Testing Brantingham's Neutral Model: The Effect of Spatial Clustering on Stone Raw Material Procurement

Model description

This is a model description following the ODD protocol (Grimm et al., 2010) of a study (Oestmo et al., 2016) investigating what effect spatial clustering has on the outcome of the neutral model of raw material procurement by Brantingham (2003).

Overview:

Purpose:
To examine what effect spatial clustering has on the neutral model outcome.

State variables and scales:
One agent is foraging according a random walk, wiggling walk, or seeking walk and has a toolkit of a fixed size. Materials are distributed on the landscape according to a probability of clustering p_r ('prandom'). If p_r is set to 1 the raw materials are distributed in a random way across the landscape. If p_r is set to 0 the raw material are distributed together in one central cluster on the landscape. The landscape has 250,000 cells and there are 5,000 material sources with either 5000 unique raw material types or 20 unique raw material types. The model stops when 35000 time steps have been run.

Process overview and scheduling:

Figure 1 shows the main structure of the scheduling of activities in the model. One agent with a mobile toolkit of fixed capacity is randomly placed on the environment. If the threshold is set to 0, at each time step, the agent moves to one of the nearest eight neighboring cells or stays in the present cell, with equal probability (=1/9). Each time step a fixed amount of raw material is consumed dependent only upon its frequency in the mobile toolkit. If a raw material source is encountered, the toolkit is re-provisioned up to its maximum capacity before moving again at random. If no raw material source is encountered, the forager moves immediately at random. If the 'threshold' function is set to a value >0 and the forager has a quantity of raw material in the toolkit equal to that value the forager will seek to the closest raw material source to replenish the toolkit. When the quantity of raw material is above the threshold the agent moves at random, discarding a material every time step, and when encountering a source the toolkit is re-provisioned up to maximum capacity. Simulations are run until 35000 time steps have been simulated.

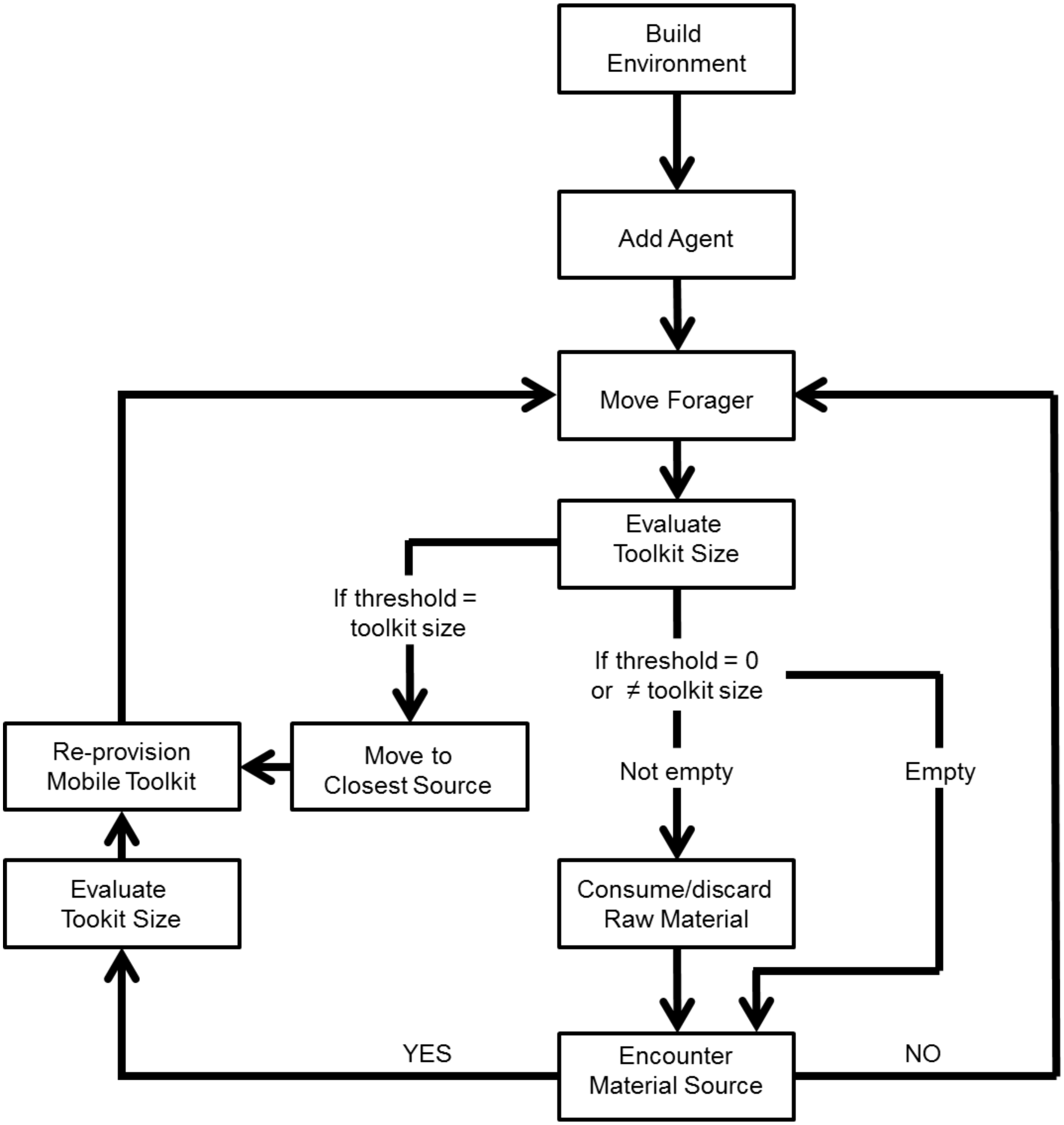

Figure D1. Spatial clustering model scheduling.

Design Concepts:

Basic principles: **Which general concepts, theories, hypotheses, or modeling approaches are underlying the model's design?**

Brantingham (2003) points out that a valid criticism of the neutral model approach is that random walk in the environment can be considered an unrealistic foraging behavior; that a forager would never ignore the difference between raw material types. Additionally, he states that future evaluations of the neutral model should be conducted using a real landscape with real source locations. This model partly addresses both by looking at the effect that spatial clustering or raw material sources have on the neutral model outcome. Spatial clustering of raw material sources simulates a more realistic scenario because raw material sources are located on the landscape according to geological structures and geophysical processes, which often results in same type raw material sources clustering together on the landscape. One key measure that is collected in the model to evaluate the effect that spatial clustering has is time without raw material in toolkit. Another limitation of the original neutral model that is addressed is the unrealistic assumption that there are 5000 unique raw material types distributed across the landscape. It is more realistic that 1-25 raw material types are distributed among 5000 sources, which in turn are distributed across the landscape according to geological structures and geophysical processes.

<u>Emergence:</u> **What key results or outputs of the model are modeled as emerging from the adaptive traits, or behaviors, of individuals?**

Distribution of frequencies of distances of material as part of the toolkit compared to the source of the material. This is an indication how far material may travel. Distribution of richness of material sources in the toolbox. Time without raw material in toolkit.

<u>Adaptation:</u> **What adaptive traits do the individuals have? What rules do they have for making decisions or changing behavior in response to changes in themselves or their environment?**

Agent moves either in random, wiggle, or seeking behavior and do not learn, adapt or evolve.

<u>Objectives:</u> **If adaptive traits explicitly act to increase some measure of the individual's success at meeting some objective, what exactly is that objective and how is it measured?**

There are no adaptive traits.

<u>Learning:</u> **Many individuals or agents (but also organizations and institutions) change their adaptive traits over time as a consequence of their experience? If so, how?**

The agent does not learn.

<u>Prediction:</u> **Prediction is fundamental to successful decision-making; if an agent's adaptive traits or learning procedures are based on estimating future consequences of decisions, how do agents predict the future conditions (either environmental or internal) they will experience?**

The agent does not predict.

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

Agent can sense whether there are material source on the cell it occupies. The agent can sense the amount and distribution of materials in its tool box. If threshold value is set to <0 and the forager has a quantity of raw material in toolkit equal to that value the forager can sense which raw material source is closest and will directly move there.

Interaction: **What kinds of interactions among agents are assumed? Are there direct interactions in which individuals encounter and affect others, or are interactions indirect, e.g., via competition for a mediating resource?**

There is only one agent.

Stochasticity: **What processes are modeled by assuming they are random or partly random?**

When the movement is set to random the agent moves randomly. Decisions on use of material are done randomly. When the p_r value is set to 1 raw materials are distributed randomly on the landscape.

Collectives: **Do the individuals form or belong to aggregations that affect, and are affected by, the individuals?**

No

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

Distribution of distance of material traveled and richness of material sources in the toolbox. Time without raw material in toolkit.

Details:

Initialization: **What is the initial state of the model world, i.e., at time t = 0 of a simulation run?**

Table 1 provides the parameters as used in the model.

Table 1: Spatial clustering model variables/parameters

Variable description	Variable	Units	Model Variables/Range
Simulated world size in *X* dimension	X	grid cells	500
Simulated world size in *Y* dimension	Y	grid cells	500
x-coordinate position of raw material/foragers	x	grid cells	Sources locations depending on prandom function; Forager randomly placed

y-coordinate position of raw material/foragers	y	grid cells	Sources locations depending on prandom function; Forager randomly placed
Number of agents moving about the landscape	fixed	arbitrary units	1
Toolkit size	space 100 - sumv	arbitrary units	0-100
Type of movement strategy	randomwalk	arbitrary units	equalchance; wiggling
Threshold of seeking more raw materials	threshold	arbitrary units	0-100
Raw material scenario	nrmaterials	arbitrary units	5000; 20
Source distribution on the landscape	distribution	arbitrary units	random; clustered
Probability of clustering of source locations	prandom	arbitrary units	0-1.000
Number of unique raw material sources	materialsources	arbitrary units	0-5000
Raw material type/source label if nrmaterials=20	materialtype	materialtype	0, 1, 2…20
Raw material unit from any source	i	arbitrary units	1
Quantity of material from source *i* in mobile toolkit	v_i	arbitrary units	Minimum = 0; maximum = 100
Total material of all types in mobile tool kit	sumv	arbitrary units	Minimum = 0; maximum = 100
Probability of discarding material of source *i* in toolkit	vi /Σi vi	arbitrary units	0-100
Probability of discarding materialtype in toolkit, min and max amount	∑materialtype / sumv	arbitrary units	Minimum = 0; maximum = 100
Maximum forager move length at each time step	l	grid cells	1
Distance traveled in *N* time steps; per maximum move length	N	grid cells	1

Input data: **Does the model use input from external sources such as data files or other models to represent processes that change over time?**

No

Submodels: **What, in detail, are the submodels that represent the processes listed in 'Process overview and scheduling'? What are the model parameters, their dimensions, and reference values? How were submodels designed or chosen, and how were they parameterized and then tested?**

The mobile toolkit is simulated as a vector vi where each element represents the amount of stone raw material from individual sources in the toolkit of unique type i and by raw material types denoted by materialtype. The maximum size of the toolkit is 100, and the sum of the elements of vi (Σi vi) has to be smaller or equal to 100. The amount of material added to the toolbox when a material source is encountered is 100 - Σi vi, meaning that the toolbox is filled up to the maximum capacity. Every time step one unit of material is consumed from the tool box. The probability that material source i is consumed is $v_i / \Sigma_i v_i$, meaning that it is relative to the frequency of available materials. Material sources do not deplete in the environment during the duration of the simulation. If threshold is set to <0 the forager will seek to closest raw material location if the quantity of raw material in toolkit is equal to the threshold value.

Model implementation

The model is implemented in Netlogo 5.2.1.

References

1. Grimm, V., U. Berger, D.L. DeAngelis, J.G. Polhill, J. Giske, and S.F. Railsback (2010) The ODD protocol: A review and first update. *Ecological Modelling* 221(23): 2760-2768.

2. Brantingham, P.J. (2003) A Neutral Model of Stone Raw Material Procurement, *American Antiquity* 68(3): 487–509.

3. Oestmo, S., Janssen, M.A., Marean, C.W., 2016. Testing Brantingham's Neutral Model: The Effect of Spatial Clustering on Stone Raw Material Procurement, in: Barceló, J.A., Del Castillo, F. (eds.), Simulating Prehistoric and Ancient Worlds, Springer, pp. 175-188.