Much quantitative social science and behavioral research has focused on identifying statistical relationships in cross-sectional data. While rigorous and tractable, this research typically assumes the objects of study are independent of one another, and thus assumes away the complex social processes that we hope to understand. Qualitative (ethnographic and comparative-historical) lenses have allowed us to view the social world as a web of interdependent and contingent processes, with macro-level cultures, communities and organizations emerging from and constraining the micro-level interactions of individuals, relationships, and families. An explosion of recent work in Sociology has used computer simulation to think systematically and rigorously about these complex social dynamics. Simulation research can offer rich, nuanced process models similar to qualitative work, but employs a rigorous, transparent, and replicable framework that can be extended to other research contexts, similar to statistical approaches.

Theorists use computer models to elucidate, extend, integrate, and validate social theory. Policy analysts use computer models to predict outcomes of policy scenarios in complex and interactive domains. Managers use computer models to design efficient and robust organizational operations and implement effective interventions. This proliferation of simulation work has generated great interest in computer modeling methods. This seminar will give participants a deep critical exposure to the most prominent sociological literatures using simulation, and use these models as a springboard to learn and practice the methods of social simulation.

We will focus primarily on agent-based simulation, with a brief introduction to some more traditional modeling approaches (including closed-form analytic solutions and system-level simulation). Students must share an interest in abstract theory, but do not need any specialized training in mathematics or computer science for this course.

REQUIRED BOOKS


GRADES: 75% Participation (including discussions & reflections); 25% Final Project. This class is a collaborative project, so most of the evaluation depends on your engagement in our peer learning exercises. There is no exam and you will not be evaluated on memorizing concepts, but your participation in class discussion and sharing your work through the weekly reflections and discussant opportunities are crucial.

INDEPENDENT STUDY: Students may arrange to earn 1 or more additional independent study credits for building skills with hands-on supplementary projects (e.g., replications).
SEMINAR REQUIREMENTS

- **Intensive Pre-Seminar Workshop:**
  Before the course begins, you experience a 2-day skill-building workshop, offered through ISSR. This workshop exposes you to core concepts, classes of models, methodological lessons, and relevant software packages. Following from this workshop, we will apply these skills to deeply investigate models, simulation projects, and intellectual debates.

- **Seminar project:**
  Each student will work on a modest and flexible seminar project. This might be a conventional term paper, such as a review essay, but I encourage you to instead design a project that will advance your career (some modeling work toward a publishable paper, a grant proposal, a future job, etc.). For most, this will be a replication or extension of an existing model (perhaps a model on this syllabus). In any case, collaboration (with other students) or double-dipping (combining a seminar project with some other seminar) will be fine, if this contributes to a publishable product that is useful for you. The final project is a capstone aiming to make the class useful for you, but it is not a centerpiece of the course.

- **Lab meeting:**
  Our Wednesday labs include 60-90 minutes of required structured activities along with 30-60 more minutes of optional open exploration. (The official lab time is 3:30-5:00 but we have the room until 5:30 in case students want to continue working.)

- **How to read the articles and chapters** –
  There isn’t much reading for this class, but we deeply engage the models that we study. See the syllabus for assigned pages and skim or ignore other pages. Strive to understand how the models work. We are here to understand the methods of building and exploring models. For this purpose, we won’t distract ourselves with thoughts about what might be missing from a model, how it could be extended, why the model is or isn’t useful, how its assumptions may be unrealistic, or how misleading the framing of the article may be. If you can deeply study a model, dissect it, reconstruct it, and replicate it, this experience will teach you deep methodological lessons that you can carry into your own area of study. Let this note guide you in your weekly ‘reflections’ below and your role as discussant.

- **For one class session you will serve as “lead discussant” and for one session you will serve as “secondary discussant.” Work out your session preferences with me.**
  The lead discussant gives a brief orientation with discussion questions relevant to our learning goals above. The secondary discussant offers supplementary comments and questions. Either may choose to address points from colleagues’ “reflections” below.

- **Each week, all students who are not discussants write “reflections” on the reading:**
  Write a one-page single-spaced explication of some model(s) in the reading to help us understand how it works. This could be a flowchart, pseudocode, or software replication. Submit to Moodle by Noon on Sunday. See “How to read the articles” above for guidance.
COURSE SCHEDULE

INTENSIVE 2-DAY SKILL-BUILDING ‘BOOT CAMP’ WORKSHOP

WEEK 1 (Jan 22): Orientation to Seminar and Lab

This is a preliminary lab session before the first formal meeting of the class. We will discuss the structure, norms, and expectations of the class. In particular, we will explain the roles of lead discussant and secondary discussant, allow you to select future weeks where you will perform these roles, and explain the expectations of the weekly reflections that you will submit on the day before each seminar meeting. We will also practice some software skills that will be used in later labs.


[In week 1 there is no need for you to submit reflections on the reading.]

LAB 1 (Jan 22) Lederle Graduate Research Center A210

WEEK 2 (Jan 27) MEET IN THOMPSON 919: Introduction

We begin by discussing a variety of motivations for simulation in the social sciences. Prognostic simulation uses data-driven (“realistic”) models to forecast future trends and events. Methodologists use simulation to generate surrogate datasets with known properties for the purpose of validating or calibrating their analytical tools. Planners use simulation to aid in decision-making. Increasingly, social scientists are using simulation as a virtual laboratory for conducting “computational experiments” to investigate basic theoretical questions. We will focus mostly on the latter use of simulation as a flexible tool for inventing and refining theory. We begin with classic readings by Schelling and Axelrod, who motivate the use of “bottom-up” (agent-based) formal models to understand the emergence of nonobvious macro-level patterns from micro-level behavioral regularities. Gilbert gives a more general orientation.

READING (required for this first class):


LAB 2 (Jan 29) Lederle Graduate Research Center A210

* = reading to be found on Moodle
Hanneman et al and Leik & Meeker demonstrate “top-down” (system-level) simulation as a method for developing and refining theory in Sociology. They differentiate the goals of computational experiments from the goals of empirical research and from alternative methods of formalization (logic and mathematics). They also demonstrate that simulation can be used for macrosociological research on political and cultural changes over long time spans, as well as microsociological research on groups and local interaction.


FURTHER READING

[Discrete system dynamics]


[Continuous system dynamics; requires familiarity with Differential Calculus]


LAB 3 (Feb 5) Lederle Graduate Research Center A210

* = reading to be found on Moodle
WEEK 4 (Feb 10): Agent-Based Simulation as a Theory-Building Tool
[Lead Discussant: Mehak; Secondary Discussant: Shuyin]

Axelrod’s *Evolution of Cooperation* remains one of the most influential implementations of agent-based modeling, having earned tens of thousands of citations across the natural sciences and social sciences. That book examined the robustness of strategies in an iterated prisoner’s dilemma tournament, examining conditions for the emergence of individually-costly cooperation. This week’s readings – looking at extensions of Axelrod’s study to ‘noisy’ environments – illustrate two perennial debates in social simulation. K Kollock’s criticism of Axelrod (as well as Reeves & Pitts’ criticism of Kollock) raises the question of model sensitivity and the robustness of conclusions from simulation. Bendor, Kramer, and Swistak’s criticism of Kollock (as well as Binmore’s criticism of Axelrod) raises questions about the strengths and limitations of simulation as an alternative to mathematical analysis.

[Implementation available in Excel]


FURTHER READING


LAB 4 (Feb 12) Lederle Graduate Research Center A210

* = reading to be found on Moodle
WEEK 5 (Feb 18): System-Level and Agent-Based Models of Evolutionary Dynamics
[Lead Discussant: Aaron; Secondary Discussant: Tyler]

This week we maintain our interest in the emergence of cooperation in the prisoner’s dilemma. However, we look at work that recasts this problem with ecological and evolutionary lenses, examining the “fitness” of strategies leading to propagation in a population of other strategies. In ecological models, the fitness of strategies depends on the distribution of other strategies in the population, and their proliferation depends on their fitness. Hirshleifer et al. demonstrate the use of deterministic system-level models to understand these dynamics. Like Kollock, Axelrod and Takahashi use agent based stochastic models, but their models are explicitly evolutionary, allowing for mutation (or innovation) along with selection (or social learning), and thus the emergence of strategies not present in the initial population.


FURTHER READING


LAB 5 (Feb 19) Lederle Graduate Research Center A210

* = reading to be found on Moodle
Critical mass theory incorporates another form of interdependence in individuals’ choices: Agents’ propensity to engage in a behavior may depend on the frequency of other agents who are engaging in that behavior. That is, each agent may choose to join a strike only if a sufficient share of peers (that actor’s ‘threshold’) also join the strike. Agents in a population may have different thresholds because they are more or less interested in the strike goals or concerned about negative repercussions. A prominent class of models describes heterogeneous propensities to join in collective behavior as a distribution of thresholds in the population, and then derives a macro-level function for the dynamic behavior of the population resulting from that distribution: The overall level of collective action (such as participation in a riot or seminar) at a given time is a function of the previous level of participation. In these models, both the interdependence of actors’ choices and heterogeneity among actors can be characterized and analyzed as a function for the behavior of the aggregate.


FURTHER READING


LAB 6 (Feb 26) Lederle Graduate Research Center A210

* = reading to be found on Moodle
In this week we consider structural models, which allow for direct interdependence in agents’ choices that is not reducible (for practical purposes) to a function for macro-level behavior. Agents make autonomous choices, but are influenced by the behaviors of other agents in their neighborhood. Thomas Schelling introduced a now-classic argument about how individual preferences can aggregate to counterintuitive macro-level outcomes (such as pervasive racial segregation in neighborhoods of agents who would be happy in integrated neighborhoods). Bruch and Mare challenge Schelling’s argument as a specific empirical claim about racial segregation in neighborhoods. Again, an exchange of comment and reply illuminates for us some issues at stake in computational modeling experiments.


FURTHER READING


LAB 7 (March 4) Lederle Graduate Research Center A210

* = reading to be found on Moodle
WEEK 8 (March 9): Applications: Network Critical Mass Models of Collective Action
[Lead Discussant: Pedro; Secondary Discussant: Mehak]

This week we look at extensions to the previous models, where agents’ choices depend on the choices of their neighbors. But the structure of social contacts is not modeled as ‘spatial’ (i.e. a regular lattice of contacts, as on a grid). Instead, agents observe or influence one another through ‘social networks’ that may allow irregular sets of contacts: Some agents may be more connected than others, some may be more central in the overall structure, some overall structures can be more centralized than others, and these variations in structure and position allow researchers to investigate abstract relationships between social networks and collective behavior. Our readings for this week are important early contributions in the sociological literature on critical mass models and the network dynamics of collective action.


FURTHER READING


LAB 8 (March 11) Lederle Graduate Research Center A210

*= reading to be found on Moodle
WEEK 9 (March 23): Applications: Network Models of Social Inequality
[Lead Discussant: Augusto; Secondary Discussant: Felipe]

This week we delve into more advanced contemporary models in social science literatures on inequality. DiMaggio and Garip use a computational experiment to investigate inequality deriving from network externalities in a process for adoption of new technology. Kogut, Colomer, and Belinky investigate the implications for the population of corporate directors (and the network resulting from interlocking boards) of a policy that mandates a modest quota of female directors on corporate boards.


Kogut, Bruce, Colomer, Jordi, and Mariano Belinky. 2014. “Structural equality at the top of the corporation: Mandated quotas for women directors.” Strategic Management Journal, 35: 891–902.* [Implementation available in Python]

Kogut, Bruce, Colomer, Jordi, and Mariano Belinky. 2014. “Structural equality at the top of the corporation: Mandated quotas for women directors.” Appendix pages 1-6.*

FURTHER READING


LAB 9 (March 25) Lederle Graduate Research Center A210

* = reading to be found on Moodle
WEEK 10 (March 30): Applications: Models of Convergence and Differentiation
[Lead Discussant: Helene; Secondary Discussant: Scott]

In this week, we consider basic models of the proliferation of ideas, practices, or behaviors across populations. All of these models can be taken to represent dynamic networks driven by homophily, where individuals preferentially interact with others who share “culture” with them. Latané and Axelrod include an explicit representation of space (2-D cellular automata), while Mark allows the network to emerge purely as a function of cultural familiarity.

[Implementation available in Pascal, Visual Basic, Netlogo]

[Implementation available in GAUSS, Netlogo]

FURTHER READING


[Implementation available in Excel]


LAB 10 (April 1) Lederle Graduate Research Center A210

* = reading to be found on Moodle
WEEK 11 (April 6): Applications: Models of Polarization and Alliance in Conflict
[Lead Discussant: Tyler; Secondary Discussant: Scott]

This week we consider models of aggregation or bifurcation, depicting the processes by which agents align with one another (and against others) to generate coherent macrolevel patterns – such as military alliances between nations or polarization of political beliefs in populations.

[Implementation available in Java, Netlogo]

[Implementation available in R]

FURTHER READING


LAB 11 (April 8) Lederle Graduate Research Center A210

* = reading to be found on Moodle
WEEK 12 (April 13): Applications: Models of Norm Emergence and Maintenance
[Lead Discussant: Shuyin; Secondary Discussant: Nathan]

Here we examine the evolution of norms as an outcome of interaction among heterogeneous agents. Strang and Macy model firms adopting strategies in uncertain environments, where their beliefs about the efficacy of strategies depend on the performance of other firms in their environment. This demonstrates the possibility that even maladaptive strategies may emerge and be promoted as ‘fads’ in the population. Centola and Macy model development and enforcement of norms, showing conditions under which populations will publicly enforce norms that they do not privately support.


FURTHER READING


LAB 12 (April 15) Lederle Graduate Research Center A210

* = reading to be found on Moodle
**WEEK 13 (April 22): Review Session: Methodological Judgment Calls in Simulation**

This week we will review many methodological judgment calls that a simulation researcher must face: system-level vs. agent based, continuous vs. discrete time, synchronous vs. asynchronous updates (and order of activation), deterministic vs. stochastic (and various roles of stochasticity), continuous vs. discrete state space, local vs. global influence, network topology, choice functions and functional forms, specification of parameter values and initial conditions, experimental design (which parameters to fix or manipulate), range and granularity of manipulations, numerical exploration and illustration vs. mathematical proof, statistical analysis, number of replications, number of iterations, stability analysis and convergence, sensitivity analysis, interpretation and presentation of results, replication and alignment of simulations, verification and validation, calibration with empirical data, software tools, and many more…

There is no one ‘right’ answer for these judgment calls, but different right answers for different purposes and different audiences. In the past 12 weeks you have studied and discussed these concepts in applying them to research articles in our seminar, and practiced the concepts in our hands-on lab sessions. This week we will look at a single model I developed, then follow its revision through several rounds of journal review, as it encountered and responded to challenges on many of the above issues raised by different reviewers and editors.

[Implementation available in Matlab]


**WEEK 14 (April 27): TBA / Final Presentations / Wrap-Up**

The last week is flexible until I determine how to best advance the research programs of the seminar participants. We will likely spend our last week on seminar projects, including presentations, demonstrations, and peer review.

**LAB 14 (April 29) Lederle Graduate Research Center A210**

* = reading to be found on Moodle
This course does not require a background in college mathematics. However, a foundation in math would be helpful for theoretical work on social dynamics (as well as statistics). See a few recommendations below.

*Calculus for Biology and Medicine* (Neuhauser 2009) – This is a condensed textbook, mostly applied to population dynamics. It surveys differential and integral calculus, providing an accessible introduction to differential equations, linear algebra, and dynamical systems.

*A Course in Mathematical Modeling* (Mooney & Swift 1999) – This is an accessible undergraduate textbook in math modeling, using mostly applications to population dynamics. It surveys differential and difference equations, including deterministic and stochastic versions. It works through examples in *Mathematica*, and also discusses fitting models to data.

*Introduction to Mathematical Sociology* (Bonacich & Lu, 2012) – This is an introduction to various mathematical foundations most commonly applied in the social sciences: set theory, probability theory, graph theory, matrix algebra, and complexity theory, with applications in network analysis, social network theory, population demography, evolutionary game theory, and network exchange theory.

The following books offer more specialized extensions to some of the basic lessons introduced in this course:

*Agent Based Computational Demography* (Billari & Prskawetz, 2003) – This is an accessible collection of ABM applications to demographic processes (e.g. migration, mating, mortality).

*Agent Based and Individual Based Modeling* (Railsback & Grimm 2012) – Basic introduction to modeling highly integrated with learning the Netlogo environment.

*Game Theory Evolving* (Gintis 2009) – This is an accelerated introduction to evolutionary game theory, including a brief review of differential equations and dynamical systems theory.

*Historical Dynamics: Why States Rise and Fall* (Turchin 2003) – This is an application of system dynamics to historical and political explanation.

*Matrix Population Models* (Caswell 2001) – General text in matrix models of population dynamics (of particular interest to demographers and ecologists), in both continuous and discrete time. It works through examples in *Matlab* and includes a review of matrix algebra.

* = reading to be found on Moodle