derivative assets are defined to provide a deeper insight into their management strategies.

Marché des taux

The aim of the course is to explain how risks associated with interest rates and derivative assets are managed. We study yield curves, zero-coupon rate calculations, bond pricing, CMS, etc.

Logiciels industriels

Introduction to Abaqus software and SAS statistical software
Finite element implementation
The aim of this course is to familiarize students with various scientific computing libraries for implementing finite element methods.

Systèmes satellitaires

Problems of flight dynamics in attitude and position of artificial satellites, associated open/closed loop control techniques. Mission analysis / orbit control : principle of positioning, maneuver optimization in Keplerian dynamics with analysis of orbital disturbances and impacts on orbit control.
Attitude control : modeling of satellite attitude dynamics, description of environmental disturbances, active and passive stabilization techniques, sensors and actuators, control laws and performance.

Modélisation en biologie

Systems biology can be defined as a branch of biology that takes an interdisciplinary approach to the study of complex biological phenomena.
By jointly exploiting increasingly numerous and accurate biological data on the one hand, and powerful modeling tools used in more traditional engineering sectors (statistical learning, deterministic or stochastic mechanistic modeling, control theory) on the other, systems biology has proved to be a tool of choice for elucidating the emergent properties of systems on scales as diverse as the cell, the tissue, even the organism, with fascinating and very important applications in biomedical research and synthetic biology.
In this course, we will illustrate the power of such a systems modeling approach on numerous examples: the modeling of metabolic reaction networks, intracellular signaling pathways, genetic regulation networks will be evoked, some model analysis tools will be presented and therapeutic applications (in cancerology in particular) will be mentioned.
No particular biology prerequisites are required to follow this course. Good knowledge of dynamic systems analysis and probability/statistics is desirable.

Modélisation géométrique

This course is an introduction to geometric modeling, i.e. the mathematical, numerical and computational tools that enable the creation of digital 3D objects for the purpose of designing, simulating and validating new industrial products and processes. The representation of 3D geometry using trimmed NURBS curves and surfaces will be the focus of this course. We'll be introducing parametrized curves and surfaces (NURBS curves and surfaces, product-tensor and triangular parametrizations) in their generality, as well as some special classes of widely-used surfaces such as Coons surfaces, ruled surfaces, involute surfaces and canal surfaces. Geometric computational problems on these models will also be covered, including intersection problems (implicit representation issues), distance computations, offsets, orthogonal projection, nearest point

computations, as well as problems of connection, geometric continuity, model tightness and repair. Finally, representations of geometry by mesh and subdivision surfaces will be discussed, as well as conversions between these different geometric representations.

Machine Learning for Image Analysis

This course focuses on the representation and enhancement of visual image quality. It introduces various tools for image analysis, such as frequency representations and the wavelet transform. Continuous and geometric representations are also studied. Finally, machine learning tools dedicated to image processing are analyzed, in particular SVM classification, clustering algorithms and dictionary learning.

Applied Artificial Intelligence

This course studies some major applications in the field of artificial intelligence. These include 3D scene analysis and reconstruction, biological imaging, new data in biology, biometric applications, forgery generation and detection with neural networks, and compression in the field of massive data.

Virtual Reality

This course provides an introduction to the animation of three-dimensional objects and, more generally, to the construction of three-dimensional environments. It also teaches students how to illuminate objects and modify their rendering. Numerous computer developments are used to put the theoretical concepts studied into practice.