NYU TANDON SCHOOL OF ENGINEERING

Finance & Risk Engineering

FRE-GY.9733,
Special Topics in Financial Engineering

Dynamic Optimization under Strategic Interaction

Instructor Information

- Instructor: Xin Zhang, Ph.D.
- Term: Spring Term, 2025.
- Class Time: TBD
- Location: TBD
- Office Hours: TBD
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Course Information

This is a graduate level course in stochastic differential games. This course discusses dynamic games between two players and strategic decision making by small interacting agents in large populations that appear in finance and economics. While it focuses on different applications such as duopolistic market, production of exhaustible resources, and price impact, the necessary mathematical theory will be derived and explained in class. Additionally, the first part of the course is devoted to a brief introduction of optimal transport. It not only serves as a tool in the research of large population games, but also stands as a significant topic with applications in economics in its own right.

Prerequisites: A good knowledge of probability theory and real analysis is essential for this course. Familiarity with basics of stochastic processes and stochastic control is helpful.

Course Overview and Goals

This course focuses on applications of dynamic games in finance and economics such as duopolistic market, principal-agent problem, and price impact in mean field problems. Students will be able to solve concrete examples using mathematical tools.

At the end of this course, students will be able to:

- Understand basics of optimal transport, its economics interpretation as matching problems, and duality result and equilibrium. Get to know derivation of optimal solution in the case of quadratic surplus.

- Get to know Nash equilibrium in stochastic differential games, its applications in duopolistic market. Use HJBI equation to solve examples.
- Know different examples of mean field games such as price impact, production of exhaustible resources. Derive HJB-FP forward-backward system. Understand convergence problems in mean field game.
- Understand mean field control as a central planner problem. Solve linear quadratic models. Derive HJB equation on Wasserstein space.

Course Requirements

Class Participation

Students are strongly suggested to attend every lecture.

Assignments

Some examples and proofs will be left as exercises.

Tests & Quizzes

We will have a midterm written exam, and a final project.

Assigned Readings

Understand the slides and lecture notes for this course

Grading of Assignments

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

Assignments/Activities	% of Final Grade
Homework	30%
Midterm exam	30%
Finial project	40%

Letter Grades

Letter grades for the entire course will be assigned as follows:

F	<60
C	65
C+	70
B-	75
B	80
A-	85
A	90

Course Schedule

Topics and Assignments

Week/Date	Topic	Reading	Assignment Due
Week 1, optimal transport	Matching problem in economics, notion of optimal transport	Slides and Lecture notes	TBA
Week 2, optimal transport	Kantorovich duality and equilibrium	Slides and Lecture notes	TBA
Week 3, optimal transport	Optimal planning with quadratic surplus	Slides and Lecture notes	TBA

Week 4, optimal transport	Application to Propagation of chaos	Slides and Lecture notes	TBA
Week 5, two player stochastic differential games	Prisoner's dilemma, Nash equilibrium	Slides and Lecture notes	TBA
Week 6, two player stochastic differential games	Duopolistic market, HJBI equation	Slides and Lecture notes	TBA
Week 7, two player stochastic differential games	Principal-agent problem	Slides and Lecture notes	TBA
Week 8, mean field games	A toy example of starting time of meeting	Slides and Lecture notes	TBA
Week 9, mean field games	HJB-FP forward-backward system, approximate equilibrium	Slides and Lecture notes	TBA
Week 10, mean field games	Production of exhaustible resources, model of growth and distribution of salaries	Slides and Lecture notes	TBA
Week 11, mean field games	Derivation of Master equation	Slides and Lecture notes	TBA
Week 12, mean field games	Convergence problems in mean field game	Slides and Lecture notes	TBA

Week 13, mean field control	Problem of central planner, Linear quadratic model	Slides and Lecture notes	TBA
Week 14, mean field control	HJB on Wasserstein space	Slides and Lecture notes	TBA
Week 15	Final Exam	N/A	N/A

Course Materials

Recommended Textbooks & Materials

- *Optimal Transport Methods in Economics* by Alfred Galichon
- *Optimal Transport for Applied Mathematicians: Calculus of Variations, PDEs, and Modeling* by Filippo Santambrogio
- *Optimal Control Theory: Applications to Management Science and Economics* by Suresh P. Sethi
- *Mean Field Games and Applications* by Olivier Guéant, Jean-Michel Lasry, Pierre-Louis Lions
- *Notes on Mean Field Games* by Pierre Cardaliague

Policies

Academic Misconduct

A. Introduction: The School of Engineering encourages academic excellence in an environment that promotes honesty, integrity, and fairness, and students at the School of Engineering are expected to exhibit those qualities in their academic work. It is through the process of submitting their own work and receiving honest feedback on that work that students may progress academically. Any act of academic dishonesty is seen as an attack upon the School and will not be tolerated. Furthermore, those who breach the School's rules on academic integrity will be sanctioned under this Policy. Students are responsible for familiarizing themselves with the School's Policy on Academic Misconduct.

B. Definition: Academic dishonesty may include misrepresentation, deception, dishonesty, or any act of falsification committed by a student to influence a grade or other academic evaluation. Academic dishonesty also includes intentionally damaging the academic work of others or assisting other students in acts of dishonesty. Common examples of academically dishonest behavior include, but are not limited to, the following:
    1. Cheating: intentionally using or attempting to use unauthorized notes, books, electronic media, or electronic communications in an exam; talking with fellow students or looking at another person's work during an exam; submitting work prepared in advance for an in-class examination; having someone take an exam for you or taking an exam for someone else; violating other rules governing the administration of examinations.
    2. Fabrication: including but not limited to, falsifying experimental data and/or citations.
    3. Plagiarism: Intentionally or knowingly representing the words or ideas of another as one's own in any academic exercise; failure to attribute direct quotations, paraphrases, or borrowed facts or information.
    4. Unauthorized collaboration: working together on work that was meant to be done individually.
    5. Duplicating work: presenting for grading the same work for more than one project or in more than one class, unless express and prior permission have been received from the course instructor(s) or research adviser involved.
    6. Forgery: altering any academic document, including, but not limited to, academic records, admissions materials, or medical excuses.

Disability Disclosure Statement

Academic accommodations are available for students with disabilities. Please contact the **Moses Center for Students with Disabilities** (212-998-4980 or mosescsd@nyu.edu) for further information. Students who are requesting academic accommodations are advised to reach out to the Moses Center as early as possible in the semester for assistance.

Inclusion Statement

The NYU Tandon School values an inclusive and equitable environment for all our students. I hope to foster a sense of community in this class and consider it a place where individuals of all backgrounds, beliefs, ethnicities, national origins, gender identities, sexual orientations, religious and political affiliations, and abilities will be treated with respect. It is my intent that all students' learning needs be addressed both in and out of class, and that the diversity that students bring to this class be viewed as a resource, strength and benefit. If this standard is not being upheld, please feel free to speak with me.