

Année universitaire 2024/2025

Intelligence Artificielle, Systèmes, Données - 2e année de Master - Formation en apprentissage

Crédits ECTS : 60

LES OBJECTIFS DE LA FORMATION

Cette formation d'excellence offre de solides connaissances en mathématiques appliquées et conception de systèmes d'intelligence artificielle afin de couvrir l'ensemble des problématiques de traitement de données massives que rencontre les entreprises. Elle met l'accent sur l'articulation entre apprentissage automatique, gestion et fouille de grandes masses de données, paradigmes du Big Data, représentation des connaissances, le traitement des données et sur les méthodologies récemment développées.

Cette formation a pour objectifs d'acquérir les compétences :

- Former des informaticiens capables de maîtriser les problèmes conceptuels, sémantiques et algorithmique soulevés par l'intelligence artificielle et la science des données
- Développer une compréhension générale et en profondeur des différentes facettes de l'IA
- Former des étudiants disposant de solides connaissances théoriques ainsi qu'une bonne expérience pratique de l'Intelligence Artificielle et des Sciences des Données

PRÉ-REQUIS OBLIGATOIRES

- Titulaires d'un diplôme BAC+4 (240 crédits ECTS) ou équivalent à Dauphine, d'une université ou d'un autre établissement de l'enseignement supérieur dans les domaines suivants : informatique, mathématiques appliquées avec un attrait pour l'informatique et l'algorithme
- Etudiants en dernière année d'école d'ingénieur (ou ayant obtenu un diplôme d'ingénieur) en lien avec les thématiques de la formation

POURSUITE D'ÉTUDES

Les étudiants s'orientent vers des postes tels que :

Data Scientis, Concepteur/Développeur d'applications Big Data, Architecte bases de données complexes, Data Analyst, Gestionnaire de données massives, Ingénieur de recherche et développement.

PROGRAMME DE LA FORMATION

- Semestre 3
 - UE obligatoires
 - Fondamentaux de l'apprentissage automatique
 - Optimisation pour l'apprentissage automatique
 - Bases de données avancées (SBGD non classiques)
 - Apprentissage Profond
 - Systèmes, paradigmes et langages pour les Big Data
 - Ethique et science des données
 - Fouille de Graphes
 - Qualité des données

- Traitement automatique des langues - NLP
- Apprentissage par renforcement
- Semestre 4
 - UE obligatoires
 - Apprentissage profond pour l'analyse d'images
 - Flux de données
 - Recherche Monte-Carlo et Jeux
 - Visualisation de données
 - IA sur le Cloud
 - Projet Sciences des Données
 - Modélisation de problèmes
 - Machine Learning sur Big Data
- Semestre
 - UE obligatoires
 - Memoire

DESCRIPTION DE CHAQUE ENSEIGNEMENT

Apprentissage Profond

ECTS : 3

Description du contenu de l'enseignement :

This course is about using deep learning tools.

The objective of the course is to be able to design deep neural networks and to apply them to various problems. The language used for the course is Torch. It relies on the Lua scripting language augmented with tensor specific instructions. During the course, we will use simple examples to learn how to generate and transform data in Torch as well as how to learn from this data. We will cover deep neural networks, deep convolutional neural networks and some optimizations of the architecture such as residual nets.

Apprentissage par renforcement

ECTS : 3

Description du contenu de l'enseignement :

- Models: Markov decision processes (MDP), multiarmed bandits and other models
- Planning: finite and infinite horizon problems, the value function, Bellman equations, dynamic programming, value and policy iteration
- Basic learning tools: Monte Carlo methods, stochastic approximation, temporal-difference learning, policy gradient
- Probabilistic and statistical tools for RL: Bayesian approach, relative entropy and hypothesis testing, concentration inequalities
- Optimal exploration in multiarmed bandits: the explore vs exploit tradeoff, lower bounds, the UCB algorithm, Thompson sampling
- Extensions: Contextual bandits, optimal exploration for MDP

Compétence à acquérir :

Reinforcement Learning (RL) refers to scenarios where the learning algorithm operates in closed-loop, simultaneously using past data to adjust its decisions and taking actions that will influence future observations. Algorithms based on RL concepts are now commonly used in programmatic marketing on the web, robotics or in computer game playing. All models for RL share a common concern that in order to attain one's long-term optimality goals, it is necessary to reach a proper balance between exploration (discovery of yet uncertain behaviors) and exploitation (focusing on the actions that have produced the most relevant results so far).

The methods used in RL draw ideas from control, statistics and machine learning. This introductory course will provide the main methodological building blocks of RL, focussing on probabilistic methods in the case where both the set of possible

actions and the state space of the system are finite.

Bibliographie, lectures recommandées :

- [Reinforcement Learning: An Introduction, Richard S. Sutton & Andrew G. Barto](#), Second Edition, MIT Press, 2018
- [Bandit Algorithms, Tor Lattimore & Csaba Szepesvári](#), Cambridge University Press, 2020

Apprentissage profond pour l'analyse d'images

ECTS : 3

Description du contenu de l'enseignement :

Deep learning has achieved formidable results in the image analysis field in recent years, in many cases exceeding human performance. This success opens paths for new applications, entrepreneurship and research, while making the field very competitive.

This course aims at providing the students with the theoretical and practical basis for understanding and using deep learning for image analysis applications.

The course will be composed of lectures and practical sessions. Moreover, experts from industry will present practical applications of deep learning.

Lectures will include:

- Introduction to machine learning
- Artificial neural networks, back-propagation algorithm
- Convolutional neural network
- Design and optimization of a neural architecture
- Successful architectures (AlexNet, VGG, GoogLeNet, ResNet)
- Analysis of neural network function
- Image classification and segmentation
- Auto-encoders and generative networks
- Current research trends and perspectives

During the practical sessions, the students will code in Python, using Keras and Tensorflow. They will be confronted with the practical problems linked to deep learning: architecture design; optimization schemes and hyper-parameter selection; analysis of results.

Prerequisites: Linear algebra, basic probability and statistics

Bases de données avancées (SBGD non classiques)

ECTS : 3

Description du contenu de l'enseignement :

Le cours a pour objectif d'apprendre aux étudiants les aspects fondamentaux des différents types bases de données qu'elles soient basées sur le SQL, le NoSQL (Not Only SQL) ou récemment le NewSQL.

Le cours s'articule en trois parties.

Dans la première partie, l'accent est mis sur les bases de données relationnelles : leurs avantages et leurs inconvénients, ainsi que la correspondance objet-relationnel (Object-Relationnel Mapping -ORM) avec la norme JPA.

La deuxième partie présentera les différents modèles noSQL (clé-valeur, document, graphe), les notions de disponibilité et de partitionnement à la cohérence (propriétés BASE, théorème CAP), les différents systèmes NoSQL (MongoDB, Cassandra, CouchBase, ...), les avantages et les inconvénients du NoSQL.

La troisième partie sera consacrée aux bases NewSQL : leur définition et leurs caractéristiques, les nouvelles architectures et la notion de DBaaS (Database as a service), leurs avantages et leurs inconvénients.

Les notions apprises seront mises en pratique dans un projet où les étudiants devront manipuler différents types de bases de données afin de les comparer.

Ethique et science des données

ECTS : 1.5

Description du contenu de l'enseignement :

The course will be the occasion, for future data scientists, and for students in general, to question the benefits and risks of science.

The course will permit them to approach from a pragmatic viewpoint questions they may have to face some day, and issues such as the various facets of privacy, the fairness of automatic decisions, the transparency of algorithmic processes, their explainability.

Compétence à acquérir :

Les étudiants devront être capable de comprendre les principaux enjeux éthiques en matière de données et d'intelligence artificielle tout en ayant un aperçu des différentes obligations juridiques existantes et en cours de création à l'échelle de l'Union européenne

Flux de données

ECTS : 3

Description du contenu de l'enseignement :

Ce cours a pour objectif de décrire les principes des systèmes capables de traiter les grandes masses de données en temps réel ou en temps quasi-réel et d'expliquer les apports des architectures microservices dans ce contexte.

Ce cours est découpé en trois parties :

- Streaming des données : Présentation des différentes architectures et frameworks permettant de capturer, traiter, analyser et visualiser les données massives en temps réel
- Architectures microservices : Principes de découpage des systèmes en services simples, facilement couplés assurant l'agilité du système global ainsi que les technologies et les pratiques de développement associés seront traités dans cette partie du cours.
- Projet : Mise en pratique avec Java d'une application mettant en œuvre Spark Streaming et les microservices en REST.

Fondamentaux de l'apprentissage automatique

ECTS : 4.5

Description du contenu de l'enseignement :

The aim of this course is to provide the students with the fundamental concepts and tools for developing and analyzing machine learning algorithms.

The course will introduce the theoretical foundations of machine learning, review the most successful algorithms with their theoretical guarantees, and discuss their application in real world problems. The covered topics are:

- Introduction to the different paradigms of ML and applications
- Computational learning theory
 - PAC model
 - VC-dimension
 - Rademacher complexity,...
- Supervised learning
 - Logistic regression and beyond
 - Perceptron
 - SVM
 - Kernel methods
 - Decision trees and Random Forests
 - Ensemble methods: bagging and boosting
- Unsupervised learning
 - Dimensionality reduction: PCA, ICA, Random Projections, Kernel PCA, ISOMAP, LLE
 - Density estimation
 - EM
 - Spectral clustering
- Online learning
- Multiclass and ranking algorithms
- Practical sessions

Bibliographie, lectures recommandées :

References:

- Mohri, M., Rostamizadeh, A., & Talwalkar, A. (2012). Foundations of machine learning. MIT press.
- Shalev-Shwartz, S., & Ben-David, S. (2014). Understanding machine learning: From theory to algorithms. Cambridge university press.
- Vapnik, V. (2013). The nature of statistical learning theory. Springer science & business media.
- Bishop Ch. (2006). Pattern recognition and machine learning. Springer
- Friedman, J., Hastie, T., & Tibshirani, R. (2001). The elements of statistical learning (Vol. 1, No. 10). New York, NY, USA:: Springer series in statistics.
- James, G., Witten, D., Hastie, T., & Tibshirani, R. (2013). An introduction to statistical

Fouille de Graphes

ECTS : 3

Description du contenu de l'enseignement :

The objective of this course is to give students an overview of the field of graph mining and network science. Since graphs form a complex and expressive data type, we need methods for extracting information efficiently. Moreover, graph applications are very diverse and need specific algorithms.

The course presents new ways to model, mine and analyze graph-structured data and include many examples of applications. Lab sessions are included allowing students to practice graph mining and network science.

Outline of the course:

1. Centrality measures
2. Spectral graph theory and graph signal processing
3. Community detection
4. Machine learning and deep learning on graphs
5. Node classification and link prediction
6. Graph representation learning
7. Diffusion process and epidemics on networks

Compétence à acquérir :

1. Manipulate and create graphs using Python's NetworkX library
2. Master the centrality, community detection, classification and machine learning algorithms
3. Know how to use your knowledge in network science to solve problems arising in other domains (cloud points, image, audio files, ...)

IA sur le Cloud

ECTS : 3

Description du contenu de l'enseignement :

The main aim of this course is to present to students and give them the possibility to acquire knowledge about typical Cloud architectures to support all the phases of typical IA data processing:

Covered topics include data storage and preparation as well as deployment and execution of machine learning algorithms. A particular attention will be given to the typical cloud architectures and the way they can ensure optimal data processing in IA pipelines, by taking into account the monetary cost of resources among other traditional parameters.

Machine Learning sur Big Data

ECTS : 3

Description du contenu de l'enseignement :

This course focuses on the typical, fundamental aspects that need to be dealt with in the design of machine learning algorithms that can be executed in a distributed fashion, on Hadoop clusters, in order to deal with big data sets, by taking into account scalability and robustness.

Machine learning algorithms are more and more used today, and there is an ever increasing demand of machine learning algorithms that scales over massive data sets.

This course focuses on the typical, fundamental aspects that need to be dealt with in the design of machine learning algorithms that can be executed in a distributed fashion, on Hadoop clusters, in order to deal with big data sets, by taking into account scalability and robustness. So the course will focus on a bunch of main-stream, sequential machine learning algorithms, by taking into account the following crucial and complex aspects. The first one is the re-design of algorithms by relying on programming paradigms for distribution and parallelism based on map-reduce, to this end Spark will be used. The second aspect is experimental analysis of the Spark implementation of designed algorithms in order to test their scalability and precision. The third aspect concerns the study and application of optimisation techniques in order to overcome lack of scalability and to improve execution time of designed algorithm.

The attention will be on machine learning technique for dimension reduction, clustering and classification, whose underlying implementation techniques are transversal and find application in a wide range of machine learning algorithms. For some of the studied algorithms, the course will present techniques for a from-scratch implementation in Spark core, while for other algorithms Spark ML will be used and end-to-end pipelines will be designed. In both cases algorithms will be analysed and optimised on real life data sets, by relying on a local Hadoop cluster, as well as on a cluster on the Amazon WS cloud.

Bibliographie, lectures recommandées :

References:

- Mining of Massive Datasets

<http://www.mmds.org>

- High Performance Spark - Best Practices for Scaling and Optimizing Apache Spark

Holden Karau, Rachel Warren

O'Reilly

Memoire

ECTS : 6

Modélisation de problèmes

ECTS : 3

Optimisation pour l'apprentissage automatique

ECTS : 3

Description du contenu de l'enseignement :

Optimization is at the heart of most recent advances in machine learning. Indeed, it not only plays a major role in linear regression, SVM and kernel methods, but it is also the key to the recent explosion of deep learning for supervised and unsupervised problems in imaging, vision and natural language processing. This course will review the mathematical foundations, the underlying algorithmic methods and showcase modern applications of a broad range of optimization techniques.

The course consists of several lectures with numerical illustrations in Python. It will begin with the basic components of smooth optimization (optimality conditions, gradient-type methods), then move to methods that are particularly relevant in a machine learning setting such as the celebrated stochastic gradient descent algorithm and its variants. More advanced algorithms related to non-smooth and constrained optimization, that encompass known characteristics of learning problems such as the presence of regularizing terms, will also be described. The various algorithms studied during the lectures will be tested on real and synthetic datasets: these sessions will also address several practical features of optimization codes such as automatic differentiation, and built-in optimization routines within popular machine learning libraries such as PyTorch.

Compétence à acquérir :

- Identify the characteristics of an optimization problem given its formulation.
- Know the theoretical and practical properties of the most popular optimization techniques.
- Find the best optimization algorithm to handle a particular feature of a machine learning problem.

Mode de contrôle des connaissances :

Written exam+Course project.

Bibliographie, lectures recommandées :

L. Bottou, F. E. Curtis, and J. Nocedal. *Optimization Methods for Large-Scale Machine Learning*, 2018.

J. Wright and Y. Ma, *High-Dimensional Data Analysis with Low-Dimensional Models*, 2022.

S. J. Wright and B. Recht. *Optimization for Data Analysis*, 2022.

Projet Sciences des Données

ECTS : 3

Description du contenu de l'enseignement :

The goal of this module is to provide students with a hands-on experience on a novel data-science/AI challenge using state-of-the-art tools and techniques discussed during other classes of this master.

Students enrolled in this class will form groups and choose one topic among a list of proposed topics in the core areas of the master such as supervised or unsupervised learning, recommendation, game AI, distributed or parallel data-science, etc. The topics will generally consist in applying a well-established technique on a novel data-science challenge or in applying recent research results on a classical data-science challenge. Either way, each topic will come with its own novel scientific challenge to address. At the end of the module, the students will give an oral presentation to demonstrate their methodology and their findings. Strong scientific rigor as well as very good engineering and communication skills will be necessary to complete this module successfully.

Qualité des données

ECTS : 3

Description du contenu de l'enseignement :

Ce cours a pour objectif d'enseigner une méthodologie pour diagnostiquer et corriger les problèmes dus à la non qualité des données, mettre en œuvre une démarche qualité des données et mesurer ses effets. Il donne également un aperçu des outils existants et de leur utilisation.

Les différentes sources de données et leur exploitation. Mesure de la qualité des données et principales méthodes existantes. Cout de la qualité. Méthodes d'identification et de correction des données suivant leur type (manquantes, aberrantes, erronées, ...). Indicateurs et suivi qualité des données. Amélioration de la qualité des données. Les outils logiciels et la qualité des données.

Recherche Monte-Carlo et Jeux

ECTS : 3

Description du contenu de l'enseignement :

Ce cours est une introduction aux méthodes dites de Monte-Carlo. Ces méthodes sont utilisées pour calculer des espérances, et par extension, des intégrales par simulation. L'objectif de ce cours est non seulement de fournir les bases théoriques des méthodes de Monte-Carlo, mais aussi de fournir les outils permettant leur utilisation pratique à travers des TP.

Le cours couvre les sujets suivants :

- introduction de la méthode de Monte-Carlo
 - techniques de réduction de variance
 - introduction aux suites à discrétion faible
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Systèmes, paradigmes et langages pour les Big Data

ECTS : 3

Description du contenu de l'enseignement :

The main aim of this course is to give students a deep and solid understanding of the state of the art of Big Data systems and programming paradigms, and to enable them to devise and implement efficient algorithms for analysing massive data sets.

The focus will be on paradigms based on distribution and shared-nothing parallelism, which are crucial to enable the implementation of algorithms that can be run on clusters of computers, scale as the size of input data increases, and can be safely executed even in the presence of system failures.

Lectures will give particular emphasis to the MapReduce paradigm and the internal aspects of its related runtime support Hadoop, as well as to MapReduce-based systems, including Spark and Hive, that provide users with powerful programming

tools and efficient execution support for performing operations related to complex data flows. The attention will be then given to mechanisms and algorithms for both iterative and interactive data processing in Spark. A particular attention will be given to SQL-like data querying, graph analysis, and the development of machine learning algorithms.

A large part of the course consists of lab-sessions where students develop parallel algorithms for data querying and analysis, including algorithms for relational database operators, matrix operations, graph analysis, and clustering. Lab-sessions rely on the use of both desktop computers and Hadoop clusters on the Amazon WS cloud.

Program:

1. Introduction to massive data management and processing.
2. A data operating system for distributed data management, Hadoop.
3. MapReduce paradigm, algorithm design, implementation and optimisation.
4. iterative and interactive massive data processing, algorithm design, implementation and optimisation in Spark
5. large scale data-warehouse in Hive

References:

Mining of Massive Datasets.

Jure Leskovec, Anand Rajaraman, Jeff Ullman

<http://www.mmms.org/#top>

Data-Intensive Text Processing with MapReduce.

Jimmy Lin and Chris Dyer.

Mogan & Claypool Publishers

Hadoop: The Definitive Guide - Tom White.

O'Reilly.

Apache Hadoop Yarn - Arun C.Murty, Vinod Kumar Vavilapalli, et al.

Addison Wesley

Programming Hive.

Edward Capriolo, Dean Wampler, Jason Rutherglen.

O'Reilly.

Big Data Analytics with Spark.

Traitement automatique des langues - NLP

ECTS : 3

Visualisation de données

ECTS : 3

Description du contenu de l'enseignement :

Ce cours a pour objectif de décrire les démarches, méthodes et outils utilisés pour représenter les données complexes et multiples issues des grandes masses de données en visuels simples à comprendre et à interpréter, notamment pour les utilisateurs métier et pour les décideurs.

Le cas de l'apport de la visualisation des données sous différentes formes graphiques lors de la préparation des données en amont de la modélisation et de l'utilisation des modèles et algorithmes de Machine Learning sera développé.

Le cours s'appuie sur de nombreux exemples puisés dans les domaines de la finance, de la santé, du marketing et des travaux pratiques sur des cas concrets sont également prévus.
