Model description

This is a model description following the ODD protocol (Grimm et al., 2010) of the neutral model of raw material procurement by Brantingham (2003).

Overview:

Purpose:

To show that a simple model of random encounters of materials can produce distributions as found in the archaeological record.

State variables and scales:

One agent is foraging according a random walk and has a toolkit of fixed size. Material sources are randomly distributed on the landscape. The landscape has 250,000 cells and 5,000 material sources. The model stops if the agent reaches the edge of the landscape.

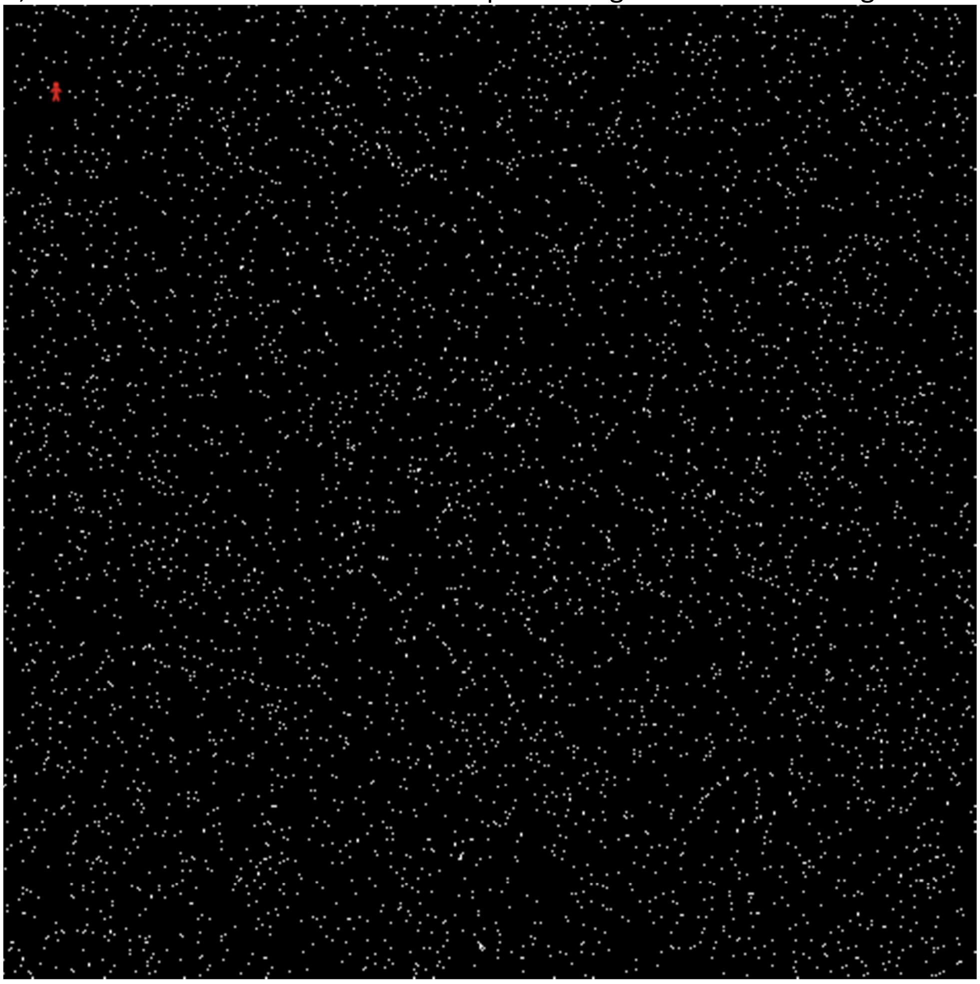


Figure 1: Landscape with randomly distributed material sources, and one forager (red person at the left top).

Process overview and scheduling:
Figure 2 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. 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 reprovisioned up to its maximum capacity before moving again at random. If no raw material source is encountered, the forager moves immediately at random. Simulations are run until 200 unique raw material sources are encountered, or the edge of the simulation world is reached.

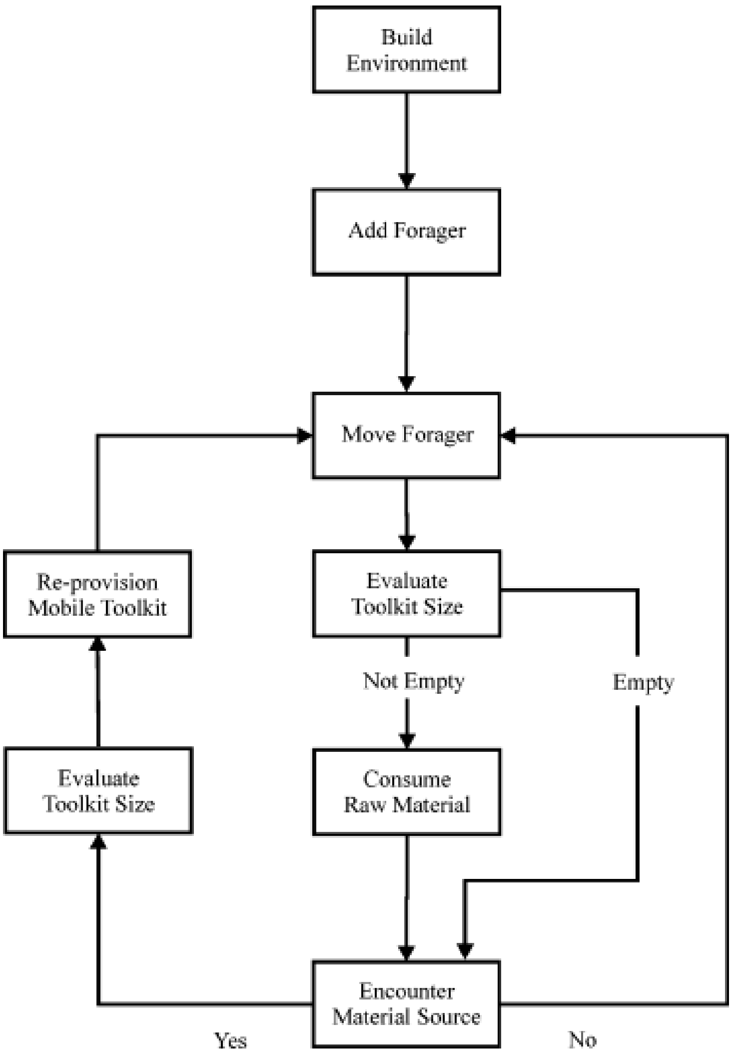


Figure 2: Figure 5 of Brantingham (2003)

Design Concepts:

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

There is debate whether changes in stone tool raw material frequencies in an archaeological assemblage can be considered a reliable proxy for human forager adaptive variability (Brantingham, 2003; Feblot-Augustins, 1993; Kuhn, 2005; Mellars, 1996). Brantingham (2003) points out that a commonly made argument is that raw material richness, transport distances, and the character of transported technologies should signal four behaviors. First, it should signal raw material selection variation due to material quality and abundance. Then, secondly, it should signal time and energy cost optimization associated with raw material procurement from spatially dispersed sources. Thirdly, it should signal planning depth that combines raw material procurement with other forager activities such as food procurement. Fourth and finally, it should signal risk minimization resulting in raw material transportation strategies focusing on quantities and forms that are energetically economical and least likely to fail. To test if raw material richness, transport distance, and the character of transported technologies is the result of adaptive behavior, Brantingham (2003: 487) presents a behaviorally neutral agent-based model that involves "…a forager engaged in a random walk within a uniform environment." The neutral model relies on the core principle (Brantingham, 2003: 491) "that all same-level components of a system are equivalent both in terms of their innate behaviors and the impact that the environment has on the expression of those behaviors." Brantingham's (2003: 491) model provides a baseline for comparison where archaeologists can be certain that "observed patterns in raw material richness, transport distance, and both quantity-distance and reduction intensity-distance relationships" is not the result of adaptation.

Emergence: **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 is part of the tool box 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.

Adaptation: **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 randomly and do not learn, adapt or evolve.

Objectives: **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.

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

Agent does not learn.

Prediction: **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?**

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.

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?**

Agents move randomly, and decisions on use of material is done randomly. Material is 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.

Details:

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

Table 1 provide the parameters as used in the model.

Table 1. Variables and Baseline Parameter Settings.

Variable description	Variable	Units	Baseline Parameter Setting/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/forager	x	grid cells	random from uniform = [1, 500]
y-coordinate position of raw material/forager	y	grid cells	random from uniform = [1, 500]
Number of unique raw material sources	n	sources	5,000
Raw material type label	i		1, 2, … 5,000
Quantity of material from source *i* in mobile toolkit	v_i	arbitrary units	minimum = 0; maximum = 100
Total material of all types in mobile toolkit; maximum toolkit capacity	Σv_i	arbitrary units	minimum = 0; maximum = 100
Amount of material collected from source *i*	a_i	arbitrary units	minimum = 1; maximum = 100
Probability of consuming material of type *i* in mobile toolkit	c_i		[0.0, 1.0]
An observed number of simulation time steps	N	time steps	
Estimated distance traveled in *N* time steps; effective foraging radius	d	grid cells	minimum = 0; maximum = 707
Maximum forager move length at each time step	l	grid cells	1
Raw material consumption rate	r	arbitrary units / time step	1
Raw material richness in mobile toolkit	k	number of types	minimum = 0; maximum = 100
Quantity of material discarded in making room for newly procured material	q_i	arbitrary units	minimum = 1; maximum = 100
Most abundant material in the mobile toolkit at a given time step	$\max[v_i]$	arbitrary units	minimum = 1; maximum = 100

Table 1: Table 1 of Brantingham (2003)

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 v_i where each element represents the amount of stone raw material in the toolkit of unique type i. The maximum size of the toolkit is 100, and the sum of the elements of v_i ($\sum_i v_i$) has to be smaller or equal to 100. The amount of material added to the toolbox when a material source is encountered is $100 - \sum_i v_i$, meaning that the toolbox is filled up to the maximum capacity.

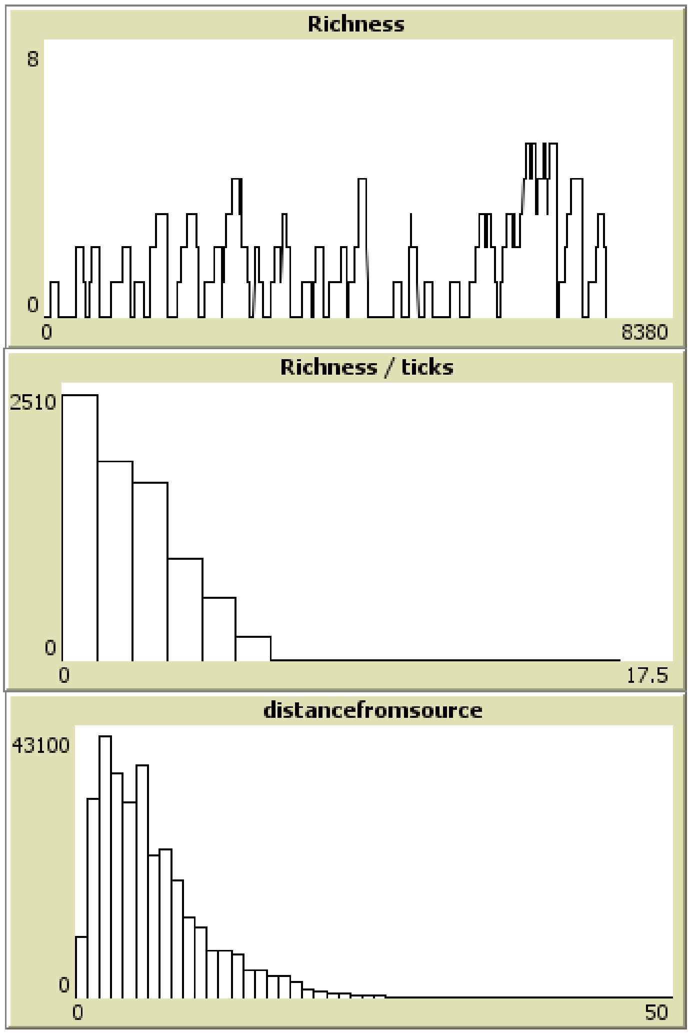
Every time step one unit of material is consumed from the tool box. The probability that material source i is consumed is $v_i / \sum_i v_i$, meaning that it is relative to the frequency of available materials. Material sources do not deplete in the environment during the duration of the simulation.

Model implementation

The model is implemented in Netlogo 5.0.3

Some results of replication

Below are some typical results of the model. The first figure shows the number of material sources in the tool box during the simulation of 7508 time steps. The middle figure shows the distribution of ticks having a certain number of different material sources in the tool box, and the bottom figure shows the distribution of material away from the source while still in the toolbox.



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. Feblot-Augustins, J. (1993) Mobility Strategies in the Late Middle Palaeolithic of Central Europe and Western Europe: Elements of Stability and Variability. Journal of Anthropological Archaeology 12:211-265.
4. Kuhn, S.L., (1995) Mousterian Lithic Technology: An Ecological Perspective. Princeton University Press, Princeton.
5. Mellars, P.A., (1996) The Neandertal Legacy: An Archaeological Perspective from Western Europe. Princeton University Press, Princeton.