Butterfly Hilltopping

An agent based model

Animal dispersion

- Many animals disperse from their home bases and travel long distances to go mate, find food or because of seasonal migration.
- Some of the paths that animals take are well known, for example migrating birds.
- Animals tend to take paths where they might get coverage from predators, find shelter and food.
- They might also choose some paths that are not very intuitive - that don’t have any beneficial characteristics.
- But we don’t see what animals see so we are left wondering why?

Virtual Corridors

- Pathways used by many individuals despite not having any particularly beneficial characteristics.
- When large numbers of dispersing animals use virtual corridors we're left wondering if there are more subtle characteristics of the landscape that influence the pathways of the animals.

Mate-finding butterflies

Observation: Butterflies move uphill and concentrate on hilltops (hilltopping) so they can mate.

Bumblebees, wasps, dragonflies also use the same strategy.

Can investigate virtual corridors in such systems.

An agent-based model for butterfly hilltopping

Demonstrate the idea of virtual corridors using an ABM by Pe'er et al. 2005 as presented in Agent-based and Individual-based Modeling: A Practical Introduction by Railsback and Grimm.

- Use the Overview, Design concepts and Details (ODD) protocol by Grimm and Railsback.
- The ODD protocol standardizes the process for formulating ABMs and helps describe them.

	Elements of the ODD protocol
Overview	1. Purpose
	2. Entities, state variables, and scales
	3. Process overview and scheduling
Design Concepts	4. Design Concepts Basic principles, Emergence, Adaptation, Objectives, Learning, Prediction, Sensing, Interaction, Stochasticity, Collectives, Observation
Details	5. Initialization
	6. Input data
	7. Submodels

See Railsback and Grimm Chapter on Canvas.

Butterfly Hilltopping : ODD protocol

1. **Purpose/Goal:** Explore questions about virtual corridors

   Under what conditions do the interactions of butterfly hilltopping behavior and landscape topography lead to emergence of virtual corridors?

   How does variability in the butterflies' tendency to move uphill affect the emergence of virtual corridors?

Entities	Butterflies	Square Patches
State Variables	Location: x-, y- coordinates At center of patch	Elevation
Scales	Simple model with generic scales	

3. **Processes**

Movement of butterflies.

At each time step, each butterfly moves once.

Butterflies do not interact so order of updating butterfly paths is not important.

4. Design Concepts

- Basic Principle - Explore concept of virtual corridors
- Corridors emerge from adaptive behavior of butterflies and interactions with the landscape they move through.
- Adaptive behavior - butterflies move uphill (hilltopping assumed)
- No learning
- Sensing - butterflies know where the highest elevation is
- No interactions though in reality butterflies interact
- Stochasticity used to represent two sources of variability due to the fact that butterflies don't always move uphill:
    - Flowers can be distracting
    - Do butterflies always get the path with the highest elevation right?

At each time step a butterfly moves directly uphill with probability q, else it moves randomly

- Observation - define the corridor width which characterizes the width of the butterfly's path from starting position to hilltop.

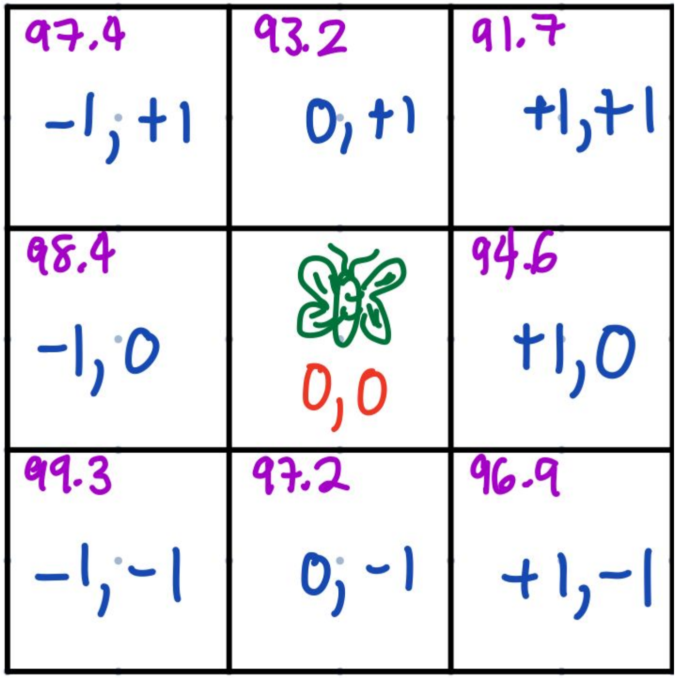
ODD Protocol continued

5. **Initialization**

Set the landscape, set the number of butterflies and their starting positions.

6. **No input data**

7. **Submodels**



<u>How butterflies move in the simulation</u>

- Move uphill - move to neighboring patch with highest elevation
- Eight neighbors per patch
- Move randomly - move to any of the neighboring patches with equal probability
- Draw number from standard uniform distribution, if less than *q* move uphill, otherwise move randomly (probability *1-q*)

Butterfly Animation

- $q = 0.4$
- Landscape a 2D function with two conical hills, peaks at *(30,30)* with elevation *100* and *(120,100)* with elevation *50*.
- Butterfly motion modeled as a 2D random walk.
- Butterflies keep moving even if they have arrived at a local hilltop.

Butterfly Corridor Width

- Animation does not say anything about virtual corridors, only simulates butterfly movement.
- Want:
  a. To observe the extent to which virtual corridors emerge.
  b. Quantify how the width of the movement paths changes as we vary q or the landscape.
- Corridor width = *(number of patches visited by any butterfly)/(mean distance between starting and ending locations)*
- Butterflies need to have clear start and end points - butterfly stops when it reaches hilltop i.e. a patch higher than all its neighbors.
- Corridor width low (approaching 1) if all butterflies follow same path uphill.
- Corridor width increases for different and crooked paths.

Model Analysis

How is the corridor width affected by the random parameter q?

Activity: Plot corridor width vs. q

Modify code to try several values of q