Syllabus
EES 4760/5760: Agent- and Individual-Based Computational Modeling

Jonathan Gilligan
Vanderbilt University

Fall 2024

1 Nuts and Bolts

1.1 Class Meetings

MW 8:40–9:55 Stevenson 2220

1.2 Professor

Jonathan Gilligan
Professor of Earth & Environmental Sciences
Professor of Civil & Environmental Engineering
Office: Stevenson 5735 (Stevenson #5, 7th floor)
`jonathan.gilligan@vanderbilt.edu`
Office Hours: TBA, or by appointment.

1.3 Email

If you want to communicate with me, be sure to begin the subject line of your email with "EES 4670" or "EES 5670". This helps assure that I will see your message quickly and respond to it.

I have set my email reader to flag all messages like this as important, so I will read them first. This also assures that I do not mistake your email for spam. I typically receive over 100 emails per day, so if you do not follow these instructions I may not notice your email.

2 Course Description

2.1 Catalog Description

Agent- and Individual-Based Computational Modeling. Applications in natural, social, and behavioral sciences and engineering. Designing, programming, and documenting models. Using models for experiments. Examples from environmental science, ecology, economics, urban planning, and medicine. Familiarity with basic statistics and proficiency in algebra are expected. [3] (MNS)

2.2 Narrative Description

Agent-based and individual-based modeling has become a powerful tool for research in many fields, including anthropology, civil engineering, computer science, ecology, economics, epidemiology, marketing, medicine, political science, public policy, robotics, sociology, transportation, and urban planning.

Agent-based modeling is used to study how individual agents (which can represent a wide range of things, such as people, animals, plants, cars, robots, or packets of information in a communications network) that make simple decisions or execute simple behaviors, can produce complex and unexpected collective behavior through their interactions. Agent-based models have been used to investigate racial segregation in American cities, traffic jams, adaptation to global warming, disease outbreaks, inflammatory response to wound infections, ecosystem dynamics, impacts of changing land-use on tropical rain forests, political instability, and market penetration of home solar-energy systems.

This course will provide an introduction to agent and individual-based modeling. You will learn how to design, program, and document agent-based computational models using the free open-source NetLogo environment. You will use these models scientifically to perform computational experiments and interpret the results.

You do not need to have any prior knowledge of computer programming, but I do expect that you are familiar with basic statistics and algebra. We will use the NetLogo environment for writing and running agent-based models. NetLogo is a widely used system that is both powerful and easy to learn, so you can quickly start to program your own models.

3 Goals for the Course

My goals for this course are that at the end of the semester:

- You will understand what scientific modeling is, including mathematical and computational modeling.
- You will become skilled with the NetLogo programming language and be able to use it for coding complete agent-based models.
- You will be able to use the ODD (Overview, Design concepts, and Details) method to document your own agent-based models and to understand how other people's models work.
- You will be able to use computational models scientifically, performing experiments and interpreting their results in order to learn about the causes and mechanisms of complex systems phenomena in the real world.
- You will understand the Pattern Oriented Modeling methodology and be able to use it to design, conduct, and interpret experiments with agent-based models.

4 Structure of the Course:

I divide the semester into three parts:

1. **Introduction to Agent-Based Models and NetLogo:** The first part of the course introduces the basic concepts of computer modeling, what agent-based models are, and how to use the NetLogo environment to write and run simple agent based models. I do not assume any prior experience with programming or computer modeling, so this part of the course will give you everything you need to get started.

2. **Designing Agent-Based Models:** Next, we study the essential components of agent-based models and develop a systematic approach to designing and implementing agent-based models that will be suitable for doing real science. This section will use examples of real agent-based models that have been used for published research.

3. **Using Models for Serious Research:** After mastering the components that good models should have, we step back from the details and work at a more strategic level to consider how we can design and use models to answer research questions in social and natural sciences.

4.1 Reading Material

There is one required textbook and one optional one, which I recommend primarily to students who are interested in social-science applications of agent-based modeling. From time to time during the term, I will assign supplementary reading on the Internet or in handouts that I will post to the class web site.

TEXTBOOKS

- **Required:**

  - Steven F. Railsback & Volker Grimm, *Agent-Based and Individual-Based Modeling: A Practical Introduction*, 2nd Edition (Princeton University Press, 2019; ISBN 978-0-691-19083-9).

    There is a companion web site to *Agent-Based and Individual-Based Modeling*, `http://www.railsback-grimm-abm-book.com/index.html`, that has additional useful information.

    All textbooks have errors. The authors maintain a list of errors that have been reported to them and you can download it from the book's web site at `http://www.railsback-grimm-abm-book.com/index.html` or from the course web site at `https://ees4760.jgilligan.org/files/Railsback_Grimm_2012_Errata.pdf`.

- **Recommended (optional):**

  - Paul E. Smaldino, *Modeling Social Behavior: Mathematical and Agent-Based Models of Social Dynamics and Cultural Evolution* Princeton University Press, 2023; ISBN 978-0-691-22414-5).

ADDITIONAL RESOURCES

This course only scratches the surface of what is possible with agent-based models, and what researchers are doing with them. I have prepared a separate handout on additional reading and computational resources for doing research with agent-based models. This handout lists a number of helpful books, journals, web sites, and software tools that you may find useful or interesting if your want to learn more.

CLASS WEB SITE

In addition to Brightspace, I have set up a server at `https://ees4760.jgilligan.org`, where I post the web versions of class slides and interactive web-based applications to that can be useful for working with data output from agent-based modeling experiments.

OVERVIEW OF READING ASSIGNMENTS

I will give out detailed reading that give specific pages to read for each class and notes on important things you should understand. **I expect you to complete the reading before you come to class on the day for which the reading is assigned**, so you can participate in discussions of the assigned material and ask questions if there are things you don't understand.

4.2 Computer Software

For this class, we will write and execute agent-based models using the NetLogo modeling system. NetLogo is free software developed at Northwestern University. You can download it from `https://ccl.northwestern.edu/netlogo/`. NetLogo is available for Windows, Mac OS X, and Linux. I have chosen it for this course because it is free, it runs on all the major operating systems, its programming language is very easy to learn; and it allows you to easily create a visual representation of your model.

You should download NetLogo version 6.4.0 (the latest version) from `http://ccl.northwestern.edu/netlogo/download.shtml` and install it on your computer.

NetLogo has been used widely both for education and also for research-grade modeling. However, no computer software is perfect and for some large or complicated models, NetLogo may be inadequate. There are a number of other open-source agent-based modeling systems that are more powerful than NetLogo and are better suited for large and complex models. However, these systems are much harder to learn and much harder for even experts to write models in. My experience is that for most modeling projects, you can get more done in a week with NetLogo than in a month or more with the other systems I know of.

Optionally, you may want to install the free R statistical software, which can help with analyzing data from NetLogo computational experiments. There is more information bout downloading and installing R on the Tools page on the class website.

4.3 Graded Work

BASIS FOR GRADING

Class participation	5%
Homework	30%
Team Project	25%
Research Project	40%

NOTE: Graduate student research projects will involve additional requirements and a longer final report than undergraduate projects, and graduate students will be assigned more homework exercises.

HOMEWORK

You will turn in homework on Brighspace. It will be due by 11:59 pm on the day it's assigned unless the assignment specifies a different time.

PROJECTS

You will do assigned team projects and one research project. On the team projects you will work with a partner or a small team to program and work with models. run experiments with the model, write up the results, and make a short presentation to the class.

For your research project, you will study an existing model, adapt it to investigate a new research question, run and analyze experiments using the model, write up the results, and make a presentation to the class.

TESTS AND EXAMINATIONS

There will not be any tests or examinations in this course. Your grade will be based on class participation, homework, modeling projects, and in-class presentations.

5 Honor Code:

This course, like all courses at Vanderbilt, is conducted under the Honor Code.

Studying: As you study for this class, I encourage you to to seek help from me or from other classmates or friends.

Homework Assignments: I encourage working together on homework assignments: you may talk with your friends and classmates about homework assignments, compare notes on how you are working a problem, and you may look at your classmates' work on homework assignments. But you must work through the problems yourself in the work you turn in: **Even if you have discussed the solution with others you must work through the steps yourself and express the answers in your own words. You may not simply copy someone else's answer.**

Team Assignments: On some assignments, in which I explicitly direct you to work with others. These team assignments will contain instructions how the honor code applies.

Research Project: The research project assignment will contain details about how the honor code applies to the research project.

If you ever have questions about how the Honor Code applies to your work in this course, please ask me. **Uncertainty about the Honor Code does not excuse a violation.**

6 Final Note:

I have made every effort to plan a busy, exciting, and instructive semester. I may find during the term that I need to revise the syllabus to give more time to some subjects or to pass more quickly over others rather than covering them in depth. Thus, while I will attempt to follow this syllabus as closely as I can, you should realize that it is subject to change during the semester.

7 Meet Your Professor

Jonathan Gilligan has worked in many areas of science and public policy. His past research includes work on laser physics, quantum optics, laser surgery, electrical properties of the heart, using modified spy planes to study the ozone layer in the stratosphere, and connections between religion and care for the environment. He is an Associate Professor of Earth & Environmental Sciences, Associate Professor of Civil & Environmental Engineering, and the director of the Vanderbilt Climate and Society Grand Challenge Initiative.

Professor Gilligan's current research investigates the role of private-sector organizations as well as individual and household behavior in cutting greenhouse gas emissions; how "smart cities" can use technology to reduce environmental harm and promote health and citizen empowerment; water conservation policies in American cities; vulnerability and resilience to environmental stress in Bangladesh; and developing new directions for climate policy in the US. He is principal investigator of a new project to study how sustainable energy infrastructure can address the growing disparities between urban and rural communities in the Southeastern United States.

In 2017, Professor Gilligan and Professor Michael Vandenbergh shared the Morrison Prize for the highest-impact paper on sustainability law and policy published in the previous year. Professors Gilligan and Vandenbergh have developed this work into a book, *Beyond Politics: The Private Governance Approach to Climate Change* (Cambridge University Press, 2017).

In addition to his academic work, Professor Gilligan dabbles in writing for the theater. His stage adaptation of Nathaniel Hawthorne's *The Scarlet Letter*, co-written with his mother Carol Gilligan, has been staged at The Culture Project in New York City, starring Marisa Tomei, Ron Cephas Jones, and Bobby Cannavale, and was later performed at Prime Stage Theatre, Pittsburgh and in a touring production by The National Players. Prof. Gilligan and Carol Gilligan also wrote the libretto for an opera, *Pearl*, in collaboration composer Amy Scurria, and producer/conductor Sara Jobin, which was performed at Shakespeare & Company in Lenox MA, starring Maureen O'Flynn, John Bellemer, Marnie Breckenridge, John Cheek, and Michael Corvino, and in Shanghai China, starring Li Xin, Wang Yang, John Bellemer, and Lin Shu.

Schedule of Classes (Subject to Change)

IMPORTANT NOTE: This schedule gives a rough indication of the reading for each day. See the assignment sheets posted on Brightspace and the course web site for the detailed daily assignments.

Date	Topic	Reading
Wed., Aug. 21	Introduction	No reading
Mon., Aug. 26	The computer modeling cycle	*Railsback & Grimm* Ch. 1, Handouts (on Brightspace)
Wed., Aug. 28	Introduction to NetLogo	*Railsback & Grimm* Ch. 2
Mon., Sep. 2	Specifying models: The ODD protocol	*Railsback & Grimm* Ch. 3
Wed., Sep. 4	Your first model	*Railsback & Grimm* Ch. 4
Mon., Sep. 9	Using models for science	*Railsback & Grimm* Ch. 5
Wed., Sep. 11	Testing and validating models	*Railsback & Grimm* Ch. 6
Mon., Sep. 16	Choosing Research Projects	*Railsback & Grimm* Ch. 7
Wed., Sep. 18	Emergence	*Railsback & Grimm* Ch. 8
Mon., Sep. 23	Observation	*Railsback & Grimm* Ch. 9
Wed., Sep. 25	Sensing	*Railsback & Grimm* Ch. 10
Mon., Sep. 30	Adaptive Behavior and Objectives	*Railsback & Grimm* Ch. 11
Wed., Oct. 2	Prediction	*Railsback & Grimm* Ch. 12
Mon., Oct. 7	Interaction	*Railsback & Grimm* Ch. 13
Wed., Oct. 9	Team Presentations	No reading
Mon., Oct. 14	**FALL BREAK**	
Wed., Oct. 16	Research Project ODDs	No reading
Mon., Oct. 21	Scheduling	*Railsback & Grimm* Ch. 14
Wed., Oct. 23	Stochasticity	*Railsback & Grimm* Ch. 15
Mon., Oct. 28	Collectives	*Railsback & Grimm* Ch. 16
Wed., Oct. 30	Patterns	*Railsback & Grimm* Ch. 17–18
Mon., Nov. 4	Theory Development	*Railsback & Grimm* Ch. 19
Wed., Nov. 6	Parameterization and Calibration	*Railsback & Grimm* Ch. 20
Mon., Nov. 11	Parameterization and Calibration 2	*Railsback & Grimm* Ch. 20
Wed., Nov. 13	Analyzing ABMs	*Railsback & Grimm* Ch. 22
Mon., Nov. 18	Sensitivity and Robustness	*Railsback & Grimm* Ch. 23
Wed., Nov. 20	Looking Ahead: ABMs Beyond this Course	*Railsback & Grimm* Ch. 24

Date	Topic	Reading
Mon., Nov. 25		
Wed., Nov. 27	**THANKSGIVING BREAK**	
Mon., Dec. 2	Presentations	No reading
Wed., Dec. 4	Presentations	No reading