IS 795/895: Agent-Based Modeling & Simulation for International Studies
Fall 2009

CRN 15835/15836
Wednesdays, 4:20–7:00 p.m.
Room: Batten Arts & Letters 7009

Associate Professor David C. Earnest, Ph.D.
Department of Political Science & Geography
Graduate Program in International Studies
Office: Batten Arts & Letters 7010

Contact:
Email: dearnest@odu.edu
Phone: 757-683-3934 (direct)
757-683-5700 (GPIS office)

Fall 2009 Office Hours:
Mondays, 1:00 to 3:00 p.m.
Tuesdays, 11:00 a.m. to 12:00 noon
Or
By Appointment

Syllabus

Catalogue Description

This course introduces masters and doctoral students to complex systems theory and to the application of agent-based modeling technologies to a variety of social systems. The course seeks to train graduate students to use basic computer simulations as a tool of inference for their research in international studies. Topics include the principles of chaos and complex systems and their relevance to contemporary issues in world politics; the epistemological foundations of simulation; object-oriented programming for the beginner; basic genetic algorithms, and the inferential challenges of nonlinear systems. Consistent with the University's commitment to modeling and simulation, the course emphasizes the interdisciplinary nature of agent-based modeling and simulation and welcomes students from a variety of disciplines, including physics, chemistry, geography, biology, engineering, sociology, psychology, economics and international studies.

Discussion

The interdisciplinary study of complex systems represents an important intellectual movement that challenges both traditional boundaries between disciplines in academia and conventional methods for understanding "systems," whether they are physical, biological or social. "Complex systems" share a number of properties that belie our disciplinary distinctions: they consist of a large number of autonomous actors, interacting independently in the absence of central authority. This decentralized structure allows complex systems to evolve, change, grow, adapt and even to anticipate, producing surprising dynamics. Examples are numerous: ecologies thrive or collapse depending on the interactions of species; particles produce waves and turbulence; social networks propagate disease; voters create electoral instability. As scientists have come to understand the behavior of complex systems, however, we have faced the simultaneous challenges of developing new methods and of training students in these techniques. Fortunately, as computing technology

has evolved students find the methods of complex systems theory more accessible than ever. This course seeks to acquaint students with one methodology for understanding such systems: agent-based modeling and simulation (ABM for short). Students will learn to apply concepts of complex systems theory and ABM methods to their research interests.

This course introduces student to chaos and complex systems theory and reviews applications of the agent-based modeling methods to a variety of problems. It teaches student some basic techniques for simulating systems using an agent-based modeling repertoire called NetLogo (http://ccl.northwestern.edu/netlogo/). Though a number of agent-based simulation tools are available, NetLogo is ideal for our purposes because it is easy to learn, is free, and yet is a powerful simulation tool. **The goal of the course is for the student to use NetLogo, in conjunction with his or her knowledge of complex systems theory and their own discipline, to simulate the behavior of a complex system and to test a number of hypotheses.** Students are expected to present their model to their classmates at the end of the term.

The course plan is divided into three sections. The first section introduces students to basic ideas of modeling & simulation (M&S), and how ABM relates to other M&S methodologies. This section also reviews how scholars of international studies have used ABM in their research. Once students are familiar with epistemological claims of ABM researchers, the second section introduces them to the techniques, algorithms and software theorists use to model complex systems. Finally, the third section reviews ABM applications to contemporary issues in international relations, international economics, and comparative politics. It also equips students with advanced techniques for modeling adaptive or "smart" agents.

Since modeling & simulation is a relatively new research paradigm, it likely will feel unfamiliar and intimidating to some students. The course seeks to help students in two ways. First, the course introduces students to the vast resources of the ABM modeling and simulation community, including the NetLogo User's Group and library of community models. We also seek to uphold the norms of this community, which emphasizes the open source nature of the work we do. For example, the course encourages students to share their source code for the models they develop. I expect students to provide the source code for their models to the rest of the class. In this way the students and course instructors alike learn from each other's modeling ideas.

Second, the goal of the course is to develop an understanding of how complex systems in international studies work, not how to write a program in NetLogo. The software should not be a barrier to the student's learning. Accordingly, I encourage students both to work with each other and to work with me. During the semester, we will divide each class session into two elements: lecture and discussion of the week's readings, followed by hands-on instruction in NetLogo. For this reason, I encourage you to bring a laptop computer to class each week; if you do not own a laptop, please let me know so that I can make alternate arrangements. Each week I will help you learn the software, work with you on writing code for your exercises, and help you develop your final model for your research project. Students should feel free to call on me for help.

Prerequisites

Students should complete either **MSIM 601** or the **MSIM 611-612 modeling and simulation foundation courses** before taking this seminar. I also expect students to have completed IS 600: Research Methods for International Studies; because we will conduct experiments in this course, students need to be familiar with the basic concepts of experimental design. Finally, although not a pre-requisite course, IS 620: Advanced Statistical Techniques in International Studies provides a useful foundation in statistics.

I expect students to have mastered basic international relations theories and concepts, including neorealism, neoliberal institutionalism, and the agent-structure debate. Though not required, the following courses serve as a useful foundation for this seminar.

ECON 650: International Economics

IS 601: International Relations Theory

Since international studies are the basic domain for our work in this course, students coming from other disciplines with less background in international studies may have to do a little remedial work to be up to speed in this area. However, if they join the class with more background in object oriented programming or statistical modeling, they should find that this provides the leeway to manage this small disadvantage.

Finally, I also expect students to read regularly newspapers, magazines, or websites that cover international issues. Because M&S is a relatively new research paradigm in international studies, it opens up new opportunities for research. ABM may offer purchase on events and problems in world affairs that once seemed too "complex" to study. By reflecting critically on the day's news, you may identify opportunities to apply ABM methods to theoretical and empirical blind spots.

Students who are unsure whether they have the necessary background or skills for the course should consult with me.

Course Materials

You can purchase the following books at the ODU bookstore (http://www.bkstr.com/webapp/wcs/stores/servlet/StoreCatalogDisplay?langId=-1&storeId=14928&demoKey=d&catalogId=10001). You may also find copies for a competitive price at the Dominion Bookstore on Hampton Boulevard.

Required Books

Gilbert, Nigel. 2008. *Agent-Based Models*. SAGE Quantitative Applications in the Social Sciences. Los Angeles: SAGE Publications. ISBN 9781412949644.

Jervis, Robert. 1997. *System Effects: Complexity in Political and Social Life*. Princeton: University Press. ISBN 9780691005300.

Miller, John H. and Scott E. Page. 2007. *Complex Adaptive Systems: An Introduction to Computational Models of Social Life*. Princeton: University Press. ISBN 9780691127026.

Required Software

All students should have access to NetLogo v. 4.0.4 or v. 4.1RC3, a free agent-based modeling integrated development environment. You can download NetLogo at http://ccl.northwestern.edu/netlogo/. NetLogo also will be installed on the workstations in the BAL 1013 computer labs.

Course Requirements and Evaluation

I will determine your final course grade based on four tutorials, a research project, and an oral presentation to the class.

1. Tutorials (Four total at 10 percent each = 40 percent of your final grade): The tutorials teach students (a) principles of complex nonlinear systems; (b) the basic ideas of agent-based modeling & simulation; and (c) the syntax of NetLogo. The first tutorial only requires students to use a spreadsheet such as Microsoft Excel, while the remaining three require students to use NetLogo. For each tutorial, I will provide students with a handout and directions, including links to online resources you may need to complete the tutorial.

For each tutorial, I expect students to provide both a brief write-up and a copy of the file they created. For the first tutorial, the file will be a spreadsheet. For the remaining three, I expect a copy of the NetLogo file.

a. *Tutorial #1: Chaos on a Spreadsheet* (from the Douglas and Elliot 1996 reading on September 16th). You will need only a spreadsheet such as Microsoft Excel or Quattro Pro. Your results are due on **September 16th**.
b. *Tutorial #2: Introduction to NetLogo*. For this tutorial, you will complete three exercises available in the NetLogo User's Manual (go to the "Help > NetLogo User's Manual" menu item in NetLogo). The exercises appear in the left-hand pane under the heading "Learning NetLogo." Your results are due on **September 30th**.
c. *Tutorial #3: Owen Densmore's Tutorial*. When learning a new language, nothing is as important as speaking it regularly. So it is with a computer language. To help you get more comfortable with NetLogo, to get some practice, and to learn a few advanced concepts, you will complete an exercise created by Own Densmore. This tutorial uses Stuart Kauffman's (1995) example of threads and buttons to illustrate the concept of a phase transition. You can access Densmore's tutorial at his terrific webpage full of NetLogo examples; see http://backspaces.net/cw/tutorial/NetLogo/. Your model is due on **October 21st**.
d. *Tutorial #4*: *Giving Agents "Memory".* By default, agents are "dumb"—they lack both strategies memories of the system. This is wholly unsatisfying for modeling social systems; if we hope to understand social actors in international studies, we need to learn how to model agents that exhibit the cognitive characteristics of social agents: perception, heuristics, anticipation, satisficing, and strategizing (among many possible others). This tutorial illustrates how to use lists in NetLogo to endow agents with a simple memory of past events or states of a system. Your model is due on **October 28th**.

2. Research Project (four parts = 40 percent of your final grade): The goal of the course is to apply ABM methods to an interesting problem in international studies. Each student will prepare a research "project"—not a research paper in the usual sense. Rather, your project will be more like a research design with some preliminary findings. Students will develop their project over the course of the semester by focusing on five components:

a. *An annotated bibliography***.** Students will provide an annotated bibliography that reviews the literature on their research questions. The bibliography should focus both on the theoretical questions and methodologies other researchers have used. Where relevant, the bibliography should give attention to other studies that have used agent-based models. The annotated bibliography is due on **October 7th**.
b. *Metacode***.** Each student will build an ABM with which to test hypotheses. To begin the process of authoring the model, students will submit their "metacode"—basically, a plain English write-up of their proposed model. Metacode for an ABM identifies (a) the agents in the system; (b) the role of the "environment" or "structure"; and (c) the algorithms agents will follow. Because metacode is in plain English, students do not yet need to write these algorithms in NetLogo's syntax. The metacode is due on **October 14th**.
c. *Prototype*. The process of authoring an ABM can frustrate even experienced researchers when compile-time and run-time errors arise (don't worry if you are unfamiliar with the words "compile-time" and "run-time"). To help you construct a working model, I want to review how you are translating your metacode into NetLogo's syntax. As we will learn, furthermore, researchers may have a choice of different algorithms and procedures to accomplish the same inferential goal; these choices may have consequences, however, for the speed of the model. Your prototype affords me an opportunity to help you work out some of these issues before you begin testing hypotheses. The prototype is due on **November 11th**.
d. *Validation and Experiment*. Once you have a working model, you will proceed to validate it and then to conduct an experiment using NetLogo's BehaviorSpace utility. As we will read for class on December 2nd, the validation of ABMs is a particularly difficult and controversial step in the research process. Researchers have yet to come to a full consensus on what "validation" means, let alone agree

to a set of protocols to validate models. Your task is more modest: "validation" simply means that you will check your NetLogo code to make sure the model is executing algorithms that are consistent with your metacode. Once you have done so, you will conduct a series of experiments that will help you test your hypotheses. You will provide me with a brief write up of your experimental results due on **December 2nd**.

3. Oral Presentation and Write-Up of Findings (20 percent of your final grade): During the last class session of the semester on **December 9th**, students will present their research project to the class. Your oral presentation should take no more than 15 minutes and should (a) articulate your research question; (b) briefly review the literature you discussed in the annotated bibliography; (c) describe your model's agents and algorithms; (d) show the working model; and (e) discuss your experimental results. Prior to December 9th, I expect each student to email the entire class an abstract of his or her project and a copy of his/her NetLogo model. In turn, I expect each student to read everyone's abstracts and to review each model's code.

You will also submit to me a final write-up of your research project that includes your review of the literature, a description of your model, and your experimental findings. Although this final write-up is not a complete research paper, I do expect you to compose a paper that is coherent and flows logically—don't simply take your annotated bibliography, your metacode, and your experimental results and combine them in a single file. For this reason, presentation matters: not only will I judge the final write-up on its clarity and organization, but I also will assess the degree to which it incorporates changes, criticisms and suggestions I made on your annotated bibliography, metacode, prototype and experiment.

Online Resources

The NetLogo home page (http://ccl.northwestern.edu/netlogo/) is an invaluable source of information on the modeling software we use. It includes an extensively library of models submitted by NetLogo developers and links to a variety of useful sources.

The NetLogo user's group (http://groups.yahoo.com/group/netlogo-users/) maintains both an online discussion group and a list-serv to facilitate dialogue among the community of NetLogo modelers. It is an active discussion group, with typically a dozen or more posts every day. It also can be an invaluable source for advice if you face a modeling challenge or if your code does not work. I regularly notice novice users seeking advice and guidance; likewise the software's developers at Northwestern University regularly participate in the discussions with helpful suggestions. I strongly recommend you join the discussion group.

Several other web sites are valuable sources of information on the science, craft and technology of agent-based modeling. The best social science-related ABM site is Leigh Tesfatsion's Agent-Based Computational Economics page at http://www.econ.iastate.edu/tesfatsi/ace.htm. This page provides an extensive library of resources for the social science modeler, including teaching and research resources as well as an e-book for Professor Tesfatsion's own ABM course. Swarm Wiki (http://www.swarm.org/index.php/Main_Page) has grown out of the Santa Fe Institute's Swarm ABM software development kit to include ABM resources for modelers using all varieties of software. It is a particularly good repository of advanced information on the computer science of agent-based modeling. The site also maintains a general ABM discussion list serve at http://www.swarm.org/mailman/listinfo/modelling.

In addition to NetLogo, social scientists use a variety of ABM software packages. Because model validation and verification are among the challenges of agent-based modeling, it behooves all researchers to use a common modeling toolkit. If you choose to move beyond NetLogo, I recommend you choose either RePast or MASON, both of which are free. You can download RePast at http://repast.sourceforge.net/ (I recommend the "Simphony" version because of its visual development environment). The Center for Social Complexity at George Mason University, one of the most influential social simulation research institutes in the world,

publishes MASON, or the Multi-Agent Simulator of Networks and Neighborhoods. You can download a free copy from http://cs.gmu.edu/~eclab/projects/mason/.

Two of the more influential ABM journals are the *Journal of Artificial Societies and Social Simulation* at http://jasss.soc.surrey.ac.uk/JASSS.html and Computational and Mathematical Organization Theory at http://www.springerlink.com/content/102865/.

Agent-based modeling also can be a lot of fun. NetLogo inspires modelers to write some pretty amazing programs and to share them with the community of users. Two of the better sites are Owen Densmore's http://backspaces.net (check out his "Hacks") and James P. Steiner's http://www.turtlezero.com/. When you're frustrated with NetLogo's code or simply need a break, I suggest you run Steiner's "Obliteration 2009" model at http://www.turtlezero.com/models/view.php?model=obliteration_2009. But be careful—you may never get any work done again.

Grades

There is no grading curve for the seminar. It is hypothetically possible for each student to get an A, or for each to get an F. I grade each student's work on its merits, irrespective of the merit of other students' work.

Based on your on-time completion of the required assignments and your adherence to the University's honor code (see below), I will assign you a final grade from the following grade scale:

Percent	*Final Grade*
94–100	A
90–93	A–
87–89	B+
83–86	B
80–82	B–
70–79	C
60–69	D
0–59	F

Late Work

I will accept late work but will penalize you five points for each day the assignment is late, including weekend days. To avoid this penalty, you must obtain from me an extension of the due date no later than 48 hours before the assignment is due, at which time we will agree to a new due date. I reserve the discretion to grant or withhold no-penalty extensions, and will give them only for serious reasons.

Academic Integrity

I encourage you to consider the consequences of academic dishonesty—there is no quicker way to ruin an academic career, to limit your job prospects after graduation, and to assure you never receive a security clearance. Also consider this: even as serious as ODU is about disciplining violations of the honor code, the University will be far more forgiving of transgressions than will be future employers. The consequences of a violation thus will extend well beyond the university's disciplinary process and your time at ODU.

I expect all students to understand and to abide by the University's Honor Code:

> "We, the students of Old Dominion University, aspire to be honest and forthright in our academic endeavors. Therefore, we will practice honesty and integrity and be guided by the tenets of the Monarch Creed. We will meet the challenge to be beyond reproach in our actions and our words. We will conduct ourselves in a manner that commands the dignity and respect that we also give to others." *Old Dominion University Graduate Catalog 2008-2009*, p. 14.

You should understand your rights and obligations, what constitutes a violation of the honor code and academic integrity, what disciplinary procedures and sanctions you may face, and what options I have should I suspect a violation. The College's web page includes information on plagiarism as well as a tutorial on how to avoid plagiarism (see http://al.odu.edu/al/resources/grad.shtml). If you are unfamiliar with the honor code and disciplinary procedures, I suggest you visit the Honor Council's web page (http://orgs.odu.edu/hc/). You may also refer to the Code of Student Conduct, Sanctions, and Disciplinary Procedures in the *Old Dominion University Graduate Catalog 2008-2009*, pp. 14-18.

Finally, California State University-Bakersfield has a good set of resources on academic integrity at http://www.csub.edu/ssric-trd/howto/plagiarism.htm.

I take the Honor Code seriously, and will pursue vigorously the adjudication of any violations I may perceive or suspect. If I suspect a student has committed a violation, I work only with the University Hearing Officer to determine whether or not a violation has occurred. Under no circumstances will I discuss allegations of academic dishonesty with the individual student.

Students with Disabilities

In accordance with the University's policies and procedures, I will work to accommodate students with disabilities. If you require such accommodations, please contact me by email, phone or during office hours as early in the semester as possible.

Sexual Harassment

It is the policy of Old Dominion University to provide students and employees with an environment for learning and working that is free of sexual harassment, whether by members of the same sex or the opposite sex, which is prohibited by Title IX of the Education Amendments of 1972 and Title VII of the 1964 Civil Rights Act. I expect all seminar participants to understand and abide by the University's sexual harassment policy and procedures, as detailed at http://www.odu.edu/ao/eoaa/policies/ 20sexualpolicy.shtml.

Course Evaluation

The syllabus is a contract between the professor and students regarding course requirements, expectations, and assessment, which establishes my obligations to you in teaching this class. I also take this contract to include your obligation to evaluate the course at the end of the semester. Student evaluations provide important feedback for me, and they are essential for measuring teaching effectiveness in the profession. Chairs and Deans see course evaluations every year in reviewing faculty performance, and committees at all levels of the University rely on the evaluations when making decisions about faculty retention, promotion and tenure. ODU takes your input very seriously, and a high rate of student response is necessary for a meaningful assessment of teaching effectiveness. Therefore, I ask you to commit yourself to filling out the online course evaluation when prompted at the end of the semester.

Course Plan and Schedule

PART ONE: THEORETICAL AND EPISTEMOLOGICAL FOUNDATIONS

September 2nd: Introductions, class materials

September 9th: ABM versus other modeling paradigms

Readings:
- Epstein, Joshua M. 2009. "Modelling to contain pandemics." *Nature* 460, 6 (August): 687.
- Farmer, J. Doyne and Duncan Foley. 2009. "The economy needs agent-based modeling." *Nature* 460, 6 (August): 685-6.
- Gilbert, Nigel and Klaus G. Troitzsch. 1999. *Simulation for the Social Scientist.* Philadelphia: Open University Press. 1-26.
- Lazer, David et al. 2009. "Computational Social Science." *Science* 323 (6 February 2009): 721-3.
- Pepinsky, T. B. 2005. "From Agents to Outcomes: Simulation in International Relations." *European Journal of International Relations* 11, 3: 367-94.

September 16th: Complex systems theory and international studies

Readings:
- Holland, John H. 1992. "Complex Adaptive Systems." *Daedalus* 121, 1 (Winter 1992): 17-30.
- Jervis, pp. 1-28.
- Kiel, L. Douglas and Euel Elliot, "Exploring Nonlinear Dynamics with a Spread Sheet: A Graphical View of Chaos for Beginners." *Chaos Theory in the Social Sciences: Foundations and Applications,* edited by Kiel and Elliott (Ann Arbor, MI: University of Michigan Press, 1996) pp. 19-30.
- Miller and Page, pp. 1-53.

Assignment Due: Tutorial #1: Chaos on a Spreadsheet

PART TWO: THE BASICS OF AGENT-BASED MODELING

September 23rd: Thinking about agents

Readings:
- Cederman, Lars-Erik. 2001. "Agent-Based Modeling in Political Science." *The Political Methodologist* 10, 1 (Fall 2001): 16-23.
- Gilbert, pp. 1-30.
- Miller and Page, pp. 55-89.
- Sawyer, R. Keith. 2005. *Social Emergence: Societies as Complex Systems*. New York: Cambridge University Press. 145-69.

September 30th: Introduction to NetLogo

Readings:
- Gilbert, pp. 46-68
- Boolean logic refresher (handout)

Assignment Due: Tutorial #2: NetLogo Tutorials 1 through 3

October 7th: Emergence: nonlinearity, tipping, and equilibria

Readings:
- Gilbert, Nigel. 2002. "Varieties of Emergence." Transcript of introductory talk given at the Workshop on Agent 2002 Social Agents: Ecology, Exchange, and Evolution Conference. October 11-12, 2002.
- Jervis, pp. 125-76.
- Miller and Page, pp. 91-113, 141-77.
- Page, Scott. 2006. "Essay: Path Dependence." *Quarterly Journal of Political Science* 1: 87-115.

Assignment Due: Research Project, Part I: Annotated Bibliography

October 14th: Social versus physical, biological and ecological systems

Readings:
- Arthur, W. Brian. 1994. "Positive Feedbacks in the Economy." *The McKinsey Quarterly* 4, 1 (Winter): 81-96.
- Davidsson, Paul. 2002. "Agent Based Social Simulation: A Computer Science View." *Journal of Artificial Societies and Social Simulation* 5, 1. Online resource available at http://jasss.soc.surrey.ac.uk/5/1/7.html.
- Gilbert, pp. 30-46
- Jervis 1997, pp. 29-91.
- Rosenau, James N. 2003. *Distant Proximities: Dynamics beyond Globalization*. Princeton: University Press. 205-31

Assignment Due: Research Project, Part II: Metacode

October 21st: Research design and model verification

Readings:
- Gilbert, pp. 46-68
- Miller and Page, pp. 91-113, 245-54

Assignment Due: Tutorial #3: Owen Densmore's Tutorial

October 28th: Criticisms of ABM

Readings:
- Earnest, David C. and James N. Rosenau. 2006. "Signifying Nothing? What Complex Systems Can and Cannot Tell Us about Global Politics." *Complexity in World Politics: Concepts and Methods of a New Paradigm.* Neil E. Harrison, ed. Albany: SUNY Press. 143-63.
- Miller and Page, pp. 68-76
- Taber, Charles S. 2001. "Of Spells, Potions, and Computational Science." *Political Methodologist* 10, 1 (Fall): 23-26.

Assignment Due: Tutorial #4: Giving Agents "Memory"

PART THREE: ADVANCED TOPICS AND APPLICATIONS

November 4th: Evolutionary computation and "smart" agents

Readings:
- Gilbert pp. 68-74
- Holland, John H. 1992. "Genetic Algorithms." *Scientific American* 267 (July): 66-72.
- Jervis, pp. 253-195.
- Miller and Page, pp. 178-199.

November 11th: Applications (1): comparative politics

Readings:
- Bennett, D. Scott. 2008. "Governments, Civilians, and the Evolution of Insurgency: Modeling the Early Dynamics of Insurgencies." *Journal of Artificial Societies and Social Simulation* 11, 4. Online resource available at http://jasss.soc.surrey.ac.uk/11/4/7.html
- Bhavnani, Ravi. 2003. "Adaptive Agents, Political Institutions and Civic Traditions in Modern Italy." *Journal of Artificial Societies and Social Simulation* 6, 4. Online resource available at http://jasss.soc.surrey.ac.uk/6/4/1.html
- Geller, Armando and Scott Moss. 2008. "Growing QAWM: An Evidence-Driven Declarative Model of Afghan Power Structures." *Advances in Complex Systems* 11, 2 (April): 321-335.
- Lustick, Ian S., Dan Miodownik, and Roy J. Eidelson. 2004. "Secessionism in Multicultural States: Does Power Sharing Prevent or Encourage It?" *American Political Science Review* 98, 2 (May): 209-229.

Assignment Due: Research Project, Part III: Prototype

November 18th: Applications (2): international trade and conflict

Readings:
- Axelrod, Robert, and D. Scott Bennett. 1993. "Choosing Sides: A Landscape Theory of Aggregation." *British Journal of Political Science* 23 (April): 211-233.
- Cederman, Lars-Erik. 2003. "Modeling the Size of Wars: From Billiard Balls to Sandpiles." *American Political Science Review* 97, 1 (February): 135-150.
- Earnest, David C. 2008. "Coordination in Large Numbers: An Agent-Based Model of International Negotiations." *International Studies Quarterly* 52, 2 (June). 363-382.
- Tesfatsion, Leigh. 2002. "Agent-Based Computational Economics: Growing Economies from the Bottom Up." *Artificial Life* 8, 1 (Winter): 55-82.

November 25th: No class session (Thanksgiving)

December 2nd: Model validation

Readings:

- Axtell, R. et al. 1996. "Aligning Simulation Models: A Case Study and Results." *Computational and Mathematical Organization Theory* 1, 2 (February): 123-141.
- Marks, R. E. 2007. "Validating Simulation Models: a General Framework and Four Applied Examples." *Computational Economics* 30, 3 (October): 265-290.
- Moss, S. and B. Edmonds. 2005. "Sociology and simulation: statistical and quantitative cross-validation." *American Journal of Sociology* 110, 4 (January): 1095-1131
- Troitzsch, K. G. 2004. "Validating Simulation Models." *Proceedings of the 18th Simulation Multiconference*. Erlangen, Germany: Society for Modeling & Simulation International.

Assignment Due: Research Project, Part IV: Model Validation and Experiment Results

December 9th: Student presentations

Readings:

- Student research project abstracts and code

Assignments Due: Research Project, Part V: Write Up of Findings and Oral Presentation to Class

Suggested Additional Readings

Albion, Peter S. 1998. *Barriers and Bounds to Rationality: Essays on Economic Complexity and Dynamics in Interactive Systems*. Princeton: University Press.

Arthur, W. Brian. 1993. "Why Do Things Become More Complex?" *Scientific American* 268, 5 (May): 144.

Axelrod, Robert. 1997. *The Complexity of Cooperation: Agent-Based Models of Competition and Collaboration*. Princeton: University Press.

Cederman, Lars Erik. 1997. *Emergent Actors in World Politics: How States and Nations Develop and Dissolve.* Princeton: Princeton University Press.

Colella, Vanessa S., Eric Klopfer, and Mitchel Resnick. 2001. *Adventures in Modeling: Exploring Complex, Dynamic Systems with StarLogo*. Teachers College Press.

Coveney, Peter and Roger Highfield. 1995. *Frontiers of Complexity: The Search for Order in a Chaotic World*. New York: Fawcett Columbine.

Dendrinos, Dimitrios S. 1997. "Cities as Chaotic Spatial Attractors." In Kiel and Elliott, 1997 (chapter 11).

Epstein, Joshua M. 2006. *Generative Social Science: Studies in Agent-Based Computational Modeling*. Princeton: University Press.

Epstein, Joshua M. and Robert Axtell. 1996. *Growing Artificial Societies: Social Science from the Bottom Up.* Washington, DC: Brookings Institution.

Eve, Raymond A., Sara Horsfall and Mary E. Lee, eds. 1997. *Chaos, Complexity and Sociology: Myths, Models, and Theories.* Thousand Oaks, CA: SAGE Publications.

Flake, Gary W. 1998. *The Computational Beauty of Nature: Computers Explorations of Fractals, Chaos, Complex Systems, and Adaptation*. Cambridge, MA: MIT Press.

Gilbert, Nigel and Klaus G. Troitzsch. 1999. *Simulation for the Social Scientist*. Open University Press.

Holland, John H. 1995. *Hidden Order*. Reading, Mass.: Addison-Wesley.

Holland, John H. 1998. *Emergence: From Chaos to Order*. Reading, MA: Addison-Wesley.

Johnson, Steven. 2001. *Emergence: The Connected Lives of Ants, Brains, Cities and Software*. New York: Scribner.

Kauffman, Stuart. 1995. *At Home in the Universe: The Search for the Laws of Self-Organization and Complexity*. New York: Oxford University Press.

Kiel, L. Douglas and Euel Elliot, eds. 1996. *Chaos Theory in the Social Sciences: Foundations and Applications.* Ann Arbor, MI: University of Michigan Press.

Kollman, Ken, John H. Miller, and Scott E. Page. 1997. "Political Institutions and Sorting in a Tiebout Model." *American Economic Review* 87, 5 (December): 977-992.

Kuran, Timur. 1991. "Now Out of Never: The Element of Surprise in the East European Revolutions of 1989." *World Politics* 44 (October): 7-48.

Langton, Christopher G. 1995. *Artificial Life: An Overview*. Cambridge, Mass.: MIT Press.

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