«Computational Game Theory»

Tutor	Arthur Dolgopolov, European University Institute
Organization	Graduate Academy
Language	English
ECTS-Points	2
Nos. of participants	max. 20
Content	The Computational Game Theory is a course that briefly introduces two active research areas, both related to computation and algorithms. *How to design a pricing system or an auction to maximize profit when selling complex packages of goods? Can machine learning design a better taxation system? Will two reinforcement learning algorithms learn to collude and form a cartel? How would people learn in similar situations?* These are the kind of questions that can be answered through modern theoretical and computational tools of game theory. The first day covers mechanism design and game theory problems that are too difficult to solve on paper and therefore require a computer solver (the field of algorithmic mechanism design). This field has had great practical success. On the second day we will also cover ways to predict the outcomes of learning and evolutionary processes, and problems where agents have restricted computational abilities or are themselves reinforcement-learning computer algorithms, for example a simple dynamic pricing system in a duopoly competition. **Day 1: Algorithmic mechanism design –** designing the game through pricing systems, taxes etc. Topics: Classic games and impossibility theorems (Othman and Sandholm, 2009). Automated mechanism design (Sandholm, 2003). Selfish routing, combinatorial auctions, bidding languages, network formation (Nisan et al., 2007). **Day 2: Evolutionary game theory -** the game is given; we only try to predict what happens under different conditions.

	Axelrod’s tournaments and extensions (Axelrod, 1980). Moran process. Evolutionary stable strategies, etc. Convergence and stochastic stability. Two simple algorithms learn to play each other for a long time, what is the outcome? Weak acyclicity, spanning trees, perturbed dynamics (Foster and Young, 1990). **Dates:** March 21 and March 22
Prerequisites/ Materials (opt.)	Undergraduate level mathematics – derivatives, matrix operations etc. I can provide references and work out the missing parts if necessary. A laptop/computer with internet access is recommended (no coding experience expected).
Reading list (opt.)	For a general idea for the course and a less technical overview of ideas: 1. Calvano, Emilio, et al. "Protecting consumers from collusive prices due to AI." Science 370.6520 (2020): 1040-1042. 2. Axelrod, R.(1980): “More effective choice in the prisoner’s dilemma,” Journal of conflict resolution, 24, 379–403.2 3. Zheng, S., A. Trott, S. Srinivasa, N. Naik, M. Gruesbeck, D. C.Parkes, and R. Socher(2020): “The ai economist: Improving equality and productivity with ai-driven tax policies,”arXiv preprint arXiv:2004.13332. The more technical papers and textbooks: 1. Brandt, F., V. Conitzer, and U. Endriss(2012): “Computational social choice,” Multiagent systems, 213–283. 2. Calvano, E., G. Calzolari, V. Denicolo, and S. Pastorello(2020):“Artificial intelligence, algorithmic pricing, and collusion,” American Eco-nomic Review, 110, 3267–97. 3. Camera, G., M. Casari, and M. Bigoni(2012): “Cooperative strategies in anonymous economies: An experiment,” Games and Economic Behavior, 75,570–586. 4. Dal B ́o, P. and G. R. Fr ́echette(2018): “On the determinants of cooperation in infinitely repeated games: A survey,” Journal of Economic Literature,56, 60–114. 5. Dal B ́o, P. and G. R. Fr ́echette(2019): “Strategy Choice in the Infinitely Repeated Prisoner’s Dilemma,” American Economic

	Review, 109, 3929–52. 6. Foster, D. and P. Young(1990): “Stochastic evolutionary game dynamics,” Theoretical population biology, 38, 219–232.Levine, D. K. and S. Modica(2016): “Dynamics in stochastic evolutionary models,” Theoretical Economics, 11, 89–131. 7. Miller, D. A.(2012): “Robust collusion with private information,” The Re-view of Economic Studies, 79, 778–811.Newton, J. and R. Sawa(2015): “A one-shot deviation principle for stability in matching problems,” Journal of Economic Theory, 157, 1–27. 8. Nisan, N., T. Roughgarden, E. Tardos, and V. V. Vazirani(2007):“Algorithmic game theory, 2007,”Book available for free online. 9. Othman, A. and T. Sandholm(2009): “How pervasive is the Myerson-Satterthwaite impossibility?” in Twenty-First International Joint Conference on Artificial Intelligence. 10. Sandholm, T.(2003): “Automated mechanism design: A new application area for search algorithms,” in International Conference on Principles and Practice of Constraint Programming, Springer, 19–36. 11. Sandholm, W. H., Economic Learning and Social Evolution: Population Games and Evolutionary Dynamics (MIT Press, 2011).
Teaching method (opt.)	We will spend most of the time tweaking and solving different models – either theoretically on paper/blackboard or computationally in python. This will include, for example, designing strategic pricing algorithms for a duopoly market and predicting the outcome for the firms and consumers (similarly to the ones studied in Calvano, Emilio, et al. 2020)
Charge	This Graduate Academy offering is directed at researchers, post-docs and doctoral students of the University of Lucerne and its partner institutions and is free of charge for these persons.