Agent Based Modelling with Python

by Gene Callahan

Agent-based modeling (ABM) is a cutting edge research area in a variety of disciplines, from biology to politics to economics to evolutionary game theory to cinematography. It was used, for instance, to create the battle scenes in Peter Jackson's *The Lord Of The Rings* film trilogy. In a very different area, agent-based models are being developed today to help predict human responses to global warming.

Python is the perfect language for building agent-based models. With its elegant, object-oriented design, its extensive scientific, numeric, and visualization libraries, its interactive development model, and flexible data types, Python makes creating agent-based models a pleasure. This book aims to introduce the reader to the basics of creating ABM systems in Python in a way that leads the reader from trivial examples to complex systems that capture phenomena like racial segregation.

# Audience

This book is intended for developers who wish to create and implement agent based models in their projects or businesses for better decision making. Readers must be somewhat experienced in Python programming.

# Mission

This book will enable readers to build their own agent-based models in Python, either from scratch or using the freely available source code from the book, which is available online.

# Objectives and achievements

1) What is agent-based modeling good for? Why use it rather than traditional simulation strategies?

2) Why use a framework rather than building each model ad hoc?

3) How to build small test models that catch bugs more easily than large ones.

4) How to leverage objects and especially inheritance to make building models faster and easier as one proceeds.

5) How to capture model parameters and results to create a rigorous experimental setup.

# General structure

1. Discuss what agent-based modelling (ABM) is used for.
2. Introduce the basics of agent-based modelling.
3. Demonstrate a basic agent and a basic environment.
4. Use the above to create a simple but useful model.
5. Show how to incorporate space into our models.
6. Build useful space-based models.
7. Demonstrate how objects and inheritance can be leveraged to make new models easier to build.
8. Show how to handle parameter sets so as to allow genuine experiments.
9. Explain the debugging problems facing modellers and show how to overcome them.

# Detailed outline

# Chapter 1: Agent-Based Modeling: What Is It Good For? - 25 pages

## Description

We begin with a general overview of agent-based modeling. First we motivate the chapter with a description of what sort of problems ABMs are useful for addressing. Then we give an overview of how they are constructed.

## Level

BASIC

## Topics covered

1. Moving from simple rules to complex behavior
2. Life
3. ABMs in biology
4. ABMs in economics
5. ABMs in other social sciences
6. Evolutionary game theory
7. How ABMs work.

## Skills learned

Learn how to determine if ABM is appropriate for dealing with different sorts of problems he / she might be faced with.

# Chapter 2: Creating a Framework - 25 pages

## Description

Creating a framework for ABM: We will discuss what problems the framework must solve, and why the classes are built as they are.

## Level

BASIC

## Topics covered

1. A simple agent class
2. An environment in which agents can interact
3. An action loop
4. Reporting what happened

## Skills learned

Program basic classes that gives us a framework for ABM.

# Chapter 3: Helpful Python Packages - 25 pages

## Description

This chapter surveys the standard Python packages that will prove most useful in our system. We discuss packages for handling graphics, generating random numbers, manipulating collections of objects in sophisticated ways, and logging program results.

## Level

MEDIUM

## Topics covered

1. matplotlib
2. random
3. collections
4. logging
5. networkx

## Skills learned

Use the Python library to prevent re-inventing the wheel.

# Chapter 4: Our First Real Models - 35 pages

## Description

Building our first working models of real-world phenomena. We examine how large scale patterns can emerge from simple rules applying to individuals. We show how to build simple test models. Then we build several simple models of real phenomena.

## Level

MEDIUM

## Topics covered

1. Micromotives and macrobehavior
2. The importance of simple models for testing.
3. Schelling’s height model
4. The babysitting co-op

## Skills learned

Create models that tackle actual, real-world situations.

# Chapter 5: Dealing with Space - 35 pages

## Description

Creating agents that act in a spatial environment. Agents have a position, move in space, and detect the presence of other agents. We demonstrate the powerful concept of a “grid view,” which allows us to take a slice of a grid and perform any action for that slice that we could for an entire grid.

## Level

MEDIUM

## Topics covered

I. Our Space Test Model

1. An initial cut at creating space

2. Using iterators and generators: encapsulation.

II. A Bacterium in a Gradient

1. Behaving in space with a goal

2. Constructing the model: directed moves in space.

III. A Forest Fire

1. A simple cellular automaton

2. Constructing the model: grid views.

IV. Predators and Prey

1. Only model what is essential

2. Constructing the model: using grid views to move.

## Skills learned

Program agents that navigate space in sophisticated ways.

# Chapter 6: Leveraging Inheritance to Build Models More Swiftly - 35 pages

## Description

Inheritance is one of the powerful concepts composing the object-oriented programming paradigm. In this chapter, we illustrate how finding families of models, and abstracting new base classes describing those families, can make building new models a much simpler task.

## Level

ADVANCED

## Topics covered

I. Extending Predators and Prey: Adam Smith’s Fashion Model

1. Using inheritance wisely

2. Constructing the model

II. A simple financial market model.

1. More use of inheritance: code refactoring.

## Skills learned

Refactor existing code to create a generic class behind a model.

# Chapter 7: Schelling’s Segregation Model - 25 pages

## Description

In this chapter, we build our most advanced model, with many parameters

## Level

ADVANCED

## Topics covered

I. Schelling’s Segregation Model

1. Constructing the model

2. Animating our plots

## Skills learned

Program a large, complex model with many interacting parameters. Also, we use matplotlib to create an animated scatter plot. We detail how to do animation, and see how it enables a dynamic view of our model’s development.

# Chapter 8: Testing and debugging - 25 pages

## Description

How to use ABMs for experiments, and how to test and debug them. For experiments, we must be able to accurately record the parameter sets used each time we run, and record the results produced. We show how to make these tasks simple. We also cover ABM debugging techniques.

## Level

MEDIUM

## Topics covered

I. Setting and storing properties.

II. Importing data from other sources.

III. Writing out results.

IV. Creating test programs.

## Skills learned

Systematically record the results of experiments, set up data in spreadsheets and databases, and test code.

# Chapter 19: Other Python ABM Systems - 25 pages

## Description

A brief look at some other resources for doing ABM in Python. For particular purposes, another Python package might be better than Indra, the one we have been using so far.

## Level

MEDIUM

## Topics covered

I. PyGame

II. Mesa

## Skills learned

Evaluate whether to use an existing Python ABM system or write his or her own.