Syllabus, Fall 2021C, for OIDD 325:
Thinking with Models
3:30-5:00 p.m. T & R, Room: JMHH 270 and Online
Canvas:
https://canvas.upenn.edu/courses/1600669
GitHub:
https://github.com/stevenokimbrough/TwM/

Instructor: Steven O. Kimbrough
Office hours: 10:00–11:30 T & R and by appointment

0 In a nutshell

Modeling is the construction and analysis of representations of real-world phenomena. The practice is ubiquitous across the sciences, engineering, and business. It enters into many practical decision contexts, from setting international policy to making everyday business decisions and everything in between. The principal aim of this course is to acquaint students with the modeling process and, especially, to help students learn how to think critically about modeling results, as well as how to construct, analyze, and verify such models. As such the lessons of this course apply with great generality.

We will work on both the input side of modeling (conceiving, designing, and building models), and on the output side (extracting information for insight and decision making). On the input side, we will focus mainly on learning and using NetLogo for building models. NetLogo is a freely available development environment for building a special but broad class of simulation models, known as ABMs (agent-based models). ABMs are widely and increasingly used in business applications, and in science and engineering generally. NetLogo, under long development sponsored by the National Science Foundation, is designed with a "low floor, high ceiling" philosophy. That is, it is remarkably easy to learn how to create interesting models and it is richly featured enough and extendable enough to support quite advanced implementations. Originally designed to teach middle school students how to program, NetLogo models now appear in hundreds of peer reviewed scientific publications.

On the output side, our focus will be on generating multiple solutions or runs of our models and then analyzing what the resulting data can teach us. As it happens, NetLogo has excellent tools for supporting such efforts. The philosophy here is that models are instruments by which we can legitimately generate large amounts of data that can in turn be analyzed to good effect.

The course has been substantially revised in preparation for fall 2021 to include substantial treatment of social networks and of what has recently come to called microsimulation. These topics are apt for recent application developments, which we will cover in lectures; this material is being used more and more in practice.

Student deliverables for the course consist of four small group projects spread throughout the semester, along with (almost) daily in-class assignments that are checked to ascertain involvement, but only lightly graded.

Assigned readings are available online, without cost to students.

1 Class Description

When a flu pandemic strikes, who should get vaccinated first? What's our best strategy for minimizing the damage of global climate change? Why is Philadelphia racially segregated? Why do most sexually reproducing species have two sexes, in roughly even proportions? These and many other scientific and practical problems require us to get a handle on complex systems. And an important part of deepening our understanding and sharpening our intuitions requires us to think with models, that is, to use models in our deliberations about what to believe and what to do.

Modeling is the construction and analysis of idealized representations of real-world phenomena. This practice is ubiquitous across the sciences, and enters into many practical decisions from setting international policy to making everyday business decisions. The principal aim of this course is to acquaint students with the modeling process and, especially, to help students learn how to think critically about modeling results, as well as how to construct, analyze, and verify such models.

Students who take this course will learn about the varied practices of modeling, and will learn how to construct, analyze, and validate models. Most importantly, students who take this course will learn how to critically evaluate the predictions and explanations generated by models, whatever the source of these results. While we will familiarize students with a variety of types of models, our primary focus will be on computer simulations, as they are increasingly relied upon for scientific research and practical deliberation. In addition to studying general methodological discussions about modeling, this will be a "hands on," laboratory-based course. Students will practice manipulating, modifying, and analyzing models, as well as constructing models from scratch.

As an essential feature of learning about modeling we will actually design and build (program) models, which we then study. NetLogo (`https://ccl.northwestern.edu/netlogo/`) will be the main programming environment. Students will learn to program in it and build agent-based models. NetLogo was designed to be easy to learn and we assume no prior programming experience. For approximately the first 2/3 of the course we will focus on learning NetLogo and building and analyzing models in it. During approximately the last 1/3 of the semester, students will work on their term projects and the course presentations will focus on modeling issues that transcend or extend the basics of modeling in NetLogo.

1.1 Teaching Philosophy

This course, "Thinking with Models," and the subject it names (thinking with models) is about building and interpreting models, for both scientific purposes and to support decision making. Thinking with models is practiced pervasively outside the academy. It is an important and much relied upon, even essential, skill in the modern world, whether in the public, private, or third sector of the economy.

Our main goal in the course is for students to become proficient in this practice. In consequence, we emphasize above all "learning by doing" and undertaking projects as fundamental to the educational goals of the course. A portion of the time and effort in the course will follow the more traditional mode of instructors presenting information on the subject matter. The majority of the time and effort, however, will be spent in apprenticeship (or internship) mode, in which students learn by working on projects, calling on the instructors for guidance and special knowledge as needed.

Completed projects will be evaluated, of course. Project development in apprenticeship mode, however, is inherently cooperative and supportive, rather than evaluative. We emphasize throughout that the class constitutes a community of learners with shared interests in learning how to think with models.

2 Texts and Software

- NetLogo. Free download from `http://ccl.northwestern.edu/netlogo/`.
- *NetLogo User Manual* (comes with NetLogo)
- *An Introduction to Agent-Based Modeling* (Wilensky and Rand, 2015). Short name: IABM. The textbook by Wilensky and Rand is available (for free) on JSTOR as a series of PDFs: `http://www.jstor.org/stable/j.ctt17kk851`. You need to log in through the Penn library system and then it's free. Also, the files for IABM are posted on Canvas at Files; Readings; IABM-textbook.
- Other readings and handouts
- The *Teaching Notes*, available on Canvas incrementally as the course proceeds.

3 Grades

The conduct of the course will be heavily influenced by teaching philosophy (above). As such, in many class meetings there will be a short lecture and Q&A session, followed by individual and group exercises, which will be discussed later in class. Grades will be based on in-class performance, short assignments, and four group projects. The classed is designed so that anyone who participates fully and takes it seriously should, with a normal level of effort ($\approx$ 2 hours of study per hour of class time), be able to successfully master the material.

Grading: In-class exercises and assignments (20%), plus the four course projects (20% each).

4 Other Admin and Relata

- Academic integrity

  Like cookies. If you take this course, I hold you to agreement with Penn's code of academic integrity. Violations of academic integrity are on a par with sexual harassment: don't do it. See me if you have questions.

- Wellness and well-being

  Major initiatives at Penn. The norm is one of mutual aid. Everyone is at risk and everyone has a duty to be helpful. You can talk with me; my door is open.

- Anyway, we want everyone to come see us (on-line!) sometime during the semester.

5 Covid-19

We will meet in class as long as that appears sufficiently safe. Masks are required in class. If facts on the ground indicate sufficient risk, we will fall back to meeting via Zoom. We will discuss matters in this regard throughout the semester.

6 Fall 2021 Class Schedule

Note: Subject to adjustment in response to expressed interests and challenges.

1. Introduction and overview of the course.

   Reading (after class): Skim: IABM chapter 0, (Wilensky and Rand, 2015, chapter 0), "Why Agent-Based Modeling". Read carefully and thoroughly IABM chapter 1, (Wilensky and Rand, 2015, chapter 1).

2. Getting started with ABM.

   Readings (before class): from the *NetLogo User Manual* the tutorials listed below.

   - Learning NetLogo
     - Tutorial #1: Models
     - Tutorial #2: Commands
     - Tutorial #3: Procedures

   Recommended: Weisberg (2013, chapters 1 and 2).

3. The Ants Model

   Reading (before class): (Wilensky and Rand, 2015, Chapter 1).

   Bring your NetLogo-enabled laptops to class and be prepared to use them.

4. BehaviorSpace

   In the NetLogo User Manual, the BehaviorSpace Guide:

   This guide has three parts:

   - What is BehaviorSpace?: A general description of the tool, including the ideas and principles behind it.
   - How It Works: Walks you through how to use the tool and highlights its most commonly used features.
   - Advanced Usage: How to use BehaviorSpace from the command line, or from your own Java code.

   (You can skip the Advanced Usage part.)

   Recommended: Kimbrough and Lau (2016, chapter 1), file Chapter1BAbook.pdf on Canvas.

5. Creating Simple ABMs

   Bring your NetLogo-enabled laptops to class and be prepared to use them.

   Readings (before class):

   (a) (Wilensky and Rand, 2015, Chapter 2).

   (b) *NetLogo User Manual* (`http://ccl.northwestern.edu/netlogo/docs/` and installed on your computer with the NetLogo distribution):

   - Reference: Interface Guide
   - Reverence: Programming Guide

- Agents
- Procedures
- Variables
- Tick counter

(c) And review for mastery: *NetLogo User Manual* (`http://ccl.northwestern.edu/netlogo/docs/` and installed on your computer with the NetLogo distribution):

- Tutorial #1: Models
- Tutorial #2: Commands
- Tutorial #3: Procedures

Be sure to read, for the sake of doing the exercises, the "Agentsets" section of the "Programming Guide" in the *NetLogo User Manual*. Also, familiarize yourself with the commends in the "Agentset" category of the "Dictionary."

In general, you should read the entire "Programming Guide" in the *NetLogo User Manual*.

6. Conventional programming in NetLogo; lists.

7. Python Introduction

8. Program Procedures: Python and NetLogo

9. Regression and pandas (Python) for analyzing BehavioralSpace experiments

10. Exploring and Extending Agent-Based Models, 1: Fire and DLA models.

    Reading (before class): (Wilensky and Rand, 2015, chapter 3, pages 101–128), "Exploring and Extending Agent-Based Models", the Fire Model and the Diffusion-Limited Aggregation (DLA) Model.

    Model of the Week: Castello-Urtino-Catania. It's in NetLogo and it's in the Files/Readings/PedestrianBehavior/ directory on Canvas. But it only works with NetLogo version 5 (the automatic conversion to 6 fails, but you can download and install a version 5 of NetLogo). Skim the paper: Pluchino et al. (2014), "Agent-Based Simulation of Pedestrian Behaviour in Closed Spaces: A Museum Case Study."

11. Exploring and Extending Agent-Based Models, 2: Segregation and El Farol.

    Reading (before class): (Wilensky and Rand, 2015, chapter 3, pages 128–153), "Exploring and Extending Agent-Based Models", the Segregation model.

12. Wolf-Sheep Predation Model; Tour of NetLogo models

    Reading (before class): (Wilensky and Rand, 2015, chapter 4).

13. Links

    Instructor handout. Reading (before class): the "Links" section of the "Programming Guide" in the *NetLogo User Manual*.

14. Spread of Disease,(Wilensky and Rand, 2015, Chapter 6)

15. Viral Marketing (Simple Viral Marketing model) (Wilensky and Rand, 2015, Chapter 8, pages 406-415)

16. Networks, 1.

    Reading (before class): the "Networks" extension section in the *NetLogo User Manual*.

17. Networks, 2.

    Reading (before class): the "Networks" extension section in the *NetLogo User Manual*.

18. Plotting in NetLogo.

    Read: Appendix A of the teaching notes.

19. Microsimulation.

    Microsimulation + ABM = ABMS. Instructor handout. Overview of real-world applications.

20. ABMS cases, 1.

    Ideal Free Foraging model. Instructor handout.

21. ABMS cases, 2.

    Ideal Free Foraging model. Instructor handout.

22. ABMS cases, 3.

    Pickup or Delivery model. Instructor handout.

23. ABMS cases, 4.

    Pickup or Delivery model. Instructor handout.

24. ABMS cases, 5.

    Office Coffee Room model. Instructor handout.

25. ABMS cases, 6.

    Office Coffee Room model. Instructor handout.

26. ABMS cases, 7.

    Honeybee Democracy. Instructor handout.

27. Designing ABMs, 1.

    Instructor handout.

28. Designing ABMs, 2.

    Even more; Recapitulation and Summary. Looking forward.

7 Calendar, fall 2021

Last class is on Thursday, December 9, 2021.

	0	1	2
0	—	R: 2021-09-30	T: 2021-11-09
1	T: 2021-08-31	T: 2021-10-05	R: 2021-11-11
2	R: 2021-09-02	R: 2021-10-07	T: 2021-11-16
3	T: 2021-09-07	T: 2021-10-12	R: 2021-11-18
4	R: 2021-09-09	T: 2021-10-19	T: 2021-11-23
5	T: 2021-09-14	R: 2021-10-21	T: 2021-11-30
6	R: 2021-09-16	T: 2021-10-26	R: 2021-12-02
7	T: 2021-09-21	R: 2021-10-28	T: 2021-12-07
8	R: 2021-09-23	T: 2021-11-02	R: 2021-12-09
9	T: 2021-09-28	R: 2021-11-04	—

Table 1: Class number :: date correlation, for Tuesday (T) and Thursday (R) classes, fall 2021. Penn academic calendar `https://almanac.upenn.edu/penn-academic-calendar`

References

Kimbrough, S. O. and Lau, H. C. (2016). *Business Analytics for Decision Making*. CRC Press, Boca Ratan, FL.

Mann, C. C. (2012). Orion Magazine | State of the Species. `https://orionmagazine.org/article/state-of-the-species/`.

O'Sullivan, D. and Perry, G. L. (2013). *Spatial Simulation*. Wiley-Blackwell, UK.

Pluchino, A., Garofalo, C., Inturri, G., Rapisarda, A., and Ignaccolo, M. (2014). Agent-based simulation of pedestrian behaviour in closed spaces: A museum case study. *Journal of Artificial Societies and Social Simulation*, 17(1):16. `http://jasss.soc.surrey.ac.uk/17/1/16.html`.

Weisberg, M. (2013). *Simulation and Similarity: Using Models to Understand the World*. Oxford University Press, Oxford, UK.

Wilensky, U. and Rand, W. (2015). *An Introduction to Agent-Based Modeling*. The MIT Press, Cambridge, MA.