

AGENT-BASED MODELLING IN ARCHAEOLOGY

Why do it, how to do it, and what to expect

Andreas Angourakis [@AndrosSpica](#)

available at <https://andros-spica.github.io/CDAL-Angourakis-2019/>
<https://andros-spica.github.io/CDAL-Angourakis-2019/index.html?print-pdf> (printable version)

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UNIVERSITY OF
CAMBRIDGE



McDonald Institute for Archaeological Research

THE '*WHY*'

ARCHAEOLOGY

CHALLENGES

- fragmentary, coarse data
- indirect evidence
- (mostly) not experimental
- semantic ambiguity
- few consensual models
- debate on core aspects

OPPORTUNITIES

- long-term perspective
- materiality
- holistic, "naive", out-of-box thinking
- permeability to other disciplines

THE PRISM OF *COMPLEXITY SCIENCE*

- Complex system
- *complexity*: number and diversity of causal relationships
- *nonlinearity, self-organisation* and *self-similarity*
- Unifying frameworks:
 - theoretical (e.g., *generative social science, socio-ecological systems*)
 - methodological (e.g., *open databases, GIS, ABM*)

Breeder pattern in Conway's Game of Life

derivative work: George (talk)Conways_game_of_life_breeder.png: Hyperdeath [CC BY-SA 3.0 (<https://creativecommons.org/licenses/by-sa/3.0/>)], via Wikimedia Commons

AGENT-BASED MODELLING (*ABM*)

- dynamics → simulation
- Formalisation → defined logic rules
- rules → algorithms
- population → distributed processes
- bottom-up → emergent properties
- stochasticity → probabilistic results

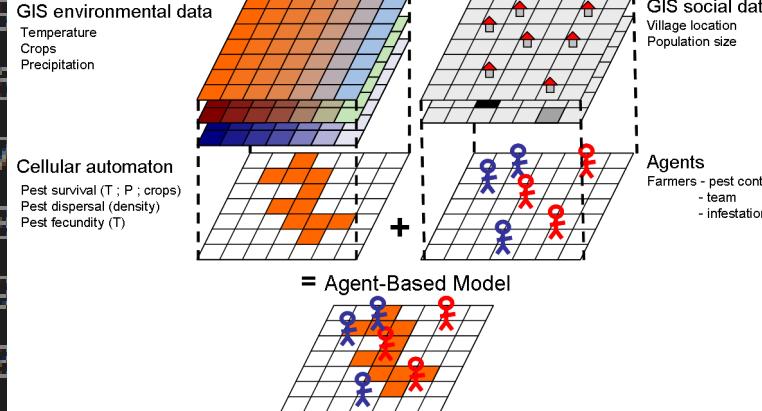
Flocking behaviour in 'Behavioral systems' by Danil Nagy in
'Generative Design', medium.com

```
13  
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16  
17 function stableMatching {  
18     Initialize all  $m \in M$  and  $w \in W$  to free  
19     while  $\exists$  free man  $m$  who still has a woman  $w$  to propose to {  
20          $w =$  first woman on  $m$ 's list to whom  $m$  has not yet proposed  
21         if  $w$  is free  
22              $(m, w)$  become engaged  
23         else some pair  $(m', w)$  already exists  
24             if  $w$  prefers  $m$  to  $m'$   
25                  $m'$  becomes free  
26                  $(m, w)$  become engaged  
27             else  
28                  $(m', w)$  remain engaged  
29     }  
30 }
```

Background: pseudo-code for the Gale-Shapley algorithm
to solve the [Stable Marriage Problem](#)

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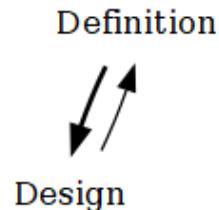
THE '**HOW**'

ABM MODELLING STEPS

Definition

Identify the system
hypotheses
questions
concepts
phenomenon of interest

ABM MODELLING STEPS

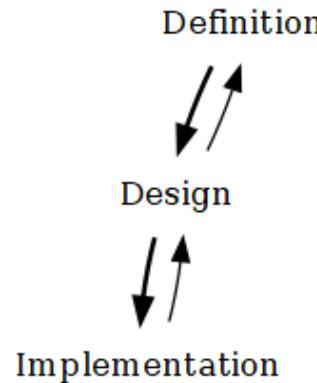


Model the system
elements and processes
required to address the system

to KISS or not to KISS?

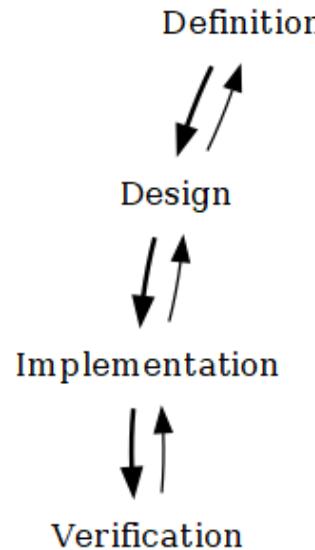
KISS = Keep It Simple, Stupid!

ABM MODELLING STEPS



Implement the model
express the elements and
processes as computer code

ABM MODELLING STEPS

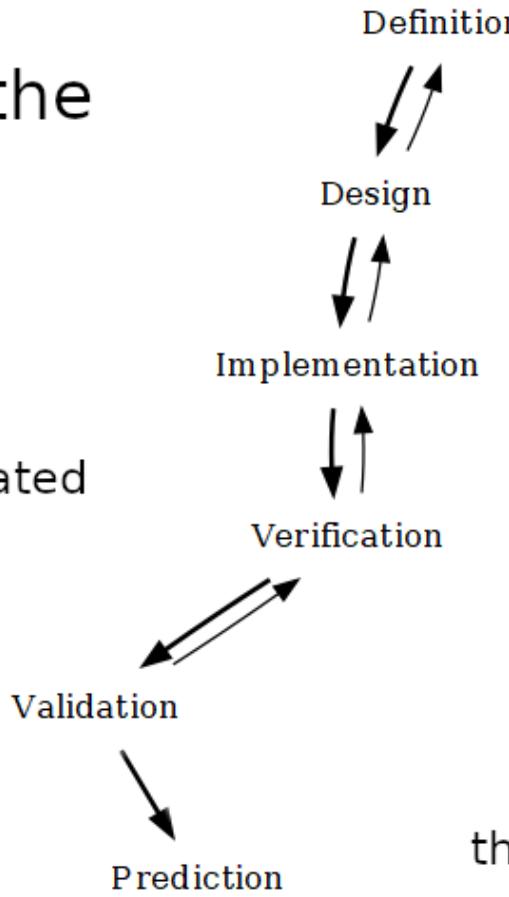


Test the model
confirm that the code
expressions of all elements
and processes represent the
intended design

ABM MODELLING STEPS

Validate the model

calibrate parameters
use external datasets
compare simulated results with observations



Predict (new) observations
the model is reliable to predict data
GIS approaches

ABM MODELLING STEPS

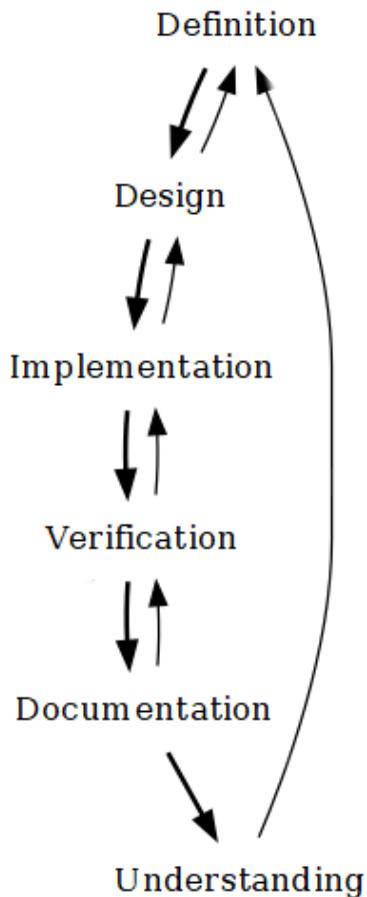
Communicate the model

assure that all
modelling decisions
are registered and
explained

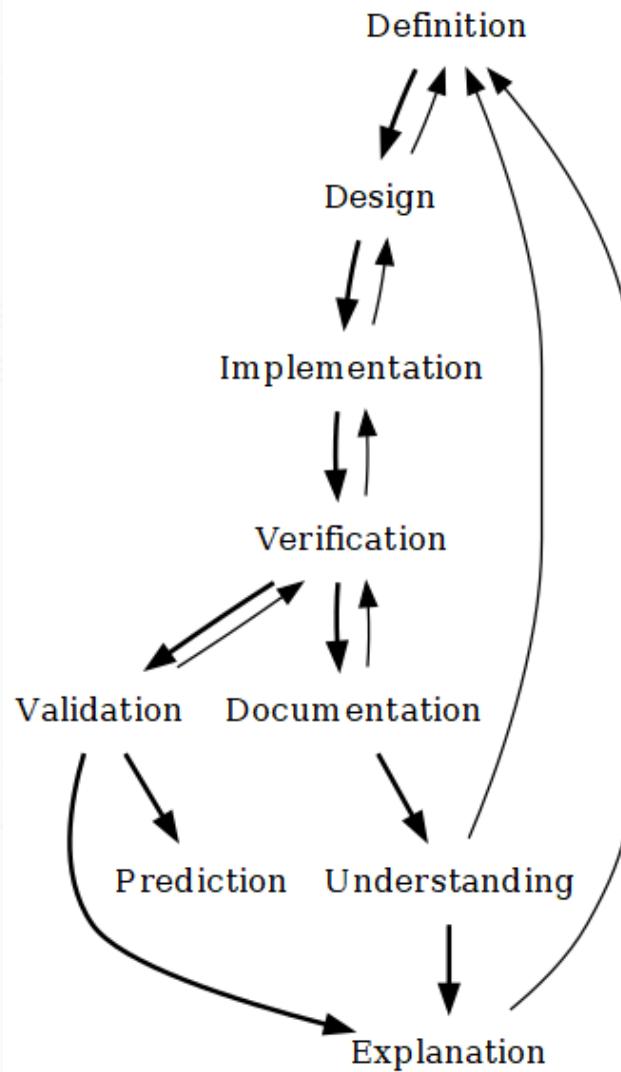
Understand the model

interact with the
model behaviour at
all levels

replicate it
break it
modify it



ABM MODELLING STEPS



EXAMPLES

SCHELLING'S SEGREGATION MODEL

- Definition:
the formation of racially mixed versus segregated neighborhoods in the United States (c. 1960-1970)
- Design:
 - two *types* of agents
 - agents occupy a *position* in a grid
 - adjacent positions are considered as *neighborhood*
 - agent *satisfaction* = ratio of neighbors of the same type (*homophily*)
 - unsatisfied agents *move* to another free position

Schelling, Thomas. 1971. "Dynamic Models of Segregation." *Journal of Mathematical Sociology* 1 (143-186).

EXAMPLES

SCHELLING'S SEGREGATION MODEL

```
def step(self):

    # FIRST PROCESS: counting similar neighbors

    similar = 0

    for neighbor in self.model.grid.neighbor_iter(self.pos):

        if neighbor.type == self.type:

            similar += 1


    # SECOND PROCESS: check if the number of similar neighbors is less than homophily,
    ## move if it isn't

    # If unhappy, move:

    if similar < self.model.homophily:

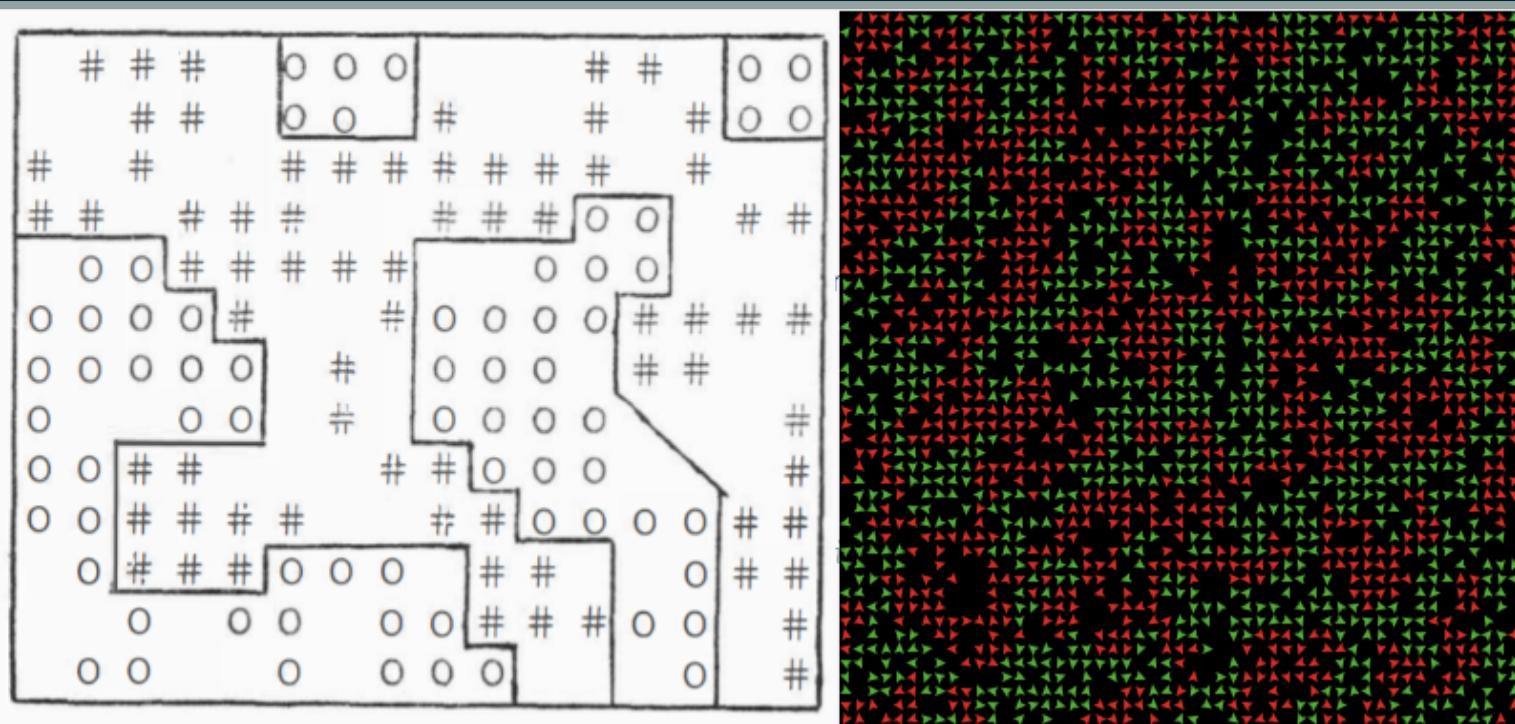
        self.model.grid.move_to_empty(self)

    else:

        self.model.happy += 1
```

EXAMPLES

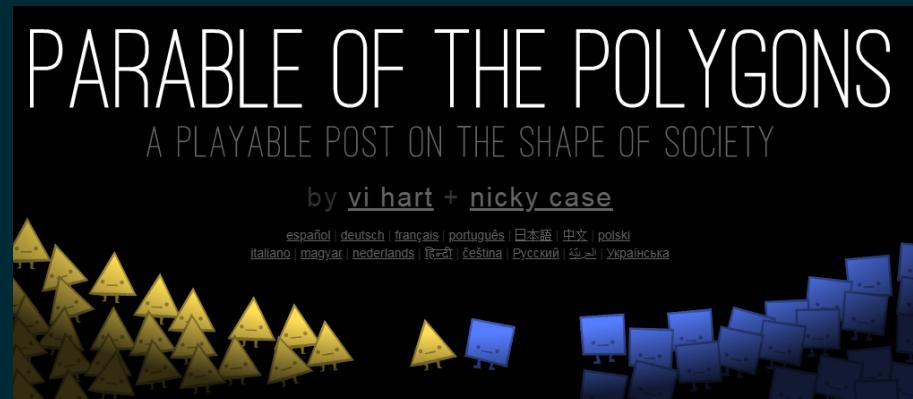
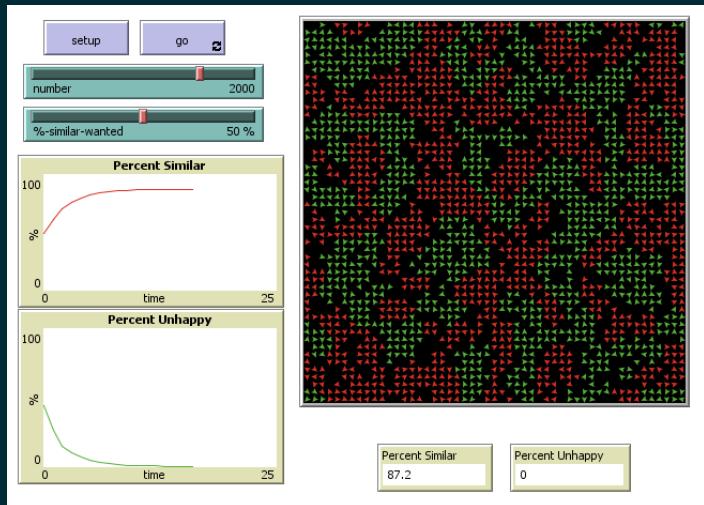
SCHELLING'S SEGREGATION MODEL



```
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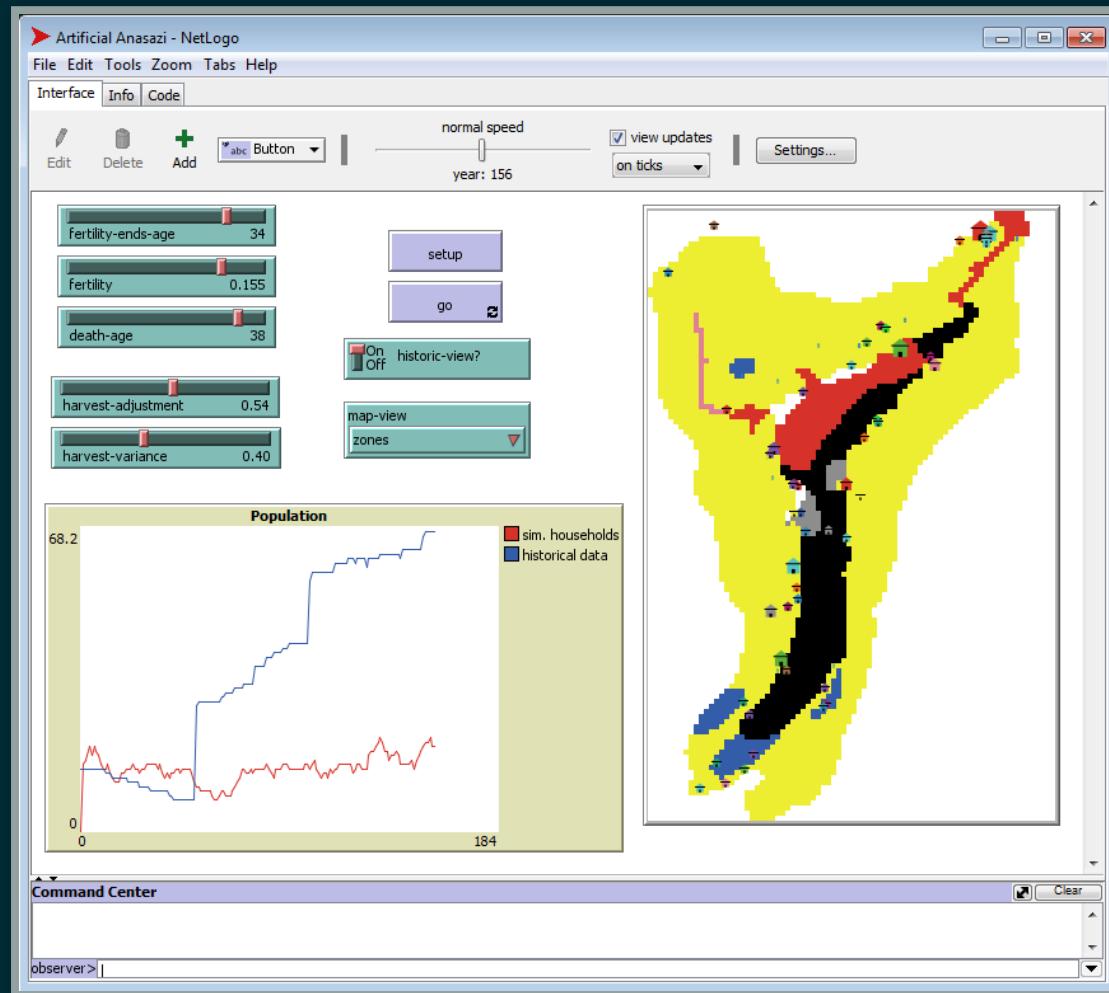
EXAMPLES

SCHELLING'S SEGREGATION MODEL



EXAMPLES

ARTIFICIAL ANASAZI



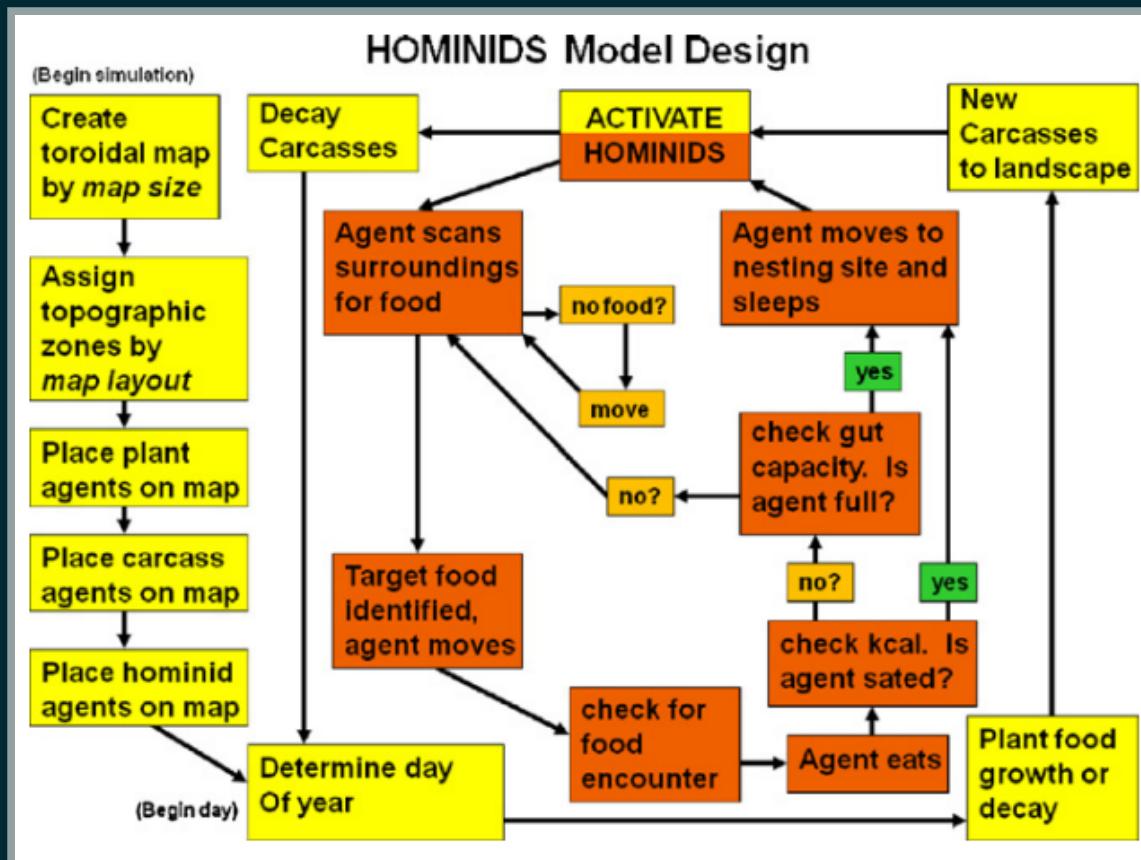
Axtell, R. L., Epstein, J. M., Dean, J. S., Gumerman, G. J., Swedlund, A. C., Harburger, J., ... Parker, M. (2002). Population growth and collapse in a multiagent model of the Kayenta Anasazi in Long House Valley. *Proceedings of the National Academy of Sciences*, 99(Supplement 3), 7275–7279. <https://doi.org/10.1073/pnas.092080799>

Janssen, M. A. (2009). Understanding Artificial Anasazi. *Journal of Artificial Societies and Social Simulation*, 12(4). <http://jasss.soc.surrey.ac.uk/12/4/13.html>

EXAMPLES

HOMINIDS

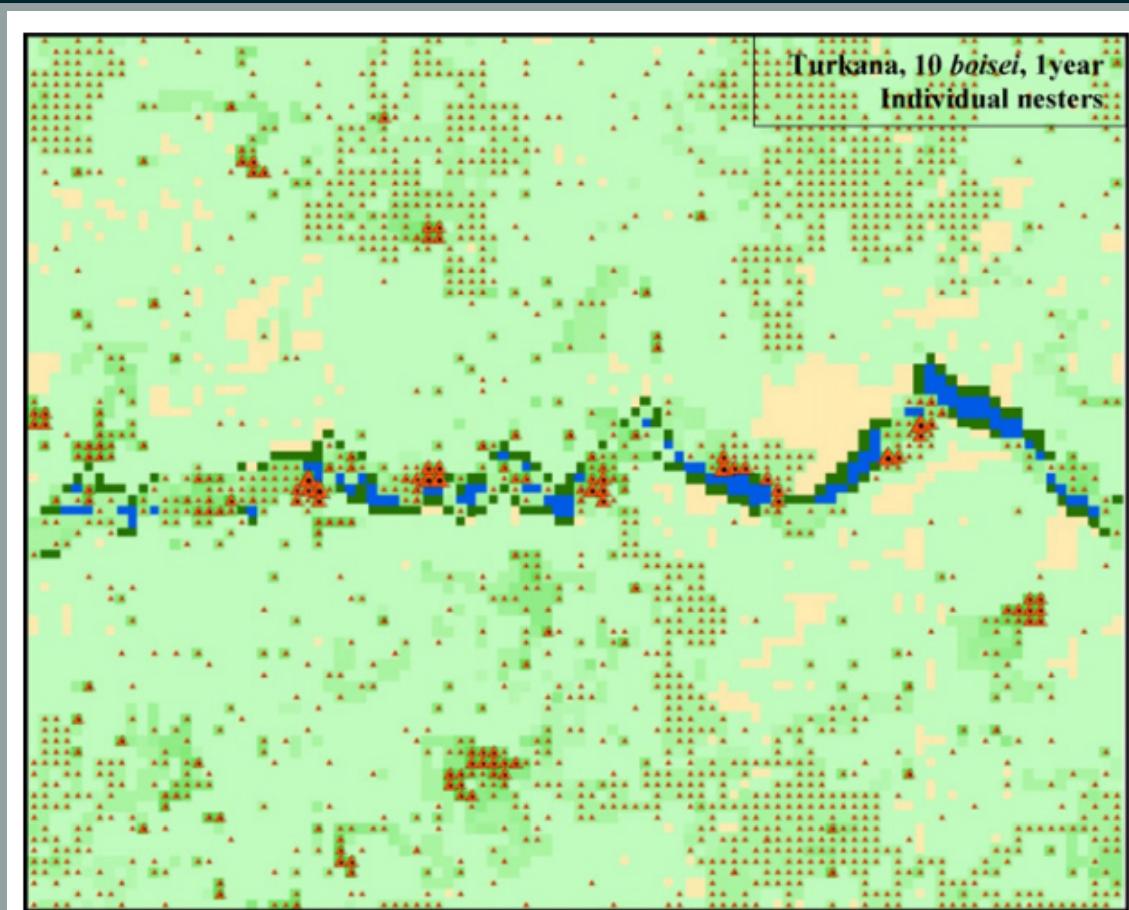
Griffith, C. S., Long, B. L., and Sept, J. M. (2010). HOMINIDS: An agent-based spatial simulation model to evaluate behavioral patterns of early Pleistocene hominids. Ecological Modelling, 221(5), 738–760. <https://doi.org/10.1016/j.ecolmodel.2009.11.009>



EXAMPLES

HOMINIDS

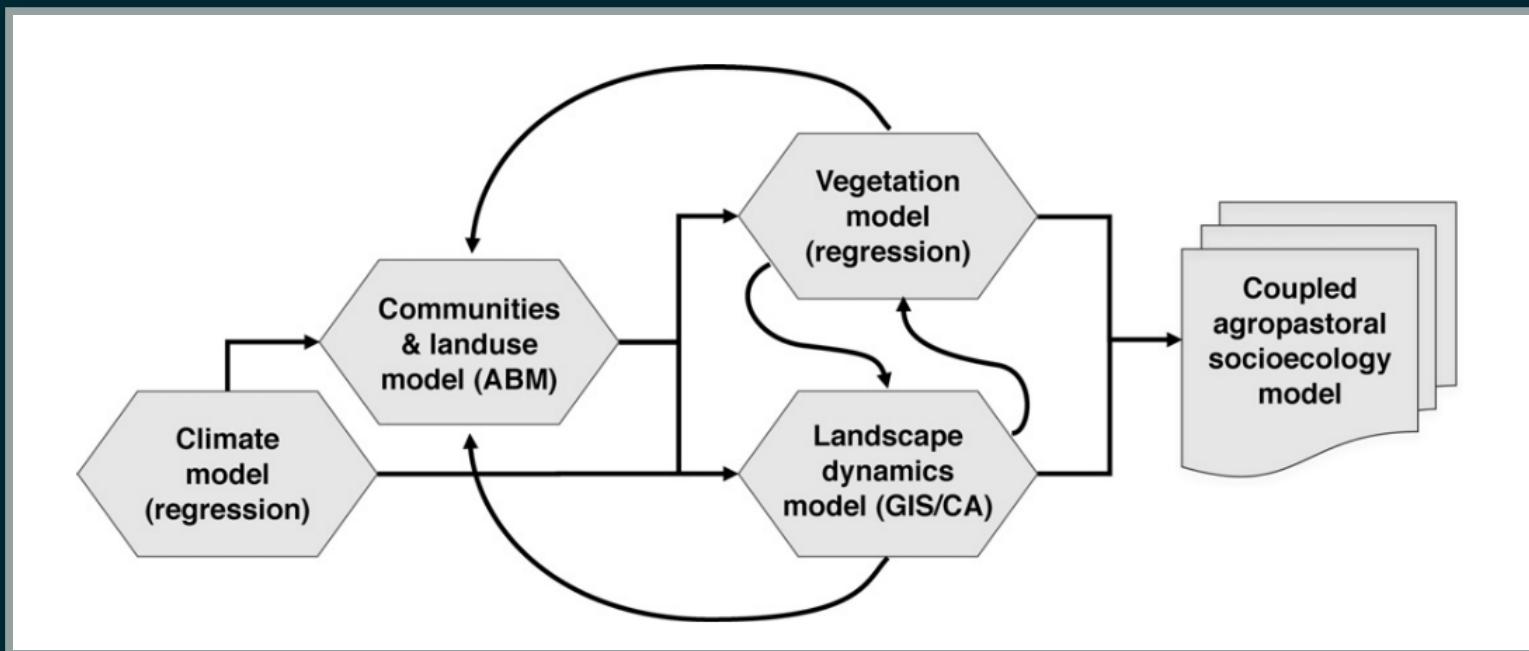
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EXAMPLES

MEDLAND

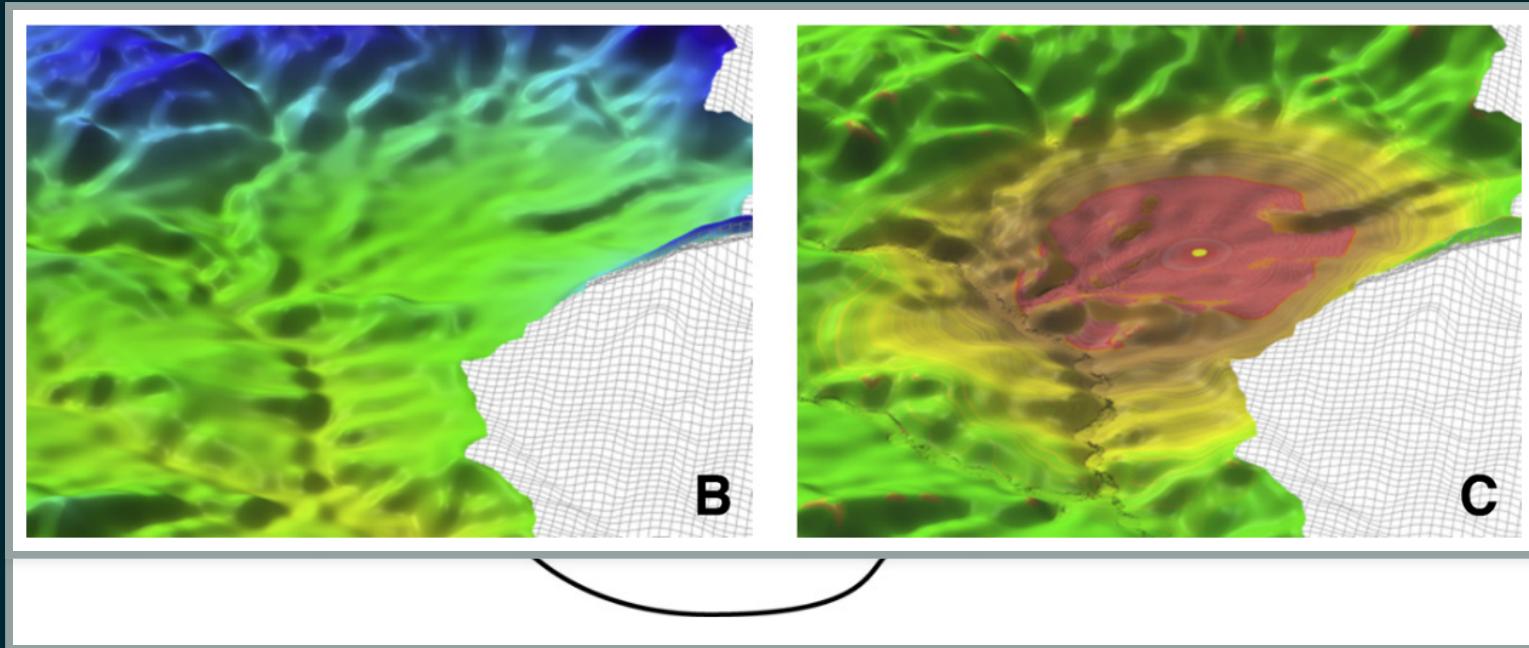
Barton, C. M., Ullah, I. I. T., Bergin, S. M., Mitasova, H., and Sarjoughian, H. (2012). Looking for the future in the past: Long-term change in socioecological systems. Ecological Modelling, 241, 42–53. <https://doi.org/10.1016/J.ECOLMODEL.2012.02.010>



EXAMPLES

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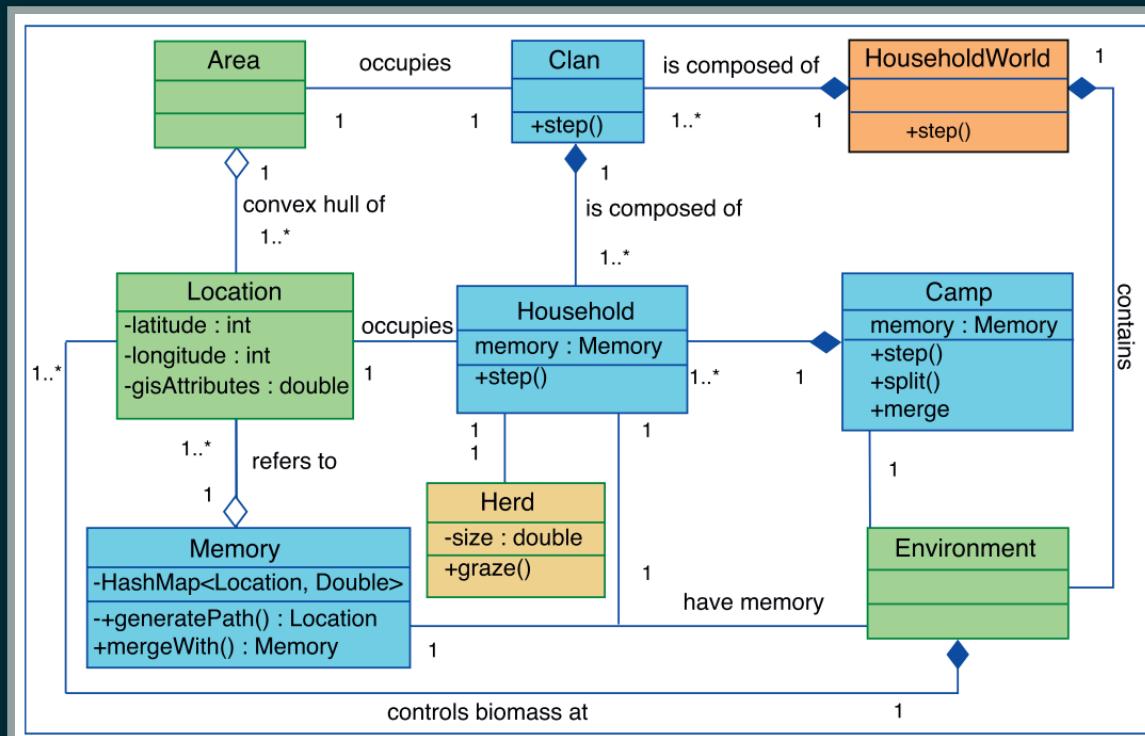
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EXAMPLES

HOUSEHOLDSWORLD

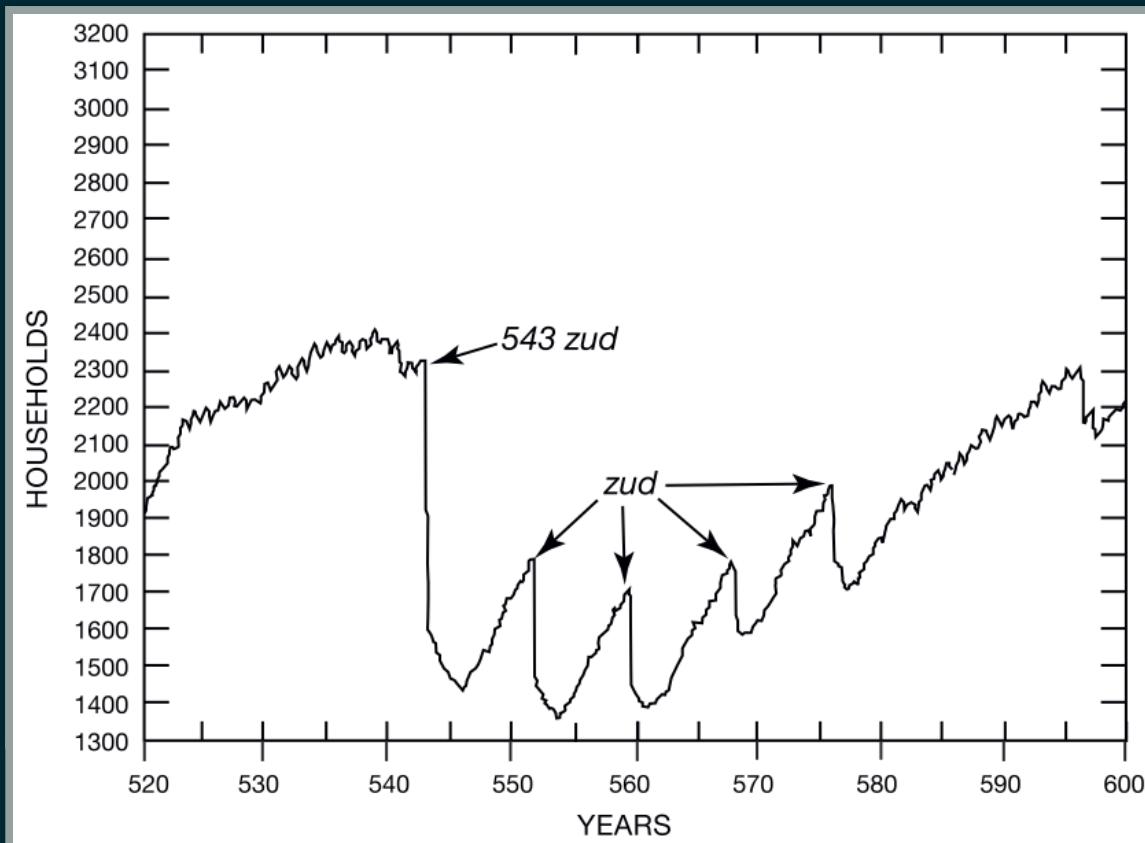
Rogers, J. D., Nichols, T., Emmerich, T., Latek, M., and Cioffi-Revilla, C. (2012). Modeling scale and variability in human–environmental interactions in Inner Asia. Ecological Modelling, 241, 5–14. <https://doi.org/10.1016/J.ECOLMODEL.2011.11.025>



EXAMPLES

HOUSEHOLDSWORLD

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EXPECTATIONS

GRAND CHALLENGES (METHOD)

- Disambiguation
- Consolidation of shared models
- Virtual laboratory
- Interdisciplinary approach

Epstein, J. M. (2008). Why Model? Journal of Artificial Societies and Social Simulation, 11(4), 12. <http://jasss.soc.surrey.ac.uk/11/4/12.html>

GRAND CHALLENGES (THEORY)

- Emergence of social and socio-ecological systems
- Resilience, adaptation, change, collapse
- Space and mobility
- Behaviour and cognition

Kintigh, K. W., Altschul, J. H., Beaudry, M. C., Drennan, R. D., Kinzig, A. P., Kohler, T. A., ... Zeder, M. A. (2014). Grand challenges for archaeology. *Proceedings of the National Academy of Sciences of the United States of America*, 111(3), 879–880.

<https://doi.org/10.1073/pnas.1324000111>

Economics focus

Agents of change

Conventional economic models failed to foresee the financial crisis. Could agent-based modelling do better?



- Social processes linked to materiality
- Any spatial or time scale
- Data standardization and collection
- Theory building/hypothesis generation

Madella, M., Rondelli, B., Lancelotti, C., Balbo, A. L., Zurro, D., Rubio Campillo, X., & Stride, S. (2014). Introduction to Simulating the Past. *Journal of Archaeological Method and Theory*, 21(2), 251–257. <https://doi.org/10.1007/s10816-014-9209-8>

Rogers, J. D., & Cegielski, W. H. (2017). Opinion: Building a better past with the help of agent-based modeling. *Proceedings of the National Academy of Sciences of the United States of America*, 114(49), 12841–12844. <https://doi.org/10.1073/pnas.1718277114>

Cegielski, W. H., & Rogers, J. D. (2016). Rethinking the role of Agent-Based Modeling in archaeology. *Journal of Anthropological Archaeology*, 41, 283–298. <https://doi.org/10.1016/J.JAA.2016.01.009>

CAVEATS

- NOT magical solution!
- Still long way to set a "standard"
- Steep learning curve (for all involved)
- Inherits any theoretical/methodological biases
- Validation, documentation and understanding often underdeveloped tasks

FUTURE?

Project Highrise



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THANK YOU!

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FURTHER REFERENCES

The-ABM-in-Archaeology-Bibliography
by Iza Romanowska and Lennart Linde