

Model Description

This is a model description of an original model discussed in Janssen et al. (2009). The model description follows the ODD protocol for describing individual- and agent-based models (Grimm et al. 2006) and consists of seven elements. The first three elements provide an overview, the fourth element explains general concepts underlying the model's design, and the remaining three elements provide details. Additionally, details of the software implementation are presented.

Purpose

The model aims to mimic the observed behavior of participants in spatially explicit dynamic commons experiments. In a typical experiment four randomly assigned participants share a renewable resource that grows on a 28 x 28 spatial grid of cells. Participants can harvest a green token by moving their virtual avatar's location on top of the token by pressing the arrow keys (left, right, up, and down). There are two modes, implicit and explicit, that can be toggled by pressing the 'M' key. In the implicit mode one collects a token automatically when one's avatar is on a cell with a token. In explicit mode one can move around without automatically harvesting tokens. When one wishes to harvest a token, the participant must press the spacebar when their avatar is on a cell with a token.

The resource renewal rate is density dependent. The probability that a green token will appear on an empty cell increases as the number of adjacent cells with tokens increases. The faster participants collect tokens, the less time that is available for regrowth, possibly resulting in overharvesting (Figure 1). The regrowth probability p_t is linearly related to the number of neighboring cells with tokens: $p_t = p \cdot n_t / N$ where n_t is the number of neighboring cells containing a green token, and N the number of neighboring cells ($N = 8$ because we use a Moore neighborhood). The parameter p is defined in such a way that the renewal of the resource is quick enough to be observed by the participants, but sufficiently slow that the participants experience a dilemma between immediate, individual benefits and longer-term, group benefits. If participants collect tokens as quickly as they can, there will soon be no tokens remaining on the screen. Once every token has been harvested, no further opportunity exists for any new tokens to be created.

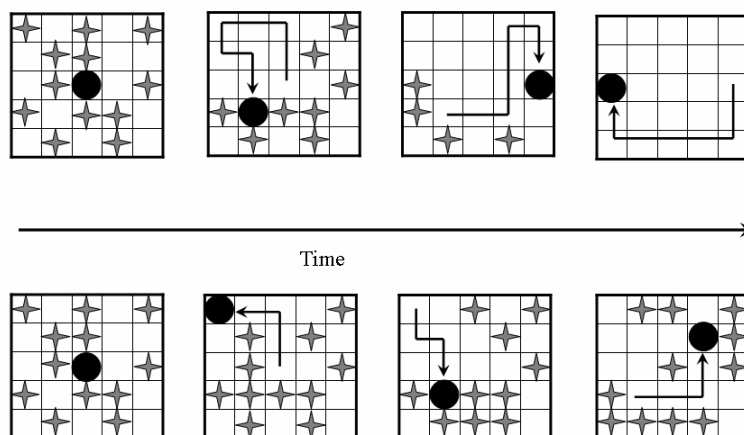


Figure 1: Four snapshots of two harvesting strategies by two different types of subjects in a hypothetical situation of a 5x5 resource, where resource units are depicted by star-shape objects. On

the top row in the figure above, the subject moves their avatar (circle) eight steps per time period. On the bottom row, the subject moves their avatar only four steps per time step.

The participants have four minutes to collect tokens and each token is worth \$0.02. Two treatments are considered: A low growth case with p equal to 0.01 and 25% of the cells initially populated with tokens, and a high growth case with p equal to 0.02 and 50% of the cells initially populated with tokens. We have 6 groups for the low growth treatment and 10 groups for the high growth treatment.

State variables and scales

There are k participants and a variable number of tokens on the screen. The state of the resource is updated every second, and agents can make a few moves per second. The number of movements agents make during a second is drawn from a probability distribution as defined below.

Process overview and scheduling

First the mode and speed of the agents are determined based on experimental data. Based on the observed behavior we assume participants use the same mode during the whole round of four minutes. 30% of the agents use the explicit mode in the low growth treatment, and 15% in the high growth treatment. The base speed of the agents is drawn from a normal distribution with mean 3 and standard deviation 0.8. Per second the number of movement can vary. The higher the base speed the higher the standard deviation of a normal distribution. The mean of this normal distribution is the drawn base speed (DBS) and the standard deviation calculated as $0.598 * DBS - 0.062 * DBS^2$.

Each second an agent make a number of movements. When an agent makes a move during a second the direction of this move is calculated. If more than one move is made, the agent only reevaluate the direction is the previous target is reached. For each decision on direction a randomly drawn agent will first calculate a score for each token and then decide which token to go to.

The score of each token is established via three components:

- the closer a token is to the agent, the more valuable the token
- the more competing agents that are close to a token, the less valuable the token
- tokens that are straight ahead in the current directional path of the agent are more valuable

As such we formulate the value of a token at location (i,j) as follows:

$$V_{i,j} = P_1 \cdot \left(\frac{1}{\text{tokendistance}} \right) + P_2 \cdot I - P_3 \cdot \text{agentdensity} \quad (1)$$

where agent density is the number of agents in radius, R_{P2} , around the potential target. I is an indicator function and is 1 when the location of the token is in the straight path of the agent, and 0 otherwise. Furthermore the sum of the weights P_i is equal to 1.

One of the tokens will be selected based on the relative value among all the tokens. When the agent reaches this position, it will select a new target. Agents also update their target once per second, or less if their speed is slower than one move per second. An agent in explicit mode does not consider a token in its same cell to be part of the eligible set of tokens from which to select. Using probabilistic choice, the probability of having a token at location (i,j) as the target is defined as

$$P[T(i, j)] = \frac{e^{\beta \cdot V_{i,j}}}{\sum_{k,l} e^{\beta \cdot V_{k,l}}} \quad (2)$$

where β is the parameter that defines how sensitive agents are to differences in the value of the tokens.

Based on the chosen target, the agent defines the direction to the target and decides to go up, down, left, or right. When a move is made, and the agent is on a cell with a token, the agent automatically collects the token when in implicit mode. However, when in the explicit mode, the agent needs to decide whether or not to collect the token. We assume that agents are more tempted to take the token when more tokens are around the cell, and the probability to collect the token is defined as

$$P[\text{collect}] = \frac{x^b}{x^b + a^b} \quad (3)$$

where x is the number of tokens in the eight cells of the Moore neighborhood divided by 8. The parameters a and b define at what density the probability is 50% ($x=a$) and how steeply the probability increases with higher values of x .

Design concepts

Sensing. The agents sense the suitability of each token.

Interaction. The agents interact indirectly via removing tokens from the resource and avoiding crowded areas.

Stochasticity. Agents make probabilistic decisions, and the regrowth of the tokens is probabilistic too, depending on the density of the resource.

Initialization

The base speed of agents is drawn from a random distribution, as well as whether agents use the explicit or implicit mode.

Input

Distribution of speed and percentage of agents using the explicit mode as described above.

Submodels

No submodels...

Model implementation

The model is implemented in a modified version of MASON 12.

References

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