ODD PROTOCOL

Overview

Purpose

What is the purpose of the model?

Modelling the movement of bees based on the environment (altitude ratios and land cover)

Entities, state variables, and scales

What kinds of entities are in the model?

Hives (origin points), bees (agents exploring their surrounding), cells with resistance values (grid space)

By what state variables, or attributes, are these entities characterized?

Hive: size, colour

Bee: size, colour, infection

Cell: colour, resistance (based on spatial data), color_value (infected hive, explored cell)

What are the temporal and spatial resolutions and extents of the model?

Spatial: Cell size is 70 meters.

Temporal: The simulation runs for 100 steps, which is based on total distance covered by bee 7 kilometres

Extent: Grid with size 14 x 14 kilometres (200 x 200 cells)

Process overview and scheduling

Who (i.e., what entity) does what, and in what order?

The bee is exploring its surroundings – chooses direction for next movement. After the action is performed is through interaction changed variable color_value of the cell to mark already explored environment.

If a bee reaches am infected hive, a new bee is created, the simulation is paused, and infected bee dies in the next step so simulation may continue.

Design concepts

Basic principles

Which general concepts, theories, hypotheses, or modelling approaches are underlying the model's design?

Basic behaviour of agents consists of decision which of neighbour cells with lower resistance value will be used for movement. The resistance values were created spatial data (altitude ratios and land cover). According to theory a bee should prefer environment with lower resistance and possible food sources. Elevation data was used to test hypothesis

whether physical barriers e. g. ridge of hills has an impact on bee movement and the spread of American Foulbrood through robbing in infected locations. The distance a bee can cover when exploring was set in this model to 7 kilometres.

Emergence

What model results are expected to vary in complex and perhaps unpredictable ways when particular characteristics of individuals or their environment change?

With certain probability an agent can choose a cell with higher resistance values instead, which then affects the explored area. The agents interact with the environment and change its variables depending on the exploration process. Choice of cell for next movement depends on the following condition: Choose a cell with lower resistance and the cell should not be already visited cell if possible (including visits from other agents). The decision is affected by decisions done by previous agents, which are different each time a simulation is run.

Adaptation

What rules do agents have for making decisions or changing behavior in response to changes in themselves or their environment?

Agents exclude already visited cells if possible when making a decision.

Objectives

If adaptive traits explicitly act to increase some measure of the individual's success at meeting some objective, what exactly is that objective?

The objective of the agents is to explore as much cells as possible in order to find a food source.

Learning

This principle is not implemented in the model.

Prediction

This principle is not implemented in the model.

Sensing

What internal and environmental state variables are individuals assumed to sense and consider in their decisions?

The choice of cell is takes place in predefined Moore neighbourhood (8 neighbouring cells). The gathered information consists of value of resistance, and possibility of presence of infected hive, or whether the cell was or was not already visited by agent.

Interaction

What kinds of interactions among agents are assumed?

Interaction is performed through change of variables of the environment by agents.

Stochasticity

What processes are modelled by assuming they are random or partly random?

In order to include stress related conditions, the choice related to resistance values is with 20 % probability set to consider even environment with higher resistance as a possible food source.

The movement itself is based on condition choose one of neighbours with lower resistance values. The main reason for this is to more closely match modelled system. Agent (bee) does not have complete information which way forward is the most beneficial (the difference in values of altitude might be quite minor), so one of the neighbouring cells with lower resistance is chosen instead of the lowest one.

In cases when no neighbour fulfils the condition (empty list) the choice is random.

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Collectives

Do the individuals form or belong to aggregations that affect, and are affected by, the individuals? How are collectives represented?

All bees in the model are part of one of three types of agent bee. Together they explore the environment in search of food sources. The result of the model is explored area by all bees in the model.

Observation

What data are collected from the ABM for testing, understanding, and analyzing it, and how and when are they collected?

Values of variable color_value changed through the exploration process by agents are together with the modelled space which consists of cells saved into shapefile at the end of simulation run. The output is vector grid, which consist of sectors that include information of visit of bee in that sector through the simulation.

Details

Initialization

What is the initial state of the model world, i.e., at time t = 0 of a simulation run? In detail, how many entities of what type are there initially, and what are the exact values of their state variables?

First modelled space with values of resistance is created from the input file. Coordinates are assigned from vector grid which is loaded into the model together with the space.

Agents of type bee and hive have their location based on their real position. During initialization process three hives with maximum of 27 are created. If infected hives are not included the value of the color_value variable is equal to zero for all cells. Visualization of the environment is based on the values of resistance in the input file

Input data

Does the model use input from external sources such as data files?

To create the environment digital elevation model data can be used. To calculate resistance of land cover data set CORINE Land Cover can be used after the categories are assigned a resistance values and the file is converted into raster type format PNG. The size of the input file should not exceed 200 x 200 pixels with resolution of 70 meters due to software limitations so resampling of input files may be necessary. To get total resistance of the environment the elevation data can be combined with the land cover after the weight of the data is adjusted accordingly. Due to purpose of analysis and visualization of results vector grid of shapefile format with the same extent and resolution as input raster files has to be included. The location of origin points for the bees is based on real location of hive.

Submodels

Submodels are not included.

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This protocol was created using (GRIMM ET AL., 2010).

GRIMM, Volker, Uta BERGER, Donald DEANGELIS, J. POLHILL, Jarl GISKE a Steven RAILSBACK, 2010. The ODD protocol. *Ecological Modelling*. **221**, 2760-2768. DOI: 10.1016/j.ecolmodel.2010.08.019. Dostupné také z: https://linkinghub.elsevier.com/retrieve/pii/S030438001000414X