IE 598: Game Theory and Optimization

Spring 2026

Instructor: Jugal Garg (jugal@illinois.edu)
Office hours: Tuesdays 9:00 - 10:00 AM (TB 216B) or by appointment

Course Description

This course explores topics at the intersection of game theory, economics, and optimization, with a focus on real-world applications such as matching medical residents to hospitals, allocating students to schools, assigning seats in courses, kidney exchange, public housing allocation, online ad auctions, and task allocation. We will study foundational concepts in game theory, mechanism design, and market-based resource allocation, including Nash equilibrium, correlated equilibrium, bargaining, Shapley value, core stability, and competitive equilibrium. These models naturally give rise to a variety of optimization problems, including linear, convex, non-convex, and complementarity formulations. A central emphasis will be on the computational and optimization techniques used to model and solve these problems effectively and efficiently.

Prerequisites: IE 310 or equivalent; basic knowledge of optimization, probability, and linear algebra; mathematical maturity

References

1. *Game Theory: Analysis of conflict* by Roger Myerson, Harvard Press, 1997.
2. *Twenty Lectures on Algorithmic Game Theory* by Tim Roughgarden, Cambridge, 2016.
3. *A Course in Game Theory* by Osborne and Rubinstein, MIT Press, 1994.
4. *Introduction to Operations Research* by Hillier and Lieberman, McGraw Hill, 2021.
5. *Convex Optimization* by Boyd and Vandenberghe, Cambridge, 2004.

Required Work and Grading Policy

1. Homework assignments (40%)
2. Project (40%)
3. 2 Quizes (10% each)
4. Class Participation (5% bounus)

Tentative Course Outline

- **Week 1-2 (competitive equilibrium):** market models; Eisenberg-Gale convex program and its dual; welfare theorems; algorithmic approaches to computing equilibria

- **Week 3-4 (resource allocation):** economic efficiency (Pareto optimality); envy-freeness; Nash social welfare; applications
- **Week 5-8 (game theory):** Nash equilibrium; minimax theorem and linear programming (LP) duality; support enumeration algorithm; Sperner's lemma; linear complementarity problem (LCP) formulation; Lemke-Howson algorithm; correlated equilibrium; bargaining and cooperation: Nash bargaining, core, Shapley value
- **Week 9-11 (price of anarchy):** selfish routing; potential games; congestion games; cost sharing games; best response dynamics; PLS
- **Week 12-13 (mechanism design):** first price auction, second price (Vickery) auction; Myerson's lemma; VCG mechanism; mechanism design without money: top trading cycle, kidney exchange
- **Week 14-15:** project presentations

Course Project

A course project can have 1-3 students. The project could be reading a couple of recent research papers, survey of some topic not covered in the class, or on a research problem. The evaluation of project is based on a written report (8-10 pages), class presentation and class feedback. We will have project presentations at the end of the course.