Année universitaire 2025/2026

Mathématiques de l'Assurance de l'Economie et de la Finance - 2e année de Master

Responsables pédagogiques :

- GUILLAUME **CARLIER** - https://dauphine.psl.eu/recherche/cvtheque/carlier-guillaume
- JULIEN **CLAISSE** - https://dauphine.psl.eu/recherche/cvtheque/claisse-julien

Crédits ECTS : 60

LES OBJECTIFS DE LA FORMATION

La **2e année du Master Mathématiques et Applications parcoursMathématiques de l'Assurance, de l'Economie et de la Finance (MASEF)** forme des mathématiciens probabilistes de haut niveau aux techniques mathématiques utilisées en gestion des risques et en économie. L'équilibre entre les cours fondamentaux et les cours à vocation plus appliquée assure aux étudiantes et étudiants une formation leur permettant selon leur choix d'options de s'orienter vers la recherche académique ou vers des postes à forte composante quantitative dans l'industrie. Les principaux débouchés sont les banques mais également les secteurs nécessitant des compétences rares en matière d'optimisation en environnement aléatoire et/ou incertain (industrie de l'énergie, enchères sur le web, etc.)

Les objectifs de la formation :

- Maitriser les fondamentaux de l'optimisation, de la décision et de la couverture de risques en environnement incertain avec ou sans interactions ;
- Maitriser des outils numériques et statistiques, dont les techniques d'apprentissage automatique ;
- Maitriser des techniques de finance quantitative avancées ;
- Acquérir du recul nécessaire à s'adapter aux évolutions, que ce soit dans le domaine de la recherche ou de l'industrie.

MODALITÉS D'ENSEIGNEMENT

Les Modalités des Contrôles de Connaissances (MCC) détaillées sont communiquées en début d'année. Les enseignements de la deuxième année de Master mention Mathématiques et Applications pour le parcours Mathématiques de l'Assurance, de l'Économie et de la Finance (MASEF) sont organisés en semestres 3 et 4. Le semestre 3 est constitué d'UE fondamentales et d'UE optionnelles et le semestre 4 est constitué d'un stage, d'une UE fondamentale et d'UE optionnelles parmi trois blocs thématiques :

- Apprentissage pour l'économie et la finance ;
- Finance et gestion des risques ;
- Économie et jeux.

La formation démarre en septembre, la présence en cours est obligatoire.

ADMISSIONS

Titulaires d'un diplôme BAC+4 (240 crédits ECTS) ou équivalent à Dauphine, d'une université, d'une grande école ou d'un autre établissement de l'enseignement supérieur dans les domaines suivants : mathématiques pures, mathématiques Appliquées.

POURSUITE D'ÉTUDES

La majorité des étudiantes et des étudiants trouve un poste à fort contenu quantitatif dans les banques, fonds d'investissement, brokers, compagnies d'assurance, sociétés de service en finance de marché (quant, structuration, trading, gestion quantitative de portefeuille).

La formation prépare naturellement, selon les options choisies, à une thèse de doctorat en finance mathématique, assurance, économie mathématique, mais également en probabilités numérique. Chaque année, deux à cinq étudiant(e)s poursuivent la spécialité par une thèse de doctorat, soit purement académique (thèse classique) soit en partenariat avec une cellule de recherche d'une entreprise privée (thèse Cifre)

Les thèses classiques sont en général effectuées au Ceremade ou au Crest et sont encadrées par l'école doctorale EDDIMO de Dauphine. Elles peuvent également être effectuées dans d'autres établissements (Université Paris 6, Paris 7, Ecole Polytechnique par exemple).

Débouchés : Analyste quantitatif, Chargé de modélisation, Consultant en Finance, Contrôleur des risques, Trading assistant, Valuation Analyst, ect.

PROGRAMME DE LA FORMATION

- Semestre 3 - 30 ECTS
  - Cours introductifs
    - A review of probability theory foundations
  - UE fondamentales
    - Monte Carlo and Finite Differences Methods with Applications to Finance
    - Stochastic Calculus
    - Stochastic Control
  - UE optionnelles (minimum 12 ECTS à valider)
    - Computational statistics and Markov chain Monte Carlo methods
    - Continuous Optimization
    - Derivative products in finance and insurance
    - Game theory, applications in economics and finance
    - Finance haute fréquence : outils probabilistes, modélisation statistique à travers les échelles et problèmes de trading
    - Machine Learning in finance
    - Term structures: interest rates, commodities and other assets
    - Valuation of financial assets and arbitrage
- Semestre 4 - 30 ECTS
  - UE fondamentales
    - Cycle of conferences: strategies and actors of portfolio management
  - Bloc 1 : Apprentissage pour l'économie et la finance
    - Python/Pytorch project
    - Reinforcement learning
  - Bloc 2 : Finance et gestion des risques
    - Contrôle stochastique et marchés de l'énergie
    - Gestion globale des risques : VAR
    - Microstructure des marchés financiers
    - Modélisation stochastique de la courbe de taux
  - Bloc 3 : Economie et jeux
    - Mean field games theory
    - Variational problems and optimal transport
  - Projet individuel
    - Mémoire de fin d'études

DESCRIPTION DE CHAQUE ENSEIGNEMENT

SEMESTRE 3 - 30 ECTS

Cours introductifs

A review of probability theory foundations

Langue du cours : Anglais

Volume horaire : 15

Description du contenu de l'enseignement :

Outline : 1. Basics of measure theory and integration 2. Probability : random variables, independence 3. Convergence of random variables 4. Law of Large Numbers and Central Limit Theorem 5. Conditional expectations 6. Martingales in discrete time 7. Gaussian vectors 8. Brownian motion : definition, existence, first properties

Compétences à acquérir :

The aim of this class is to provide a quick review of the probability theory that is required to follow the 1st semester classes in MATH and MASEF. Most of the content should already be familiar to students with a M1 in Mathematics.

UE fondamentales

Monte Carlo and Finite Differences Methods with Applications to Finance

ECTS : 6

Enseignant responsable : YATING **LIU** (https://dauphine.psl.eu/recherche/cvtheque/liu-yating)

Langue du cours : Anglais

Volume horaire : 30

Description du contenu de l'enseignement :

Chapter 1. Foundations of Monte-Carlo

- Principle of Monte Carlo Methods
- Random Number Generation
- Inverse Transform Method
- Acceptance-Rejection Method
- Gaussian Distribution

Chapter 2. Variance Reduction Techniques

- Antithetic variable
- Control Variates
- Importance Sampling

Chapter 3. Simulation of Diffusion Processes

- Exact Simulation(Brownian Motion and Black–Scholes Model)
- Euler Scheme (Construction, Strong and week error)

Chapter 4. Brownian Bridge Approach

- Brownian Bridge
- Exit Times and Barrier Options (Naive approach and Brownian Bridge Approach)

Chapter 5. Computation of Sensitivities (Greeks in finance)

- Finite Differences
- Black–Scholes Model
- Pathwise Differentiation
- Malliavin Differentiation

Chapter 6. American Options

- Discretization
- Naive Approach
- Regression Methods

Chapter 7. Finite Difference Method for Linear PDE

- Construction (Space Discretization, Time Discretization)
- Convergence (Consistency, Stability, Convergence)

Chapter 8. Finite Difference Method for Non-Linear PDE

- Non–Linear PDE
- The Linear Case Revisited
- Variational Inequality
- Hamilton–Jacobi–Bellman Equation

Compétences à acquérir :

This course provides an in-depth presentation of the main techniques for the evaluating of options using Monte Carlo techniques.

Stochastic Calculus

ECTS : 6

Enseignants : CLEMENT **COSCO**, MARC **HOFFMANN**
https://dauphine.psl.eu/recherche/cvtheque/cosco-clement
https://dauphine.psl.eu/recherche/cvtheque/hoffmann-marc

Langue du cours : Anglais

Volume horaire : 48

Description du contenu de l'enseignement :

The course consists of four parts, each occupying roughly 6 hours:

- Preliminaries (Gaussian processes, Brownian motion, martingales, local martingales, variation, quadratic variation)
- Stochastic integration (Isometry extension, Wiener integral, Ito integral, martingale property)
- Stochastic differentiation (Itô processes, Itô's Formula, Girsanov's Theorem)
- Stochastic differential equations (existence and uniqueness, Markov property, generator, connections with PDEs).

Compétences à acquérir :

This course is a practical introduction to the theory of stochastic calculus, with an emphasis on examples and applications rather than abstract subtleties. Click here for more information

Pré-requis recommandés

Probability theory foundations

Mode de contrôle des connaissances :

Final written exam, in class.

Bibliographie, lectures recommandées :

Click here for more information

En savoir plus sur le cours :https://www.ceremade.dauphine.fr/~salez/stoc.html

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Stochastic Control

ECTS : 6

Enseignant responsable : PHILIPPE **BERGAULT** (https://dauphine.psl.eu/recherche/cvtheque/bergault-philippe)

Langue du cours : Anglais

Volume horaire : 24

Description du contenu de l'enseignement :

Relationship between conditional expectations and parabolic linear PDEs. Formulation of standard stochastic control problems: dynamic programming principle. Hamilton-Jacobi-Bellman equation Verification approach Viscosity solutions (definitions, existence, comparison) Application to portfolio management, optimal shutdown and switching problems Teacher : Bruno BOUCHARD

Compétences à acquérir :

PDEs and stochastic control problems naturally arise in risk control, option pricing, calibration, portfolio management, optimal book liquidation, etc. The aim of this course is to study the associated techniques, in particular to present the notion of viscosity solutions for PDEs.

UE optionnelles (minimum 12 ECTS à valider)

Computational statistics and Markov chain Monte Carlo methods

ECTS : 6

Enseignant responsable : CHRISTIAN **ROBERT** (https://dauphine.psl.eu/recherche/cvtheque/robert-christian-p)

Langue du cours : Anglais

Volume horaire : 21

Description du contenu de l'enseignement :

Motivations Monte-Carlo Methods Markov Chain Reminders The Metropolis-Hastings method The Gibbs Sampler Perfect sampling Sequential Monte-Carlo methods

Compétences à acquérir :

This course aims at presenting the basics and recent developments of simulation methods used in statistics and especially in Bayesian statistics. Methods of computation, maximization and high-dimensional integration have indeed become necessary to deal with the complex models envisaged in the user disciplines of statistics, such as econometrics, finance, genetics, ecology or epidemiology (among others!). The main innovation of the last ten years is the introduction of Markovian techniques for the approximation of probability laws (and the corresponding integrals). It thus forms the central part of the course, but we will also deal with particle systems and stochastic optimization methods such as simulated annealing.

Continuous Optimization

ECTS : 6

Enseignant responsable : ANTONIN **CHAMBOLLE** (https://dauphine.psl.eu/recherche/cvtheque/chambolle-antonin)

Langue du cours : Anglais

Volume horaire : 24

Description du contenu de l'enseignement :

This course will review the mathematical foundations of convex/continuous (iterative) optimization methods. We will focus on the theory and mathematical analysis of a few algorithmic methods and showcases some modern applications of a broad range of optimization techniques. The course will be composed of classical lectures and one numerical session in Python. The first part covers the basic methods of smooth optimization (gradient descent) and convex optimization (optimality condition, constrained optimization, duality) with some general approach (monotone operators) and a focus on convergence rates. We will then address more advanced methods (non-smooth optimization and proximal methods, stochastic gradient descent).

Compétences à acquérir :

The objective of this course is to introduce the students to classical and modern methods for the optimization of (mostly convex) objectives, possibly nonsmooth or high dimensional. These arise in areas such as learning, finance or signal processing.

Mode de contrôle des connaissances :

Examen écrit

Bibliographie, lectures recommandées :

Exemples de livres généraux sur l'optimisation (souvent convexe) couvrant des aspects à la fois théoriques (complexité) et pratique (implémentations): Boris Polyak: Introduction to optimization, (1987). J.-B. Hiriart-Urruty and C. Lemarechal, Convex Analysis and Minimization Algorithms (1993). Yurii Nesterov: Introductory lectures on convex optimization, 2004 / Lectures on convex optimization 2018 Jorge Nocedal and Stephen J. Wright: Numerical Optimization, 2006. Dimitri Bertsekas: Convex Optimization Algorithms. Athena Scientific 2015. Amir Beck: First-Order Methods In Optimization, 2019. R. Tyrell Rockafellar: Convex analysis, 1970 (1997). H. Bauschke and P.L. Combettes: Convex analysis and monotone operator theory in Hilbert spaces (Springer 2011) Ivar Ekeland and Roger Temam: Convex analysis and variational problems, 1999. Juan Peypouquet: Convex Optimization in Normed Spaces, 2015

Derivative products in finance and insurance

ECTS : 6

Enseignant responsable : AYMERIC **KALIFE** (https://dauphine.psl.eu/recherche/cvtheque/kalife-aymeric-1)

Langue du cours : Anglais

Volume horaire : 21

Description du contenu de l'enseignement :

Participants will lear how financial institutions can build and structured products, how they value and hedge them, and what they are done for.

Compétences à acquérir :

The aim of this lecture is to train students in the practical evaluation of derivative products and the control of the associated risks. It also introduces them to the new hybrid structured products that have recently appeared in insurance.

Game theory, applications in economics and finance

ECTS : 6

Enseignant responsable : YANNICK **VIOSSAT** (https://dauphine.psl.eu/recherche/cvtheque/viossat-yannick)

Langue du cours : Anglais

Volume horaire : 18

Description du contenu de l'enseignement :

A - Basics of game theory:
1. Zero-sum games: value, optimal strategies, minmax theorem.
2. N-players normal form games: dominated strategies, best-replies, Nash equilibria, Nash’s existence theorem.
3. Extensive form: backward induction, subgame perfection, Kuhn-Zermelo theorem, behavior strategies and Kuhn’s theorem.

B- Applications and advanced topics (at most four of the following topics will be discussed, possibly less):

1. Repeated games, folk theorems, evolution of cooperation.
2. Correlated equilibria
3. Information cascades
4. Agreeing to disagree and no-trade theorems
5. Asymmetric information and market failures
6. Cooperative games : core, Shapley value
7. Evolutionary and learning in games
8. Games with incomplete information, applications to finance.
9. Experimental and behavioral economics

Compétences à acquérir :

The first part deals with game theory basics, the second one with applications in economics and finance or more advanced topics. The time spent on the basics and the choice of topics for the second part will depend on the familiarity of students with game theory, and of their thematic interests. The course is planned in English but may be taught in French if all students prefer so.

Pré-requis recommandés

A familiarity with game theory is of course preferable, but the course is accessible to students who never studied game theory before

Finance haute fréquence : outils probabilistes, modélisation statistique à travers les échelles et problèmes de trading

ECTS : 6

Enseignant responsable : MATHIEU **ROSENBAUM** (https://dauphine.psl.eu/recherche/cvtheque/rosenbaum-mathieu)

Langue du cours : Français

Volume horaire : 28

Machine Learning in finance

ECTS : 6

Enseignant responsable : PIERRE **BRUGIERE** (https://sites.google.com/view/pierrebrugiere/home)

Langue du cours : Anglais

Volume horaire : 21

Description du contenu de l'enseignement :

- Introduction to statistical learning: The Vapnik Chervonenkis dimension, PAC learning and the calibration versus prediction paradigm.
- Primal and Dual Problem, Lagrangian and KKT conditions
- Supervised learning: SVM, Mercer's theorem and the kernel trick, C-SVMs, mu-SVMs, a few words on SVMs for regressions.
- Unsupervised learning: Single class SVMs, clustering, anomaly detection, equivalence of different approaches via duality.
- Introduction to random forests and ensemble methods: bias variance trade-off, bootstrap method
- Remarks on parsimony and penalisation: Ridge and Lasso regressions, dual interpretation of Lasso.

Compétences à acquérir :

Some Statistical Learning results are presented and applied to credit rating, anomalies detection and yield curves modelling. The principal notions are presented in the context of these case studies in finance.

Pré-requis obligatoires

Linear algebra, optimisation, differential calculus

Pré-requis recommandés

Linear algebra, optimisation, differential calculus

Mode de contrôle des connaissances :

Final exam

Bibliographie, lectures recommandées :

[1] James, Hastie, Witten, Tibshirani, Taylor; An introduction to Statistical Learning: file: https://hastie.su.domains/ISLP/ISLP_website.pdf.download.html

[2] A Burkov; The hundred-pages machine learning book : chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/http://ema.cri-info.cm/wp-content/uploads/2019/07/2019BurkovTheHundred-pageMachineLearning.pdf

Term structures: interest rates, commodities and other assets

ECTS : 6

Enseignant responsable : DELPHINE **LAUTIER** (https://sites.google.com/site/delphinelautierpageweb/)

Langue du cours : Anglais

Volume horaire : 21

Description du contenu de l'enseignement :

The term structure is defined as the relationship between the spot price and the futures prices of a derivative instrument, for any delivery date. It provides useful information for hedging, arbitrage, investment and evaluation: it indeed synthesizes the information available in the market and the operators' expectations concerning the future price of the underlying asset.

In many derivative markets, especially in interest rates and in commodity markets, the concept of term structure is very important, because the contract's maturity increases as the markets come to fruition. In US 3 months interest rate futures market, for example, the maturities reach 10 years. In this course, the commodity markets are often taken as an example, to help understanding. Extensions to other assets will be done, as often as possible.

Chapter 1 presents a general introduction to derivatives today.

Chapter 2 examines the traditional theories of commodity prices and the explanation of the relationships between spot and futures prices. It proposes an empirical review of the results obtained through these frameworks and explains why these theories are still investigated today. It finally shows how to apply these theories to other assets: exchange rates and interest rates.

The traditional theories are however a bit limited when the whole term structure is considered. As a result, there is a need for a long-term extension of the analysis, which is the very subject of the Chapter 3. We first present a dynamic analysis of the term structure. Then the focus turns towards term structure models. The examples rely on the case commodity prices but can be extended to interest rates. Simulations highlight the influence of the assumptions concerning the stochastic process retained for the state variables and the number of state variables. We then explain the econometric method usually employed for the estimation of the parameters. In the presence of non-observable variables, there is a need for filtering techniques. We present the method of the Kalman filters. Finally, we study two main applications, i.e. dynamic hedging and investment valuation.

Chapter 4 is devoted to the study of structural models, ie micro-founded equilibrium models that also examine the interactions between the physical and the derivative markets. In this situation the spot price becomes endogenous. The interactions between prices are studied thanks to rational expectations equilibriums.

Compétences à acquérir :

At the end of this course, the students must have a broad knowledge about the term structures of derivative prices: the theories, the valuation methods, the econometric techniques, the empirical tests as well as the applications.

They will also be trained to use their knowledge on this topic in order to develop a critical view on recent research articles.

This course is optionnal for the MASEF's students.

Mode de contrôle des connaissances :

Ongoing assessment, 20%

Final exam, 80%.

Bibliographie, lectures recommandées :

- Danthine J.P., Donaldson J.B., Intermediate Financial Theory, 2d Ed., Elsevier, 2005.

- Hull J., Options, futures and other derivatives, 15th Ed.

- Kolb R.W. , Overdahl J.A. , Futures, options, and swaps, 5th Ed., Blackwell, 2007.

- Williams J., The economic function of futures markets, Cambridge University Press, 1986

- Wilmott P., Paul Wilmott on Quantitative Finance, 3-volume set, 2nd Ed., Wiley, 2006.

En savoir plus sur le cours :https://sites.google.com/site/delphinelautierpageweb/

Valuation of financial assets and arbitrage

ECTS : 6

Enseignants : PHILIPPE **BERGAULT**, JULIEN **CLAISSE**
https://dauphine.psl.eu/recherche/cvtheque/bergault-philippe
https://dauphine.psl.eu/recherche/cvtheque/claisse-julien

Langue du cours : Anglais

Volume horaire : 30

Description du contenu de l'enseignement :

Course outline:

I. Discrete time modelling

I.1. Financial assets

I.2. The No arbitrage condition and martingale measures (FTAP)

I.3. Pricing and hedging of European options; market completeness and 2nd FTAP

I.4. Pricing and hedging of American options (in a complete market)

II. Continuous time modelling

II.1. Financial assets as Itô processes : general theory

II.2. Markovian models : PDE pricing, delta-hedging (European options, barrier options, American options)

II.3. Local volatility models and Dupire's formula

II.4. Stochastic volatility models : how to deal with market incompleteness; (semi-)static hedging; specific models and their properties

Compétences à acquérir :

The lecture starts with discrete time models which can be viewed as a proxy for continuous settings, and for which we present in detail the theory of arbitrage pricing. We then develop on the theory of continuous time models. We start with a general Itô-type framework and then specialize to different situations: Markovian models, local and stochastic volatility models. For each of them, we discuss the valuation and the hedging of different types of options : plain Vanilla and barrier options, American options, options on realized variance, etc. Finally, we present several specific volatility models (Heston, CEV, SABR,...) and discuss their specificities.

Bibliographie, lectures recommandées :

Bouchard B. et Chassagneux J.F., Fundamentals and advanced Techniques in derivatives hedging, Springer, 2016.
Lamberton D. et B. Lapeyre, Introduction au calcul stochastique appliqué à la finance, Ellipses, Paris, 1999.

SEMESTRE 4 - 30 ECTS

UE fondamentales

Cycle of conferences: strategies and actors of portfolio management

ECTS : 2

Enseignant responsable : PHILIPPE **BERGAULT** (https://dauphine.psl.eu/recherche/cvtheque/bergault-philippe)

Langue du cours : Anglais

Volume horaire : 12

Bloc 1 : Apprentissage pour l'économie et la finance

Python/Pytorch project

ECTS : 6

Enseignant responsable : JULIEN **CLAISSE** (https://dauphine.psl.eu/recherche/cvtheque/claisse-julien)

Langue du cours : Anglais

Volume horaire : 15

Description du contenu de l'enseignement :

Course Presentation

Neural Networks for Stochastic Modeling explores how deep learning techniques can be used to analyze and estimate stochastic processes. The course introduces statistical learning fundamentals, then focuses on neural network architectures and training procedures. Finally, we apply these methods to estimate stochastic differential models through both theoretical analysis and hands-on implementation.

Course Outline

Chapter 1 — Statistical Learning Foundations & Neural Network Structure

- Supervised vs. unsupervised learning; regression vs. classification
- Pipeline of supervised learning and model evaluation
- Feedforward neural network architecture & activation functions
- Universal Approximation Theorem

Chapter 2 — Training Neural Networks

- Loss functions and optimization objectives
- Gradient-based optimization, backpropagation, SGD, Adam
- Hyperparameter selection and training heuristics

Chapter 3 — Parametric Estimation of Stochastic Processes

- Simulation and data generation for SDEs
- Neural estimation of unknown parameters from sample paths

Chapter 4 — Non-Parametric Estimation of Stochastic Processes

- Neural approximation of drift functions
- Performance evaluation against classical methods
- Optional outlook: diffusion models and generative approaches

Compétences à acquérir :

- Understand key principles of statistical learning and neural networks.
- Train feedforward networks using gradient-based methods and hyperparameter tuning.
- Generate data from stochastic differential equations for learning tasks.
- Estimate parameters and drift functions of stochastic processes with neural networks.
- Evaluate neural estimators and compare them to classical statistical methods.

Mode de contrôle des connaissances :

Project (Report + code + oral defense)

Reinforcement learning

ECTS : 6

Enseignant responsable : ANA **BUSIC** (https://www.di.ens.fr/~busic/)

Langue du cours : Français

Volume horaire : 24

Description du contenu de l'enseignement :

Outline:

- Introduction to reinforcement learning (RL) and Markov decision processes (MDP)
- Algorithms for MDPs: dynamic programming, value iteration, policy iteration, linear programming
- Multi armed bandits: exploration vs. exploitation, stochastic bandits, adversarial bandits

- Value-based RL: general ideas and basic algorithms (TD-learning, SARSA, Q-learning)
- Function approximation: linear function approximation, deep neural networks and DQN
- Policy-based and actor-critic RL: policy gradient, natural policy gradient, actor-critic algorithms
- Bandits and RL: regret bounds and UCRL algorithm
- Decentralized MDPs and multi-agent RL: complexity results, simple algorithms (e.g. idependent learners) and their applications (e.g. EV charging, wind farm control)

Organization of lectures in two parts (with 15min break):

- First part: lecture covering main notions
- Second part: more advanced material and/or exercises

Compétences 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. RL algorithms combine ideas from control, machine learning, statistics, and operations research. A common tread of all RL algorithms is the need to balance exploration (trying knew things) and exploitation (choosing the most successful actions so far). This course will introduce the main models (multi-armed bandits and Markov decision processes) and key ideas for algorithm design (e.g. model-based vs. model-free RL, value based vs. policy based algorithms, on-policy vs. off-policy learning, function approximation).

Pré-requis obligatoires

Basic notions in linear algebra and probability theory; Python

Mode de contrôle des connaissances :

Homework assignments and project

Bibliographie, lectures recommandées :

Books MDPs:

- Martin L. Puterman. Markov decision processes: discrete stochastic dynamic programming. John Wiley & Sons. 2014.
- Dimitri P. Bertsekas. Dynamic Programming and Optimal Control, Vol I, 4th Edition, Athena Scientific. 2017.
- Dimitri P. Bertsekas. Dynamic Programming and Optimal Control: Approximate Dynamic Programming , Vol II, 4th Edition, Athena Scientific. 2012.

Books RL:

- Richard S. Sutton and Andrew G. Barto. Reinforcement Learning: An Introduction. Second Edition. MIT Press, Cambridge, MA, 2018.
- Csaba Szepesvari. Algorithms for Reinforcement Learning. Morgan & Claypool Publishers. 2009.
- Sean Meyn. Control Systems and Reinforcement Learning. Cambridge University Press. 2022.

Bandit algorithms:

- Tor Lattimore and Csaba Szepesvari. Bandit algorithms. Cambridge University Press. 2020.

Implementation:

- Gymnasium
- Stable Baselines (reliable implementations of RL algorithms)
- PettingZoo
- SustainGym (A suite of environments designed to test the performance of RL algorithms on realistic sustainability tasks)

En savoir plus sur le cours :https://www.di.ens.fr/~busic/teaching/M2RL/" target="_blank">https://www.di.ens.fr/~busic/teaching/M2RL/

Bloc 2 : Finance et gestion des risques

Contrôle stochastique et marchés de l'énergie

ECTS : 6

Enseignant responsable : RENE **AID** (https://dauphine.psl.eu/recherche/cvtheque/aid-rene)

Langue du cours : Français

Volume horaire : 15

Compétences à acquérir :

Energy markets are a natural field of applications for stochastic control modelling framework. Historical applications go from water management to the pricing of swing and demand-side contracts. With the deregulation of electricity and gas markets, new applications have raised the attention of financial economists. In particular, the question of the optimal investment in generation assets in the context of climate change and the questions linked to retail competition. These domains are conducive to the utilization of stochastic differential games. This course is intended to provide a short introduction to the physics of energy market and extensive applications taken for financial and economical research papers. For their evaluation, students are expected to realize a study of a research paper for which they will provide a critical analysis of their understanding of the model, together with the reproduction of the results of the paper.

Gestion globale des risques : VAR

ECTS : 6

Enseignant responsable : EMMANUEL **LEPINETTE** (https://sites.google.com/view/emmanuel-lepinette/research-cv-and-others)

Langue du cours : Français

Volume horaire : 21

Description du contenu de l'enseignement :

Mesures de risque et régulation (Solvency, Bale): exemple de calculs. Modèles dynamiques pour les prix d'actifs financiers. Agrégation des risques de manière très générale, c'est à dire pour différents types de risque sur des exemples, aussi bien en assurance qu'en finance. Risques des produits dérivés également. Modèles multivariés. Implémentation en Python.

Compétences à acquérir :

Analyse de modèles mathématiques du risque de marché, étude des méthodes de gestion globales du risque de marché lorsque les sources d’incertitude sont multiples.

Pré-requis obligatoires

De bonnes bases en théorie des probabilités, en analyse stochastique et en Python.

Mode de contrôle des connaissances :

0.3*CC+0.7*E avec E=examen sur table et CC=contrôle continu.

Bibliographie, lectures recommandées :

Ce cous est "self-content" mais ne pas hésiter à combler ses lacunes en lisant un cours de calcul stochastique+EDS et discretisation Euler.

Microstructure des marchés financiers

ECTS : 6

Langue du cours : Français

Volume horaire : 15

Description du contenu de l'enseignement :

The field of market microstructure combines theoretical modeling, institutional knowledge, and empirical analysis to understand how prices result from the interactions of traders in financial markets. The course aims to acquaint students with (i) the canonical models in microstructure, and (ii) econometric models used to test the predictions of microstructure models.

Course structure:

1. Trading Mechanisms
2. Measuring Liquidity
3. Price Dynamics and Liquidity
4. Trade Size and Market Depth
5. Empirical Analysis

Compétences à acquérir :

Master the concepts of financial markets microstructure

Mode de contrôle des connaissances :

Evaluation: assignment and final exam

Bibliographie, lectures recommandées :

Foucault, Thierry, Marco Pagano, and Ailsa Röell, Market Liquidity: Theory, Evidence, and Policy, Oxford University Press, 2013.

Modélisation stochastique de la courbe de taux

ECTS : 6

Enseignant responsable : IMEN **BEN TAHAR** (https://dauphine.psl.eu/recherche/cvtheque/ben-tahar-imen)

Langue du cours : Français

Volume horaire : 21

Description du contenu de l'enseignement :

1. Quelques outils de calcul stochastique : rappels 2. Généralités sur les taux d'intérêt 3. Produits de taux classiques 4. Modèle LGM à un facteur 5. Modèle BGM (Brace, Gatarek et Musiela) / Jamishidian 6. Modèles à volatilité stochastique

Compétences à acquérir :

Ce cours est consacré aux modèles de taux d'intérêts à temps continu. Au travers de nombreux exemples, on décrira leurs utilisations pour évaluer les produits dérivés sur taux d'intérêt.

Bloc 3 : Economie et jeux

Mean field games theory

ECTS : 6

Enseignant responsable : CHARLES **BERTUCCI** (https://charles-bertucci.github.io/)

Langue du cours : Anglais

Volume horaire : 18

Description du contenu de l'enseignement :

Stochastic Control cours (1rst semester) is a necessary prerequisite. Mean field games is a new theory developed by Jean-Michel Lasry and Pierre-Louis Lions that is interested in the limit when the number of players tends towards infinity in stochastic differential games. This gives rise to new systems of partial differential equations coupling a Hamilton-Jacobi equation (backward) to a Fokker-Planck equation (forward). We will present in this course some results of existence, uniqueness and the connections with optimal control, mass transport and the notion of partial differential equations on the space of probability measures.

Compétences à acquérir :

Mastering of the mean field games technics.

Pré-requis recommandés

Stochastic analysis, Stochastic control.

Bibliographie, lectures recommandées :

Notes on the course: https://www.ceremade.dauphine.fr/~cardaliaguet/Enseignement.html#ENSEIGNEMENT

Variational problems and optimal transport

ECTS : 6

Enseignant responsable : GUILLAUME **CARLIER** (https://dauphine.psl.eu/recherche/cvtheque/carlier-guillaume)

Langue du cours : Anglais

Volume horaire : 24

Description du contenu de l'enseignement :

Chapter 1: Convexity in the calculus of variations-separation theorems, Legendre transforms, subdifferentiability, -convex duality by a general perturbation argument, special cases (Fenchel-Rockafellar, linear programming, zero sum games, Lagrangian duality) -calculus of variations: the role of convexity, relaxation, Euler-Lagrange equations **Chapter 2: The optimal transport problem of Monge and Kantorovich** -The forrmulations of Monge and Kantorovich, examples and special cases (dimension one, the assignment problem, Birkhoff theorem), Kantorovich as a relaxation of Monge -Kantorovich duality -Twisted costs, existence of Monge solutions, Brenier's theorem, Monge-Ampère equation, OT proof of the isoperimetric inequality -the distance cost case and its connection with minimal flows **Chapter 3: Dynamic optimal transport, Wasserstein spaces, gradient flows** -Wasserstein spaces -Benamou-Brenier formula and geodesics, displacement convexity -gradient flows, a starter: the Fokker-Planck equation, general theory for lambda-convex functionals **Chapter 4: Computational OT and applications**-Entropic OT, Sinkhorn algorithm and its convergence -Matching problems, barycenters, -Wasserstein distances as a loss, Wasserstein GANs

Compétences à acquérir :

Mastering of variational and optimal transport methods used in economy.

Projet individuel

Mémoire de fin d'études

ECTS : 18

Langue du cours : Français
