University of Pittsburgh
Spring 2020 Semester

PIA 2550: Econ meets CS: Mechanism Design and Applications

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Class Day/Time: **Wed 9-12, Room 3415**
Credits: 3 credit
Prerequisites: **None**
(recommended: statistics, discrete mathematics, set theory, game theory)

Introduction: Mechanism design is "reverse game theory": instead of starting with a game and solving for the outcome, we start from a desired outcome (for example, social welfare maximization) and design an institution that would accomplish it. These include problems of allocating resources and pricing goods from a perspective of understanding how incentives of participants can be used to improve the behavior of the overall system.

Fundamental questions in Mechanism Design turn out to have a strong relation to issues in Computer Science in several ways. First, computer science approaches, such as the focus on complexity and approximation and the use of simulations, provide a necessary bridge between mechanism design in theory and its implementation in practice. Similarly, advances in mechanism design have implication for search and recommendation. Second, in an increasingly networked environment, human participants interact with artificial agents.

This class will focus on one of its most practical area: Matching, with applications in school choice, organ exchange, doctor-hospital match, among many others. In this course we will learn about the theory and application of matching markets, its strengths and limitations, the importance of contextual details in real-world implementation, and how empirical and computational methods complements this approach.

Course Objectives: During and after this course, students are expected to

1. Understand the key concepts in matching theory.
2. Understand the interplay between economics and computer science in matching theory and its applications
3. Understand the role of empirics and simulation in testing and generating hypotheses.
4. Investigate real world applications of matching theory.

Course Schedule

WEEK	TOPIC	Contents
1 Jan. 8	Social choice, implementation, and mechanism design	What do we want to achieve as a social planner? How do we implement the social choice in a mechanism? (M1, M2)
2 Jan 15	P, NP, NP hard, and NP complete	Which problems are tractable in a reasonable time? What are the problems we should aim for approximation? (M3, M4))
3 Jan 22	Introduction to matching theory	Matching vs. Non-matching problem / School choice and Deferred Acceptance mechanism (I4) /Properties of DA / One-sided vs. two-sided matching
4 Jan 29	Empirical approach to welfare evaluation	Estimation of welfare using data and comparison among different mechanisms (E11) / Good properties vs. optimization approaches in matching problem (I3)
5 Feb 5	Properties of matching and mechanism	Formal definition of matching and mechanism and their properties / Case study: Boston Public School's choice of DA over TTC (E10, X1)
6 Feb 12	Algorithmic approach to find a matching	Uncertain preferences (A4) / With couples (A9) / Proportionality constraint (A2)
7 Feb 19	Stable matching: theory and practice	Conditions for stable outcome in matching (and matching with contract) model (E1 – E4) / Computation of stable matching (A2, A4)
8 Feb 26	Manipulation: theory and practice	Do people follow dominant strategy when the mechanism ensures it/ obviously strategy-proof (E12) / strategy proof under different assumptions (A1, A7, E6)
9 Mar 4	Research project pre-presentation	Individual research project plan sharing and discussion
10 Mar 18	Constraints in matching problems	Matching with various constraints; affirmative actions (E8) / ratio constraint (A1, A2) / budget constraint (A3, A6) / Soft bound (A5)
11 Mar 25	Application: Organ exchange	Kidney exchange (E9) / dynamic kidney exchange (A8) / Dynamic preferences (A7)
12 Apr 1	Discussion	Research project presentations and discussion

13 Apr 8	Discussion	Research project presentations and discussion

Reading Lists

A1	Yahiro et al., Strategyproof and Fair Matching Mechanism for Ratio Constraints, *Proceeding AAMAS '18 Proceedings of the 17th International Conference on Autonomous Agents and MultiAgent Systems*, Pages 59-67.
A2	Nguyen and Vohra, Stable Matching with Proportionality Constraints, *Proceeding EC '17 Proceedings of the 2017 ACM Conference on Economics and Computation*, Pages 675-676.
A3	Hamada et al., Weighted Matching Markets with Budget Constraints, *Proceeding AAMAS '17 Proceedings of the 16th Conference on Autonomous Agents and MultiAgent Systems*, Pages 317-325
A4	Aziz et al., Stable Matching with Uncertain Pairwise Preferences, *Proceeding AAMAS '17 Proceedings of the 16th Conference on Autonomous Agents and MultiAgent Systems*, Pages 344-352
A5	Kurata et al., Controlled School Choice with Soft Bounds and Overlapping Types, *Journal of Artificial Intelligence Research*, Vol 58, 2017.
A6	Kawase and Iwasaki, Near-Feasible Stable Matching with Budget Constraints, **arXiv:1705.07643 [cs.GT]**
A7	Hosseini, Larson, and Cohen, On Manipulability of Random Serial Dictatorship in Sequential Matching with Dynamic Preferences, *Proceedings of the Twenty-Ninth AAAI Conference on Artificial Intelligence*, 2015.
A8	Dickerson et al., Dynamic matching via weighted myopia with application to kidney exchange, *Proceeding AAAI'12 Proceedings of the Twenty-Sixth AAAI Conference on Artificial Intelligence* Pages 1340-1346, 2012.
A9	Biró et al., The Hospitals / Residents Problem with Couples: Complexity and Integer Programming Models. In: Gudmundsson J., Katajainen J. (eds) Experimental Algorithms. SEA 2014. Lecture Notes in Computer Science, vol 8504. Springer, Cham
A10	Ágoston et al., Interger programming methods for special college admissions problems, https://doi.org/10.1007/s10878-016-0085-x
E1	Hatfield and Milgrom, Matching with Contracts, *American Economic Review*, 95 (4): 913-935, 2005.
E2	Aygün and Sönmez, Matching with Contracts: Comments, *American Economic Review*, 103 (5): 2050-51, 2013,
E3	Hatfield and Kojima, Substitutes and stability for matching with contracts, *Journal of Economic Theory*, 145 (5): 1704-1723, 2010.

E4	Aygün and Sönmez, The Importance of Irrelevance of Rejected Contracts in Matching under Weakened Substitutes Conditions, *Boston College Working Papers in Economics* 805, Boston College Department of Economics, 2012.
E5	Ehlers et al., School choice with controlled choice constraints: Hard bounds versus soft bounds, *Journal of Economic Theory*, 153:648-683, 2014.
E6	Azar Abizada, Stability and incentives for college admissions with budget constraints, *Theoretical Economics* 11 (2016), 735–756.
E7	Kamada and Kojima, Efficient Matching under Distributional Constraints: Theory and Applications, *American Economic Review*, 105 (1): 67-99, 2015.
E8	Atila Abdulkadiroglu, College Admissions with Affirmative Action, *International Journal of Game Theory*, 33(4): 535-549, 2005.
E9	Roth et al., Efficient kidney exchange: Coincidence of wants in a market with compatibility-based preferences, *American Economic Review*, 97(3), 2007.
E10	Abdulkadiroglu and Sonmez, School Choice: a Mechanism Design Approach, *American Economic Review*, 93 (3): 729-747, 2003.
E11	Abdulkadiroglu, Agarwal, Pathak, The Welfare Effects of Coordinated Assignment: Evidence from the New York City High School Match, American Economic Review, 107 (12): 3635-89, 2017.
E12	Li, Shengwu, Obviously Strategy-Proof Mechanisms (June 19, 2017). Available at SSRN: https://ssrn.com/abstract=2560028 or http://dx.doi.org/10.2139/ssrn.2560028
E13	Abdulkadiroglu et. al., Minimizing Justified Envy in School Choice: The Design of New Orleans' OneApp, *NBER Working Paper* No. 23265 Issued in March 2017
I1	Alvin Roth, The Economist as Engineer: Game Theory, Experimentation, and Computation as Tools for Design Economics, Econometrica, 70(4), 2002
I2	Alvin Roth, What Have We Learned from Market Design? Chapter in NBER book Innovation Policy and the Economy, Volume 9 (2008), Josh Lerner and Scott Stern, editors (p. 79 - 112)
I3	Eric Budish, Matching versus Mechanism Design, *Newsletter ACM SIGecom Exchanges,* 11(2): 4-15, 2012
I4	D. Gale and L. Shapley, College Admissions and Stability of Marriage, *The American Mathematical Monthly*, 69(1): 9-15, 1962
I5	L. Shapley, H. Scarf, On Cores and Indivisibility, *Journal of Mathematical Economics*, 1(1): 23-37, 1974
X1	Landsmark et. al., Report and Recommendations of the Boston Public Schools, Student Assignment Task Force, Submitted to the Boston School Committee, 2004
M1	Blume et. al., Introduction to computer science and economic theory, Journal of Economic Theory, 156: 1-13, 2015
M2	Sandholm T. (2008) Computing in Mechanism Design. In: Durlauf S.N., Blume L.E. (eds) The New Palgrave Dictionary of Economics. Palgrave Macmillan, London
M3	Nisan and Ronen, Algorithmic Mechanism Design, *Games and Economic Behavior*, 35(1-2): 166-196, 2001