Agent-based Evolutionary Game Dynamics

From Agent-Based Simulations to Mathematical Models in Evolutionary Game Theory

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Course Overview

This course is an introduction on how to implement and analyze Agent-Based Models within the rigorous framework of Evolutionary Game Theory. It is designed to equip students from various disciplines (including Economics, Social and Political Sciences, Computer Science, Ecology, Engineering and Complex Systems) with the practical skills necessary to design, implement, and analyze dynamic models of strategic interactions where agents may learn and adapt. The course is suitable for graduate students and advanced undergraduates with basic quantitative background

Duration, format and prerequisites

This intensive 20-hour (5-day) course is structured around 10 hours of theory and 10 hours of hands-on laboratory sessions. Prerequisites: **None.** No prior coding experience or advanced mathematical knowledge is required. However, a foundational familiarity with Calculus, basic Game Theory concepts, and programming will be beneficial.

What you will find in this course

1. Focus on Implementation: The course will follow a practical, hands-on approach. We will learn to implement various Agent-Based Models (ABMs) using the NetLogo programming environment.

2. Accessibility (Low Barrier to Entry): The course does not require any prior coding experience or advanced mathematical skills. It starts from the basics of Game Theory and NetLogo, in a way accessible to diverse backgrounds.

3. Practical and Visual Learning: Agent-Based simulations are highly visual. By building and running models, you will be able to see and understand how evolutionary processes unfold, i.e. how different strategies compete, spread, thrive, or die out. This aids intuition better than abstract equations alone.

4. Connections between Theory and Simulation: A key theme of the course is the relationship between computer simulations and mathematical analysis. We will demonstrate how simulation and mathematical analysis complement each other, offering different but compatible insights. Furthermore, there are plenty of synergies to be exploited by using the two approaches together.

Learning Objectives

- Design, implement, and run simple agent-based models.
- Translate abstract evolutionary models into executable NetLogo code.
- Conduct computational experiments to analyze and understand the dynamics of agent-based models.
- Implement models of structured populations, i.e. models where agents are connected through networks.
- Understand the relation between stochastic agent-based models and deterministic ODE (Ordinary Differential Equation) models like the replicator dynamics.
- Derive mean-field or deterministic approximations (e.g., replicator dynamics) from agent-based models.
- Critically assess when mathematical abstractions are valid and when agent-based models are essential.

Outline

Each day there is a 2-hour session of teaching and a 2-hour session of programming. Total: 20 hours over 5 days.

Day	Session Type	Topic and Goal	Core Concepts Covered
1	TEACHING	Introduction to Game Theory, Evolution, and Agent-based modelling	What is Game Theory? Defining players, strategies, and payoffs. Evolutionary Game Theory (EGT) —adaptation vs. rationality. What is an Agent-Based Model (ABM)?
	LAB	The fundamentals of NetLogo	Installation and interface tour. Learning essential NetLogo (agents, variables, procedures). Running and modifying models.
2	TEACHING	The canonical model in EGT. Exploration of models	Main components in EGT models. Introduction to the exploration and analysis of ABMs using computer simulation and mathematical analysis.
	LAB	Building our first simple EGT model	Step-by-step implementation of a 2-strategy evolutionary game model. Coding agent variables and the strategy update rule based on experienced payoffs.
3	TEACHING	Analysis of agent-based models	Computational experiments. Introduction to Markov chains. Different mathematical approximations.
	LAB	Extending the model and running computational experiments	Extend the model to include noise in strategy revision. Conduct computational experiments using Behavior Space.
4	TEACHING	Games on Networks	Graph Theory 101: Nodes and Edges. The importance of local interaction: how the network influences the spread of strategies.
	LAB	Implementing Games on Networks	Implement models where players are connected in a network. Implement different network-generating mechanisms.
5	TEACHING	Stochastic ABMs vs. Deterministic Dynamics	Understanding the mathematical bridge: the connection between a stochastic ABM and its deterministic counterpart (the "mean dynamic" ODE).
	LAB	Running an agent-based model and solving its mean dynamic at runtime	Implement a model where the ABM and its mean dynamic can be compared at runtime. Compare the ABM results against the deterministic mean dynamic.

Readings

Primary text: Izquierdo, L. R., Izquierdo, S. S. & Sandholm, W. H. (2024). *Agent-Based Evolutionary Game Dynamics*. University of Wisconsin Pressbooks. https://wisc.pb.unizin.org/agent-based-evolutionary-game-dynamics

Complementary reading:

- Epstein, J. M. & Axtell, R. (1996). *Growing Artificial Societies*. Brookings Institution Press/MIT Press, Washington/Cambridge.
- Sandholm, W.H. (2010). *Population Games and Evolutionary Dynamics*. MIT Press, Cambridge.
- Weibull, J.W. (1995). *Evolutionary Game Theory*. MIT Press, Cambridge.

Schedule of the course

May 2026			
Day		Hour	Room
Mo	18	14:30 - 18:30	Via Pace, 10 - Room A
Tu	19	9:00 - 13:00	Via Pace, 10 - room A
We	20	9:00 - 13:00	Via Pace, 10 - room A
Thu	21	9:00 - 13:00	Via Pace, 10 - room A
Fri	22	9:00 - 13:00	Via Pace, 10 - room A