Chapter 18 Exercise Hints and Solutions

Agent-based and Individual-Based Modeling: *A Practical Introduction, 2nd Edition*

Please also see the note at the end of this file.

Exercise 1

Here are example answers to this exercise, for two of the models.

Helbing, et al. 2000. Simulating dynamical features of escape panic.

What patterns were important in model design?

The authors list nine "characteristic features of escape panics" in the article's third paragraph. In addition, they simulate three "Important phenomena" described starting at the last paragraph on page 488.

How did the authors search for and document the patterns?

The article states that the authors "studied related socio-psychological literature, reports in the media and available video materials, empirical investigations, and engineering handbooks". They provide citations for most patterns.

What scales do the patterns occur at and how did they affect the model's scales?

The patterns describe movement of individual people and small crowds, over distances typifying areas (buildings; stadiums) from which people might try to escape in panic. The patterns include obstacles such as fallen people, and individual exits such as doors. Hence, the spatial extent of the model was made about the area of a building exit that includes several exits. The spatial resolution must be small enough to represent individual people and the area they occupy.

The patterns include characteristics of people's motion (e.g., how rapidly they walk or run), so the time scale must be quite fine, short enough to represent how motion over the small spatial scale depends on walking and running speed.

What things were included in the model to make it possible for the patterns to emerge, and what other things were required by the problem addressed?

The problem addressed by the model is how panic impedes escape through small exits, so the model must include people in a confined area that includes small exits.

The patterns address:

- Movement speed of people, so the model must include speed as a variable of people;
- Physical interactions among people, and "arching and clogging" at exits, which means interaction among people, including contact and impeding movement, must be included;
- Movement through bottlenecks, so narrowing of the space must be included;

- Pressures built up in jammed crowds, so physical forces and their transmittal among people must be included;
- Effects of fallen or injured people, which requires modeling how people fall or become injured, and how they behave and affect other people when in those conditions;
- "Mass behavior" (simply following others instead of making independent decisions), which means model people must be able to sense what others nearby are doing and have traits for deciding when to follow others vs. when to act on their own; and
- Overlooking of alternative exits, requiring simulation of such exits.

LeBaron, B. 2001. Empirical regularities from interacting long- and short-memory investors in an agent-based stock market.

What patterns were important in model design?

The study focuses on comparison of model results to data from real stock markets. The patterns are mentioned generally in the Introduction as "features of real markets" that include patterns in investment returns, stock price volatility, and trading volume; and in the cross-correlations among those measures.

In the Results section, model results are compared directly to many patterns; those patterns are statistical measures (mean, moments, regression coefficients, etc.) of market returns, volatility, and volume; see Table I.

How did the authors search for and document the patterns?

The patterns were extracted from data on real stock markets, in particular the Standard and Poor's Index of 500 U.S. stocks, from 1926 to 1998.

What scales do the patterns occur at and how did they affect the model's scales?

The stock market data are aggregated over 30-day periods; apparently this is a common format in which historic market data are archived. Consequently, the model was built with a time step of 30 days to make its results comparable to the data.

What things were included in the model to make it possible for the patterns to emerge, and what other things were required by the problem addressed?

This study is specifically about explaining the patterns, so there is no difference between the model's purpose and explaining the observed patterns. The patterns are mostly about variability and trends in stock markets over time. Hence, the model was designed to contain processes that (unlike classical economic theory) cause trends and variability: a time series of stock returns that is partially random but with a long-term upward trend, differences among traders in trading strategies and their ability to sense (remember) information, and evolution of trading strategies over time.

What important information is unclear?

The relationship between the patterns that the model was compared to and the model's design are actually not very clear. There are many different processes that can cause volatility and

variability in real and simulated stock markets. The patterns chosen for this study are quite general and do not provide much information from which to decide which of those processes should actually be in the model. Because the model has no purpose other than explaining the patterns, there is no specific purpose or application of the model to help decide which processes need to be in it. Therefore, it is not clear exactly why the author chose to include the processes he did.

Exercise 2

Dmitri Mendeleev developed the periodic table (by 1869) by organizing the known elements in such a way that patterns in their chemical properties are reproduced by following the rows and columns of the table. The most fundamental pattern he used was that as atomic number (number of protons in the nucleus) increases, the chemical properties of elements go through cycles. These properties include ionization energy, atomic size, melting and boiling points, oxidation potential, electrical conductivity, and magnetic behavior. The table is laid out with atomic number increasing across the rows, but with gaps in the columns placed to produce regularities in chemical properties going up and down the columns as well as across the rows. Later it was discovered that these regularities within columns is due to the quantum structure of the electron shells.

From the patterns in the table, Mendeleev could correctly predict that several new elements remained to be discovered, and could estimate the chemical properties of elements that were too rare to measure.

(This information is readily available from introductory chemistry textbooks.)

Exercise 3

For this checkout queue problem, some entities, variables, and processes that may be important are: (1) the rate at which customers arrive for checkout and the variability over time in that arrival rate; (2) characteristics of each customer that might affect whether other customers prefer or avoid getting in line behind them; and (3) characteristics of checkers that could affect how quickly they process customers. Hence, some example patterns useful to observe are:

- Whether customers tend to use queues closer to where they first approach the checkout area. (This would help determine whether the model needs to be spatial: does customer and queue location matter?)
- What characteristics of customers strongly affect how long it takes them to check out. Do customers take longer if their baskets are fuller, or if they pay with credit cards, or have children with them? (These characteristics could determine what state variables the model's customers need to have.)
- What characteristics of customers cause other customers to avoid them? Do fewer people get in line behind customers with many items or behind elderly customers? (These patterns also could determine what state variables the customers need to have.)
- Whether checkers differ in the rate at which they process customers. (This could help decide whether variability among checkers needs to be represented.)

- (Statistical patterns in the timing of customer arrivals, such as the distribution of time intervals between arrivals, could be important to observe for *parameterizing* a model, as we discuss in Chapter 20. But it is not clear that such data would help decide on model structure.)

Note: Jamaica Coffee Farm model example of pattern-oriented model design

Railsback and Johnson wrote this publication specifically as an illustration of pattern-oriented model design as covered in this chapter: Railsback, S. F. and M. D. Johnson. 2011. Pattern-oriented modeling of bird foraging and pest control in coffee farms. *Ecological Modelling* **222**:3305-3319.

We make this example available via a Powerpoint file and NetLogo code also available with the instructor materials for Chapter 18. Unfortunately, it is not legal for us to distribute the publication but you should read it before using the related materials. The publication and Powerpoint file also cover the topic of Chapter 19—pattern-oriented theory development. We thank Dr. Matthew Johnson of Humboldt State University's Department of Wildlife for making the model and the photos in the Powerpoint file available.