CST-317-2016

Introduction to Earth System Science

Assignment on Agent-Based Modelling

1 Introduction

In this assignment, you will implement the Butterfly model described in the paper by Pe'er, Saltz, and Frank, K: "Virtual corridors for conservation management", *Conservation Biology*, 19:1997–2003, 2005.

The description of the model is given below, taken from Section 3.4 of the book by Railsback and Grimm: "Agent-based and individual-based modeling: A practical introduction". Princeton University Press, Princeton, NJ, 2005.

2 Purpose

The model was designed to explore questions about virtual corridors. Under what conditions do the interactions of butterfly hilltopping behavior and landscape topography lead to the emergence of virtual corridors, that is, relatively narrow paths along which many butterflies move? How does variability in the butterflies' tendency to move uphill affect the emergence of virtual corridors?

3 Entities, State Variables, and Scales

The model has two kinds of entities: butterflies and square patches of land. The patches make up a square grid landscape of 150 × 150 patches, and each patch has one state variable: its elevation. Butterflies are characterized only by their location, described as the patch they are on. Therefore, butterfly locations are in discrete units, the x- and y-coordinates of the center of their patch. Patch size and the length of one time step in the simulation are not specified because the model is generic, but when real landscapes are used, a patch corresponds to 25 × 25 m^2. Simulations last for 1000 time steps; the length of one time step is not specified but should be about the time it takes a butterfly to move 25–35 m (the distance from one cell to one of its neighbor cells).

4 Process Overview and Scheduling

There is only one process in the model: movement of the butterflies. On each time step, each butterfly moves once. The order in which the butterflies execute this action is unimportant because there are no interactions among the butterflies.

5 Design Concepts

The *basic principle* addressed by this model is the concept of virtual corridors—pathways used by many individuals when there is nothing particularly beneficial about the habitat in them. This concept is addressed by seeing when *corridors emerge* from two parts of the model: the adaptive movement behavior of butterflies and the landscape they move through. This *adaptive behavior* is modeled via a simple empirical rule that reproduces the behavior observed in real butterflies: moving uphill. This behavior is based on the understanding (not included in the model) that moving uphill leads to mating, which conveys fitness (success at passing on genes, the presumed ultimate objective of organisms).

Sensing is important in this model: butterflies are assumed able to identify which of the surrounding patches has the highest elevation, but to use no information about elevation at further distances.

The model does not include *interaction* among butterflies; in field studies, Pe'er (2003) found that real butterflies do interact (they sometimes stop to visit each other on the way uphill) but decided it is not important to include interaction in a model of virtual corridors.

Stochasticity is used to represent two sources of variability in movement that are too complex to represent mechanistically. Real butterflies do not always move directly uphill, likely because of (1) limits in the ability of the butterflies to sense the highest area in their neighborhood, and (2) factors other than topography (e.g., flowers that need investigation along the way) that influence movement direction. This variability is represented by assuming butterflies do not move uphill every time step; sometimes they move randomly instead. Whether a butterfly moves directly uphill or randomly at any time step is modeled stochastically, using a parameter q that is the probability of an individual moving directly uphill instead of randomly.

To allow *observation* of virtual corridors, we will define a specific "corridor width" measure that characterizes the width of a butterfly's path from its starting patch to a hilltop.

6 Initialization

The topography of the landscape (the elevation of each patch) is initialized when the model starts. Two kinds of landscapes are used in different versions of the model: (1) a simple artificial topography, and (2) the topography of a real study site, imported from a file containing elevation values for each patch. The butterflies are initialized by creating five hundred of them and setting their initial location to a single patch or small region.

7 Input Data

The environment is assumed to be constant, so the model has no input data.

8 Submodels

The *movement submodel* defines exactly how butterflies decide whether to move uphill or randomly. First, to "move uphill" is defined specifically as moving to the neighbor patch that has the highest elevation; if two patches have the same elevation, one is chosen randomly. "Move randomly" is defined as moving to one of the neighboring patches, with equal probability of choosing any patch. "Neighbor patches" are the eight patches surrounding the butterfly's current patch. The decision of whether to move uphill or randomly is controlled by the parameter q, which ranges from 0.0 to 1.0 (q is a global variable: all butterflies use the same value). On each time step, each butterfly draws a random number from a uniform distribution between 0.0 and 1.0. If this random number is less than q, the butterfly moves uphill; otherwise, the butterfly moves randomly.

CREDITS AND REFERENCES

Pe'er, G., Saltz, D. & Frank, K. 2005. Virtual corridors for conservation management. *Conservation Biology*, 19, 1997–2003.

Railsback, S. & Grimm, V. 2012. *Agent-based and individual-based modeling: A practical introduction*. Princeton University Press, Princeton, NJ.