FRE7821 / ECE9211, Stochastic control and Portfolio management

Instructor Information

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Course Information

- **F**RE7821 / ECE9211 MSFE and PhD in ECE
- **Course title:** Stochastic control and Portfolio management
- The first 7 weeks of semester and is accessible to Master and PhD students. This first part introduces the fundamental tools of stochastic control theory. After a quick review of the main stochastic calculus ingredients, we present the dynamic programming approach to optimal control and optimal stopping, the corresponding HJB and Obstacle-heat equations. We provide several applications to optimal portfolio allocation, American options and optimal liquidation of indivisible assets, and the corresponding time homogeneous infinite horizon versions.
- The second part of the course, reserved to PhD students, introduces viscosity solutions which provide a unique characterization for these equations and allow to address more general problems in portfolio optimization and justify the numerical approximation techniques for these equations. We next focuse on the extension to the non-Markovian setting through the theory of backward stochastic differential equations. This allows to solve a general class of leader-follower problems introduced in contract theory in economics. The final part of the course will consist of reading sessions focused on some recent aspect of the theory.
- Essentials of probability and optimization. Stochastic calculus pre-requisite is helpful but will be quickly reviewed during the first session.
- Thursdays…
- [Class room number and building]

Course Overview and Goals

- The first part of this course introduces the fundamental tools of stochastic control theory. After a quick review of the main stochastic calculus ingredients, we present the dynamic programming approach to optimal control and optimal stopping, the corresponding HJB and Obstacle-heat equations. Applications to portfolio optimization are accessible through these first results. The second part of the course introduces viscosity solutions which provide a unique characterization for these equations and allow to address more general problems in portfolio optimization and justify the numerical approximation techniques for these equations. We next focus on the extension to the non-Markovian setting through the theory of backward stochastic differential equations. This allows to solve a general class of leader-follower problems introduced in contract theory in economics. The final part of the course will consist of reading sessions focused on some recent aspect of the theory.

Week by week syllabus:

Week 1: Essentials of stochastic calculus

Week 2: The Feynman-Kac representation for linear partial differential equations

Week 3: Stochastic control of Markov diffusions, examples

Week 4: The HJB equation, the verification argument, application to portfolio optimization, the linear quadratic setting

Week 5: Optimal stopping and the obstacle equation, application to American options, and optimal liquidation.

Week 6: Mixed optimal control and stopping, examples

Week 7: Introduction to viscosity solutions

Week 8: Dynamic programming equation characterization through viscosity solutions

Week 9: Backward stochastic differential equations

Week 10: Optimal incentive and the Principal-Agent problem

Week 11: Project presentation (portfolio optimization under stochastic volatility) and reading group (Martingale diffusion optimal transport)

Week 12: Project presentation (passport options) and reading group (Differential games)

Week 13: Project presentation (Pair trading under illiquidity) and reading group (Itô's formula for the flow of SDE marginal laws)

Week 14: Project presentation (Portfolio optimization under drawdown constraints) and reading group (Mean field Optimal control, the linear quadratic setting)

Upon completion of this course, students will be able to:

- Understand the main ingredients of continuous time decision modeling
- Continuous time portfolio optimization under market imperfections
- The connection of continuous time decision modeling and nonlinear partial differential equations related to control theory
- Continuous time optimal incentive theory and optimal contracting in economics

Course Requirements

Class Participation The four last sessions are dedicated to project presentation and reading groups. Master students will be assigned a research paper to study throughout the course evolution and present their work to the class during one of the 1 hour project presentations sessions. PhD students will be assigned to prepare a topic throughout the class evolution to be presented and discussed in class during 90 minutes of the reading group sessions.

Assignments: Students will be assigned research papers to be studied during the two first parts of the course and are required to present their critical analysis of the paper during the project presentation and reading group of the last part of the course.

Tests & Quizzes: Homework during the six first weeks.

References

N. Touzi, Stochastic Control and Application to Finance, http://www.cmap.polytechnique.fr/~touzi/Master-LN.pdf

W. H. Fleming and H. M. Soner. Controlled Markov Processes and Viscosity Solutions. Springer-Verlag, 1993.

Huyên Pham. *Continuous time Stochastic Control and Optimization with Financial Applications*. Stochastic Modeling and Applied Probability 61, Springer 2009.

Bernt Oksendal and Agnès Sulem. *Applied Stochastic Control of Jump Diffusions.* Springer-Verlag 2005.

Goran Peskir and Albert N. Shiryaev. Optimal Stopping and Free Boundary Problems. Lecture Notes ETH Zürich, Birkhaüser 2006.

Grading of Assignments

The grade for this course will be determined according to the following formula:

Assignments/Activities	**% of Final Grade**
Homework	[30%]
Project	[70%]

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