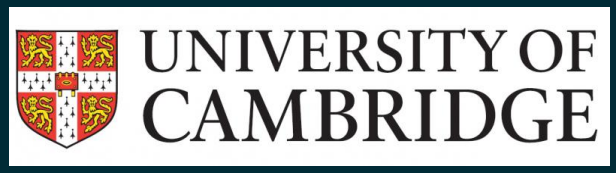
AGENT-BASED MODELLING IN ARCHAEOLOGY

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)

click on images to consult source



McDonald Institute for Archaeological Research

THE '*WHY*'

ARCHAEOLOGY

CHALLENGES

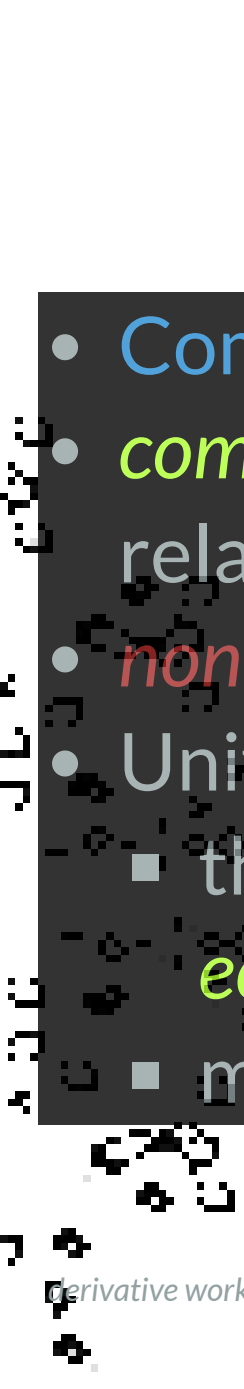
- fragmentary, coarse data
- indirect evidence
- (mostly) not experimental
- semantic ambiguity
- few consensual models
- debate on core aspects

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*)

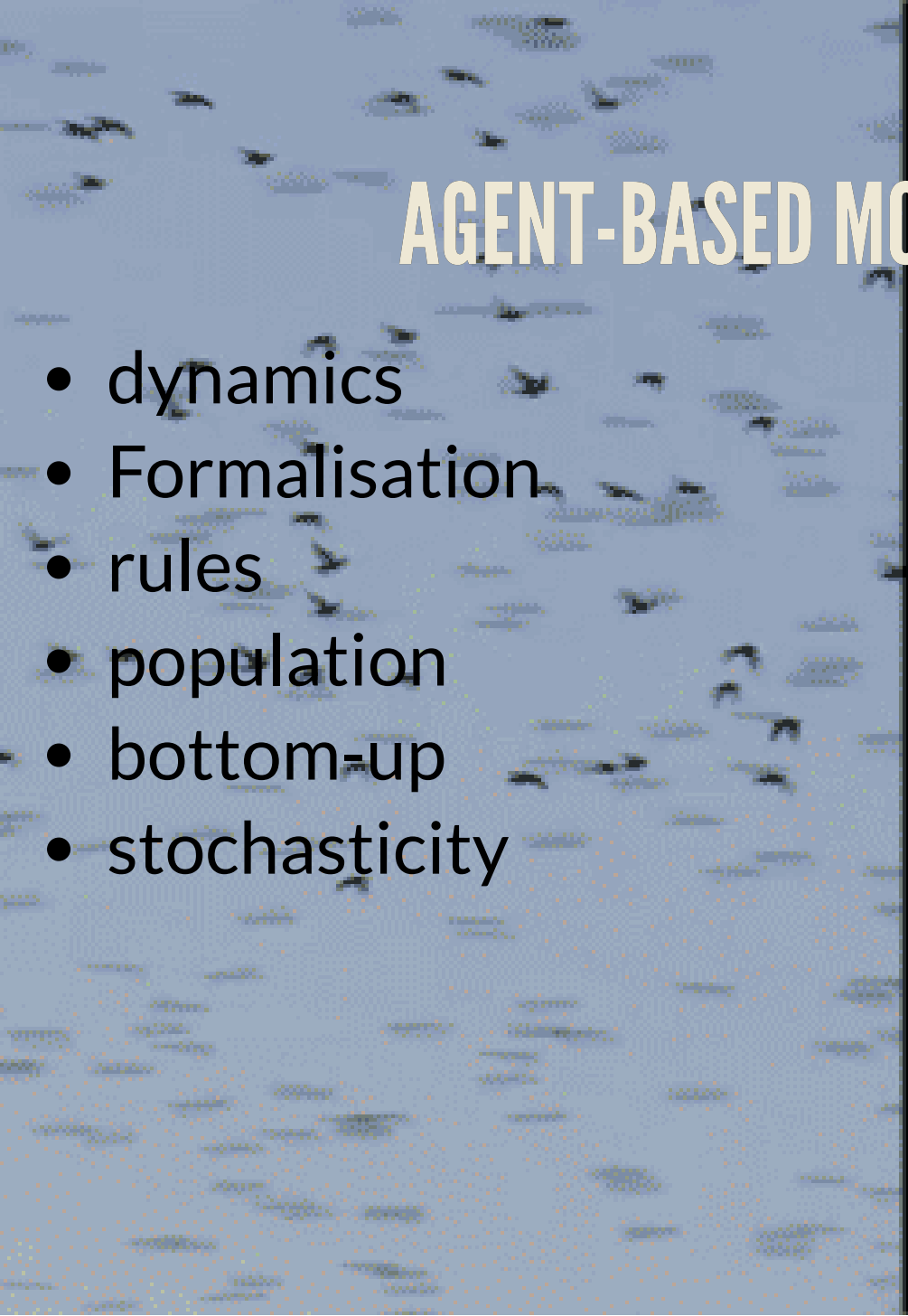


Breeder pattern in Conway's Game of Life

AGENT-BASED MODELLING (*ABM*)

- dynamics
- Formalisation
- rules
- population
- bottom-up
- stochasticity

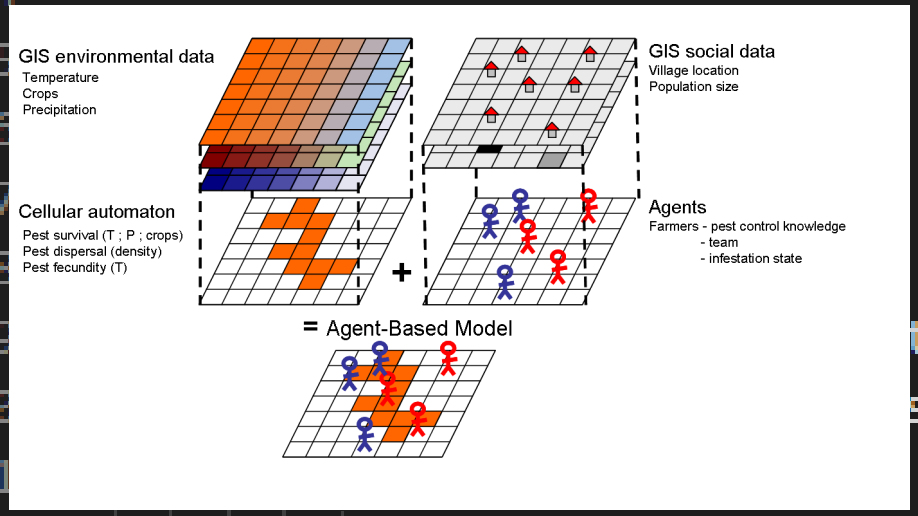
→ simulation
→ defined logic rules
→ algorithms
→ distributed processes
→ emergent properties
→ probabilistic results

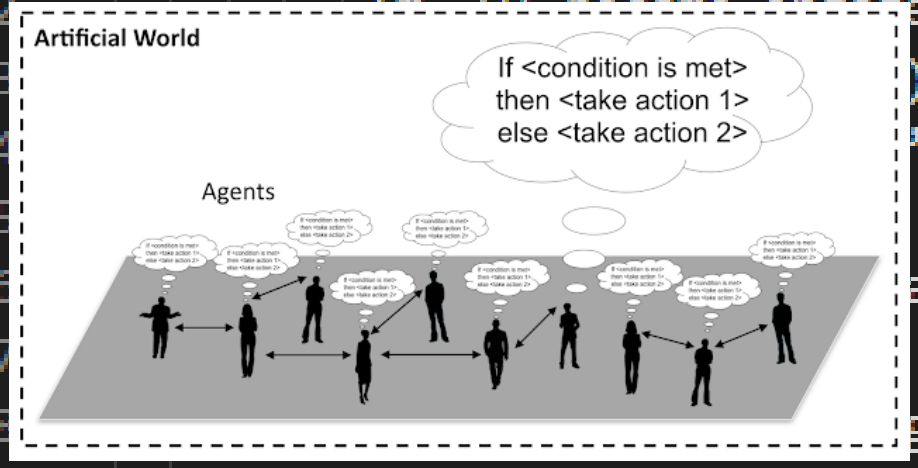


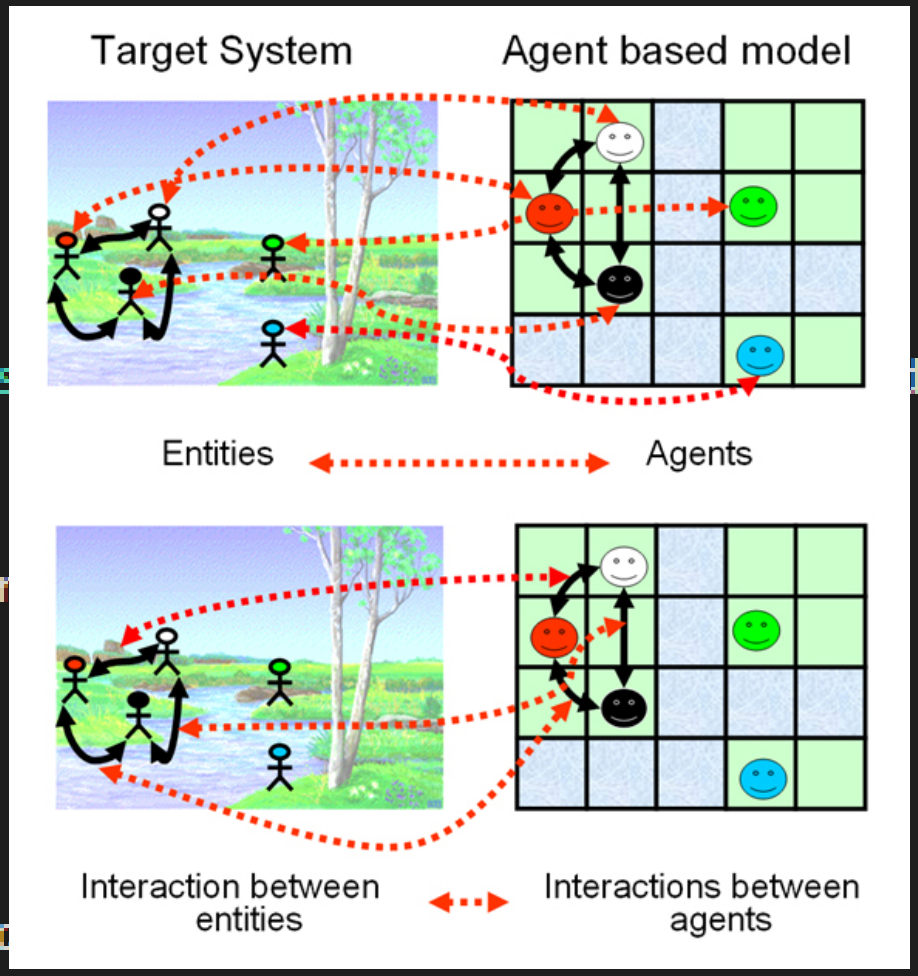
Flocking behaviour in 'Behavioral systems' by Danil Nagy in 'Generative Design', medium.com

```
function stableMatching {
    Initialize all m ∈ M and w ∈ W to free
    while ∃ free man m who still has a woman w to propose to {
        w = first woman on m's list to whom m has not yet proposed
        if w is free
            (m, w) become engaged
        else some pair (m', w) already exists
            if w prefers m to m'
                m' becomes free
                (m, w) become engaged
            else
                (m', w) remain engaged
    }
}
```

Background: pseudo-code for the Gale–Shapley algorithm to solve the Stable Marriage Problem







Background: pseudo-code for the Gale–Shapley algorithm to solve the Stable Marriage Problem

THE '*HOW*'

ABM MODELLING STEPS

Definition

Identify the system

hypotheses

questions

concepts

phenomenon of interest

ABM MODELLING STEPS

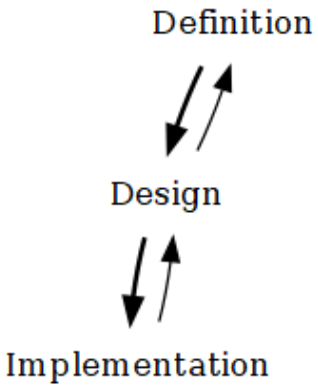
Model the system

elements and processes
required to address the system

to KISS or not to KISS?

KISS = Keep It Simple, Stupid!

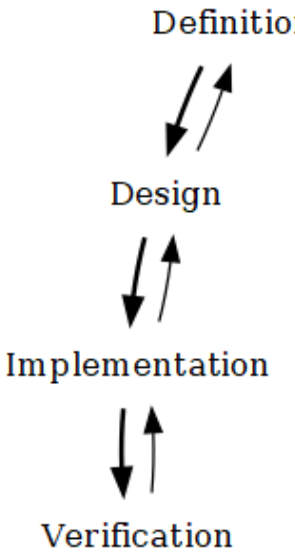
ABM MODELLING STEPS



Implement the model

express the elements and processes as computer code

ABM MODELLING STEPS



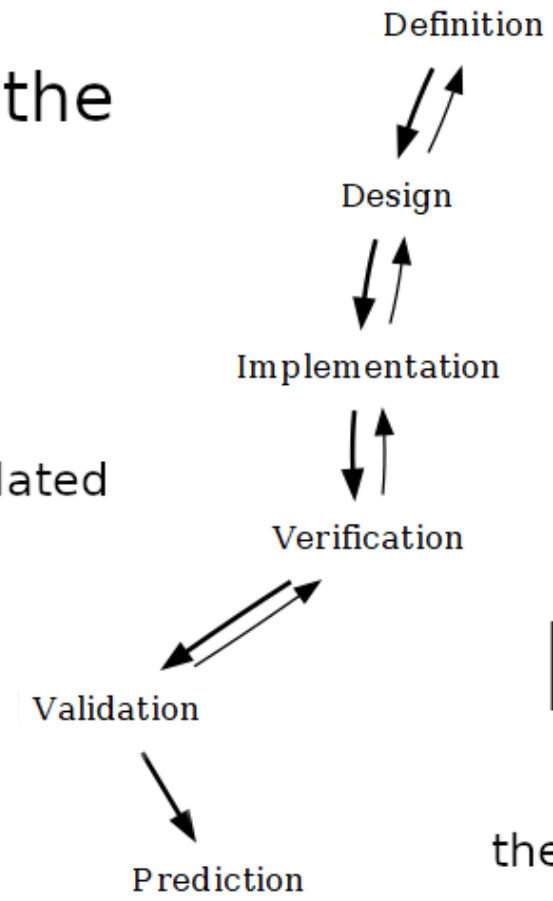
Test the model

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

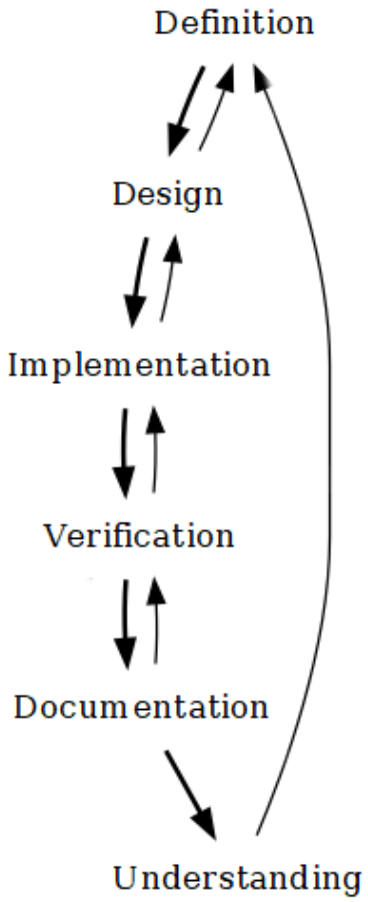
Communicate the model

assure that all modelling decisions are registered and explained

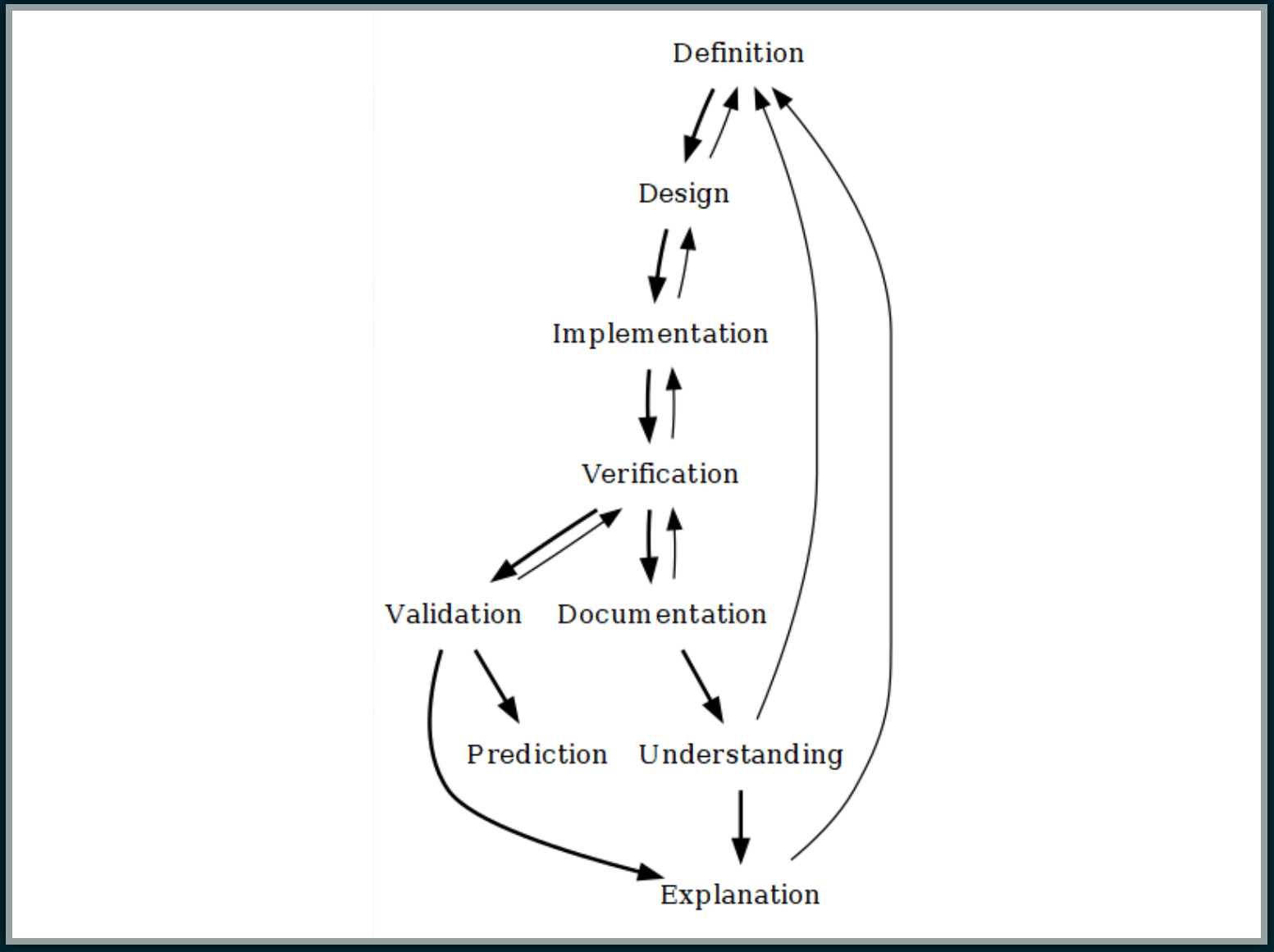
Understand the model

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

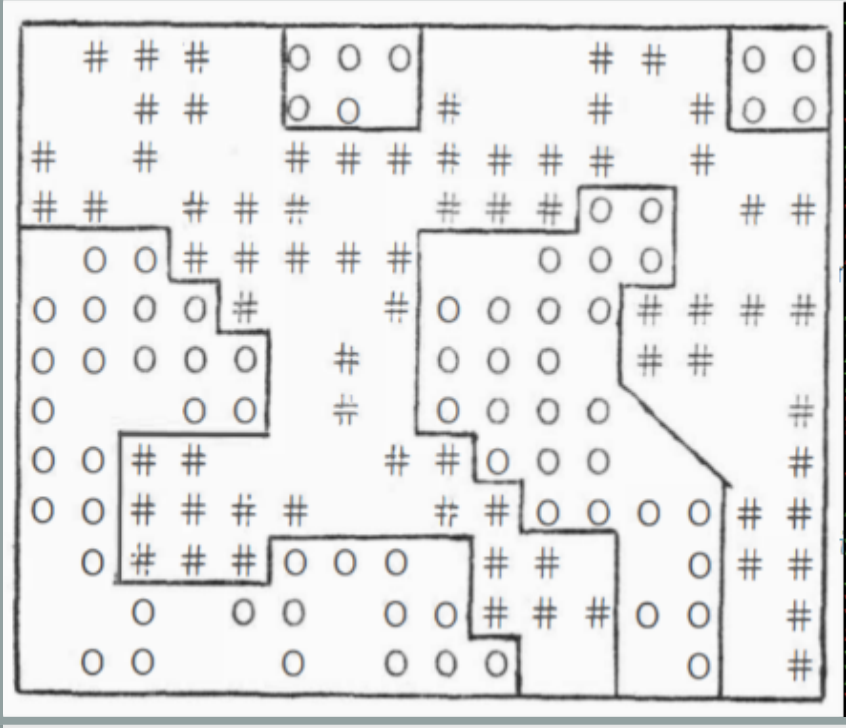
SCHELLING'S SEGREGATION MODEL

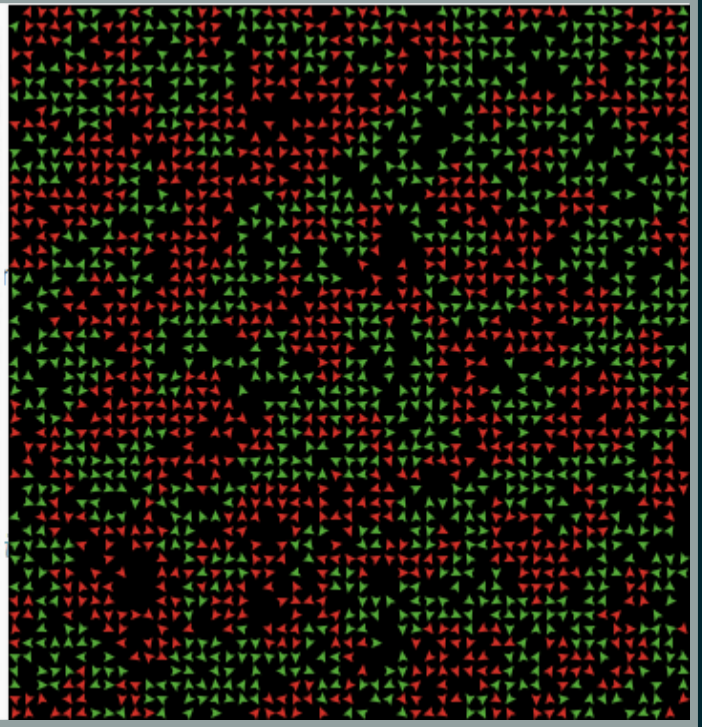
```
def step(self):
  # FIRST PROCESS: counting similar neighbors
  similar = 0
  for neighbor in self.model.grid.neighbor_iter(self.pos):
    if neighbor.type == self.type:
      similar += 1

  # 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

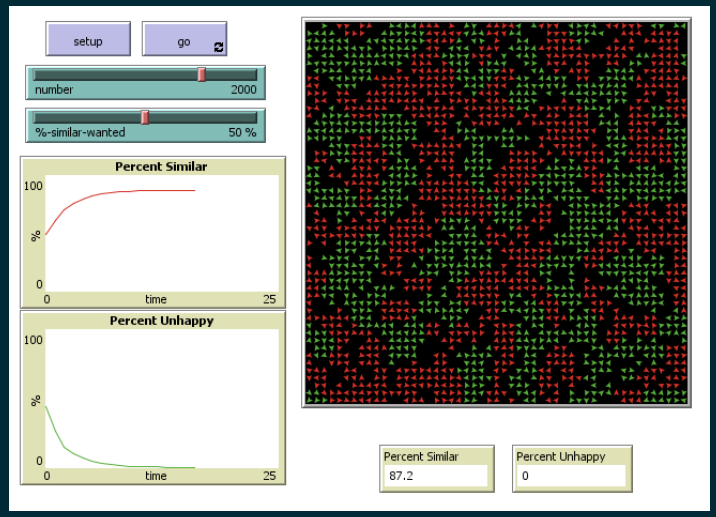


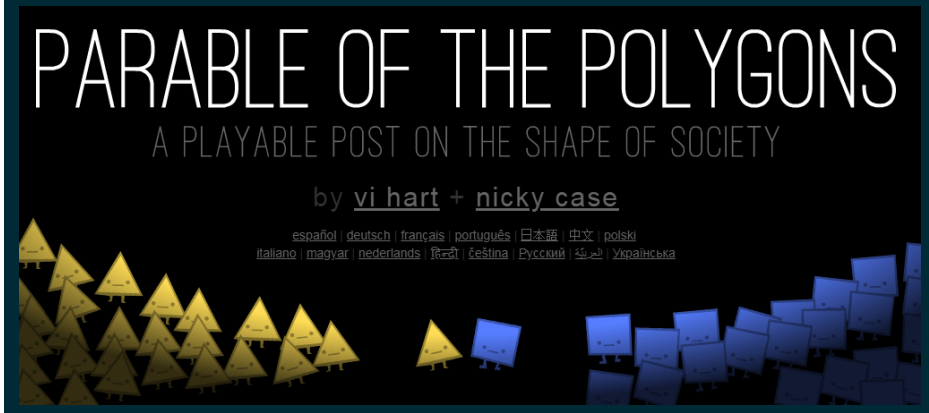


```
if similar < self.model.homophily:
  self.model.grid.move_to_empty(self)
else:
  self.model.happy += 1
```

EXAMPLES

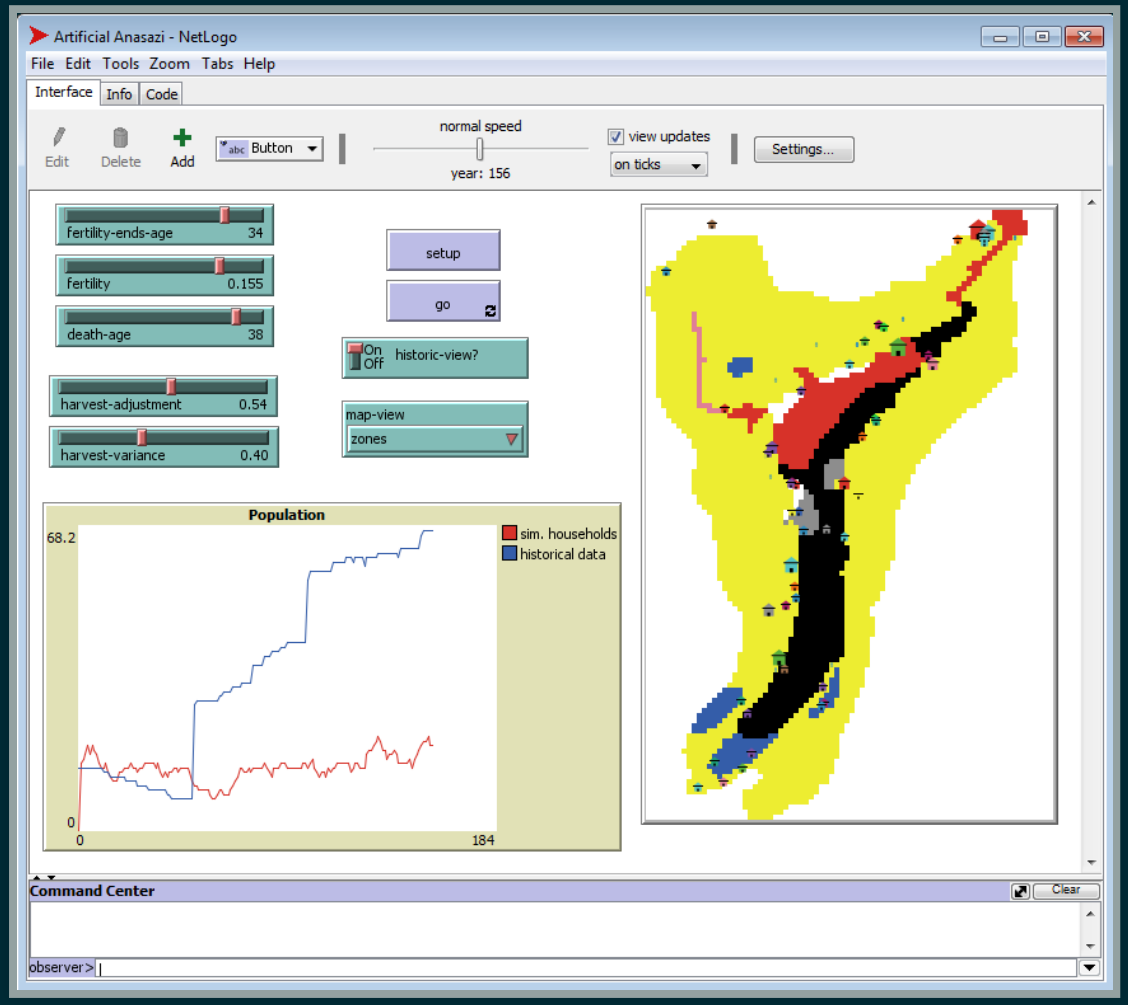
SCHELLING'S SEGREGATION MODEL





EXAMPLES

ARTIFICIAL ANASAZI



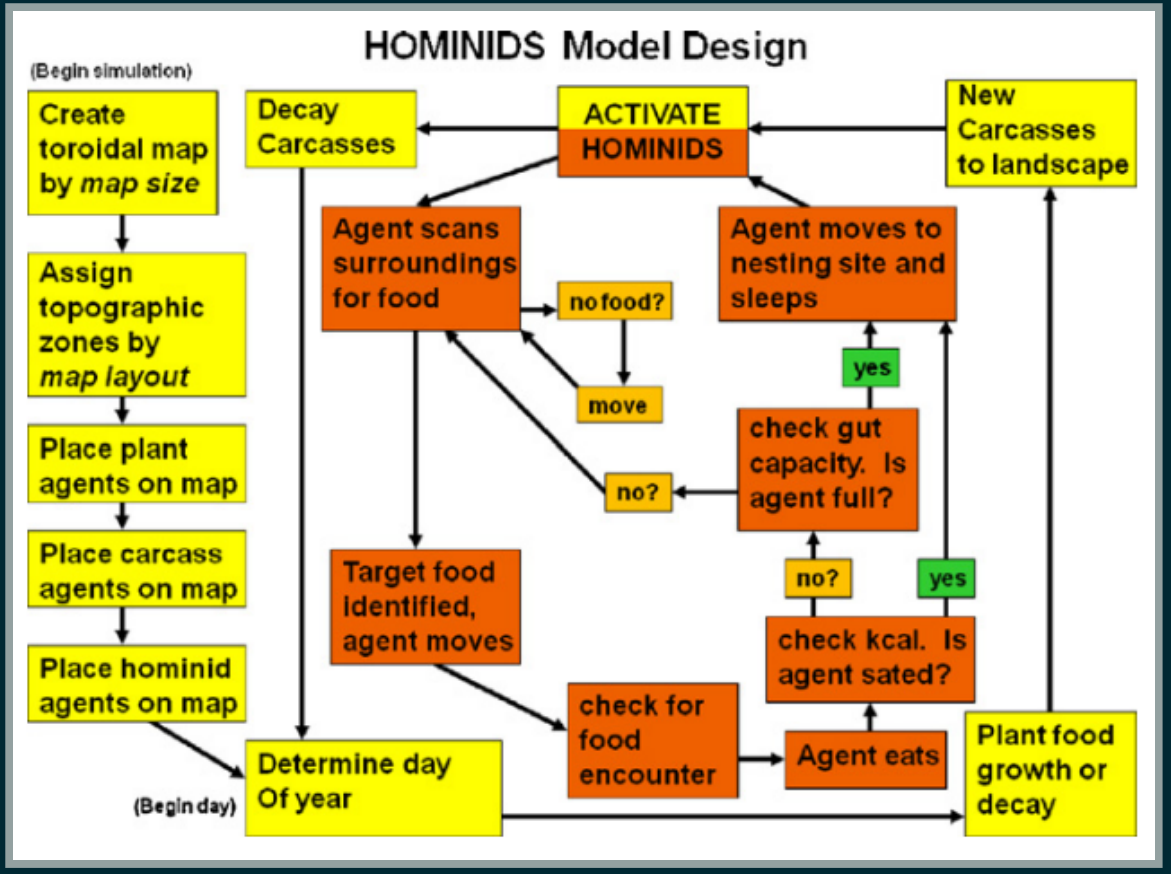
Axtell, R. L., Epstein, J. M., Dean, J. S., Gumerman, G. J., Swedlund, A. C., Harburger, J., … Parker, M. (2002). Population growth and collapse in a multiagent model of the Kayenta Anasazi in Long House Valley. Proceedings of the National Academy of Sciences, 99(Supplement 3), 7275–7279. https://doi.org/10.1073/pnas.092080799

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

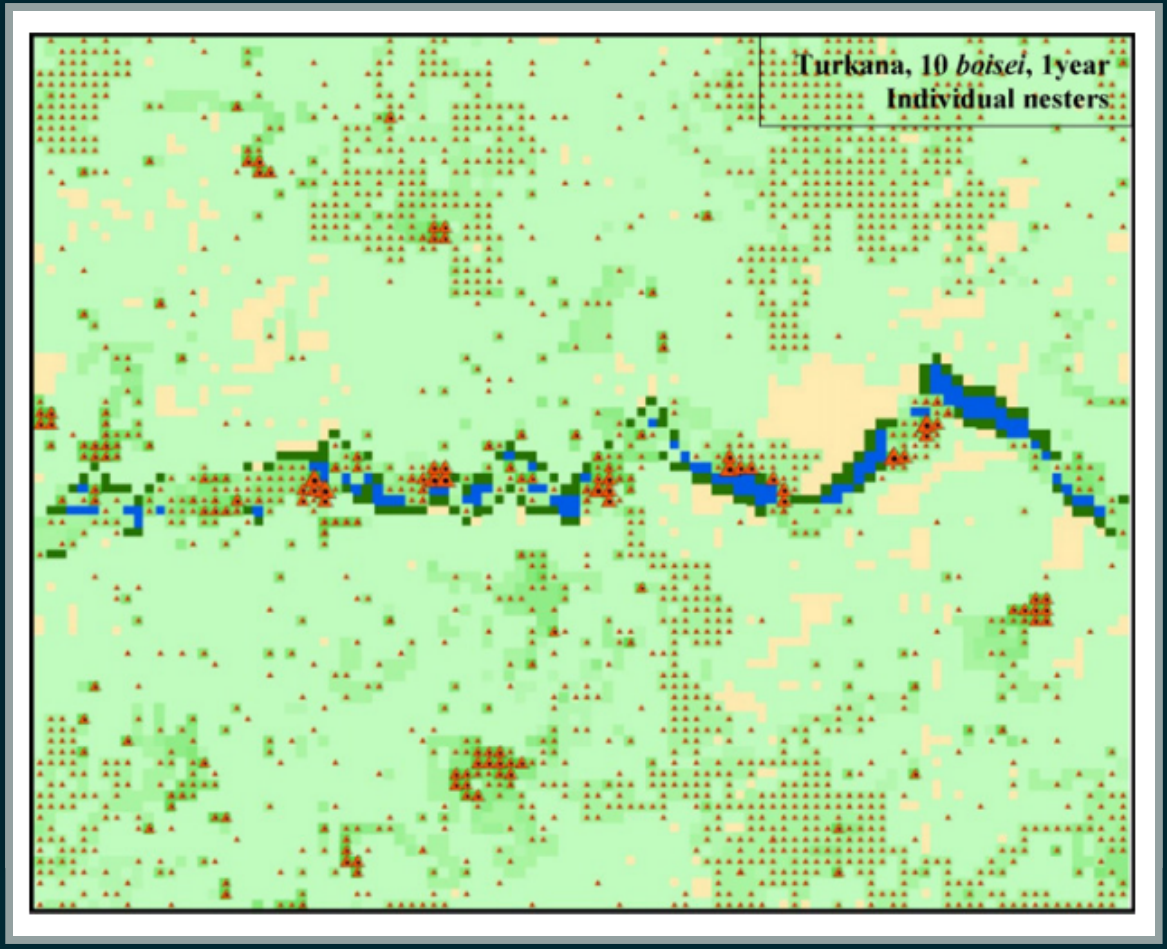
Griffith, C. S., Long, B. L., and Sept, J. M. (2010). HOMINIDS: An agent-based spatial simulation model to evaluate behavioral patterns of early Pleistocene hominids. Ecological Modelling, 221(5), 738–760. https://doi.org/10.1016/j.ecolmodel.2009.11.009



EXAMPLES

HOMINIDS

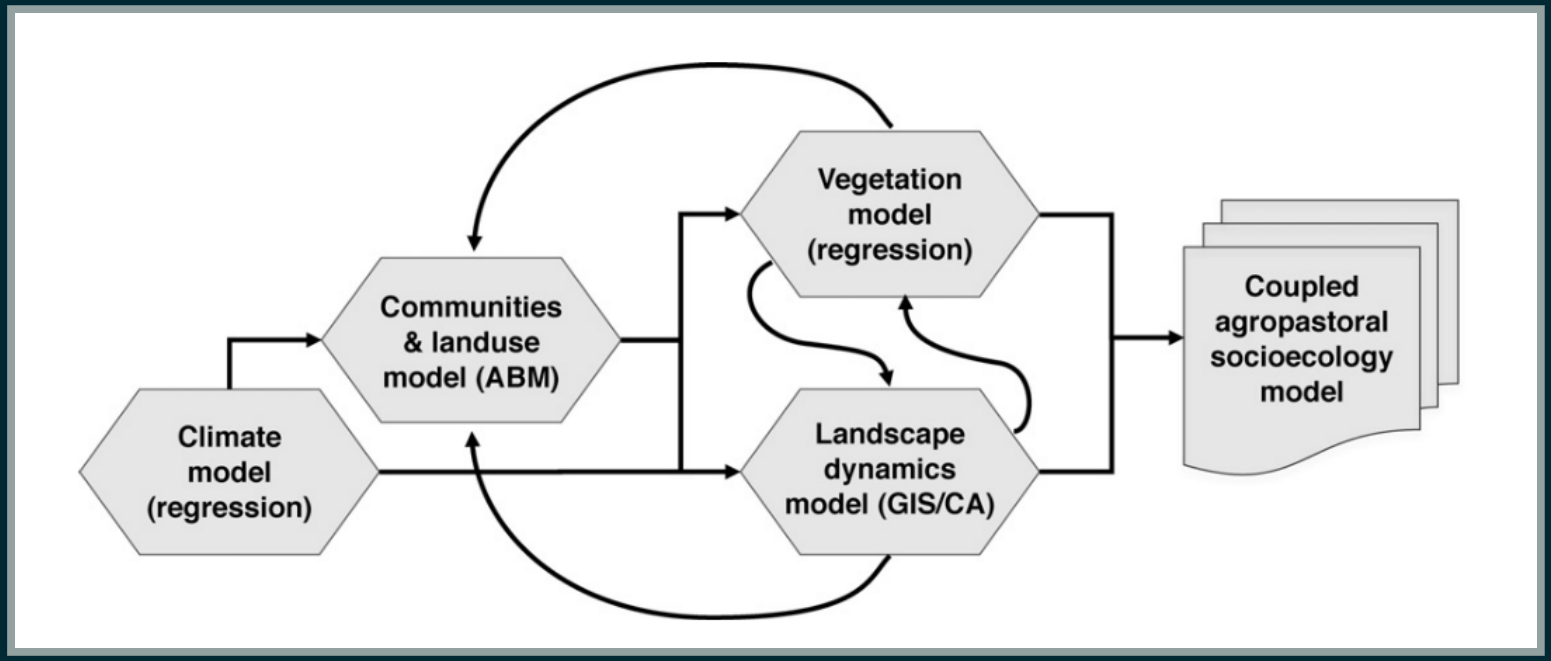
Griffith, C. S., Long, B. L., and Sept, J. M. (2010). HOMINIDS: An agent-based spatial simulation model to evaluate behavioral patterns of early Pleistocene hominids. Ecological Modelling, 221(5), 738–760. https://doi.org/10.1016/j.ecolmodel.2009.11.009



EXAMPLES

MEDLAND

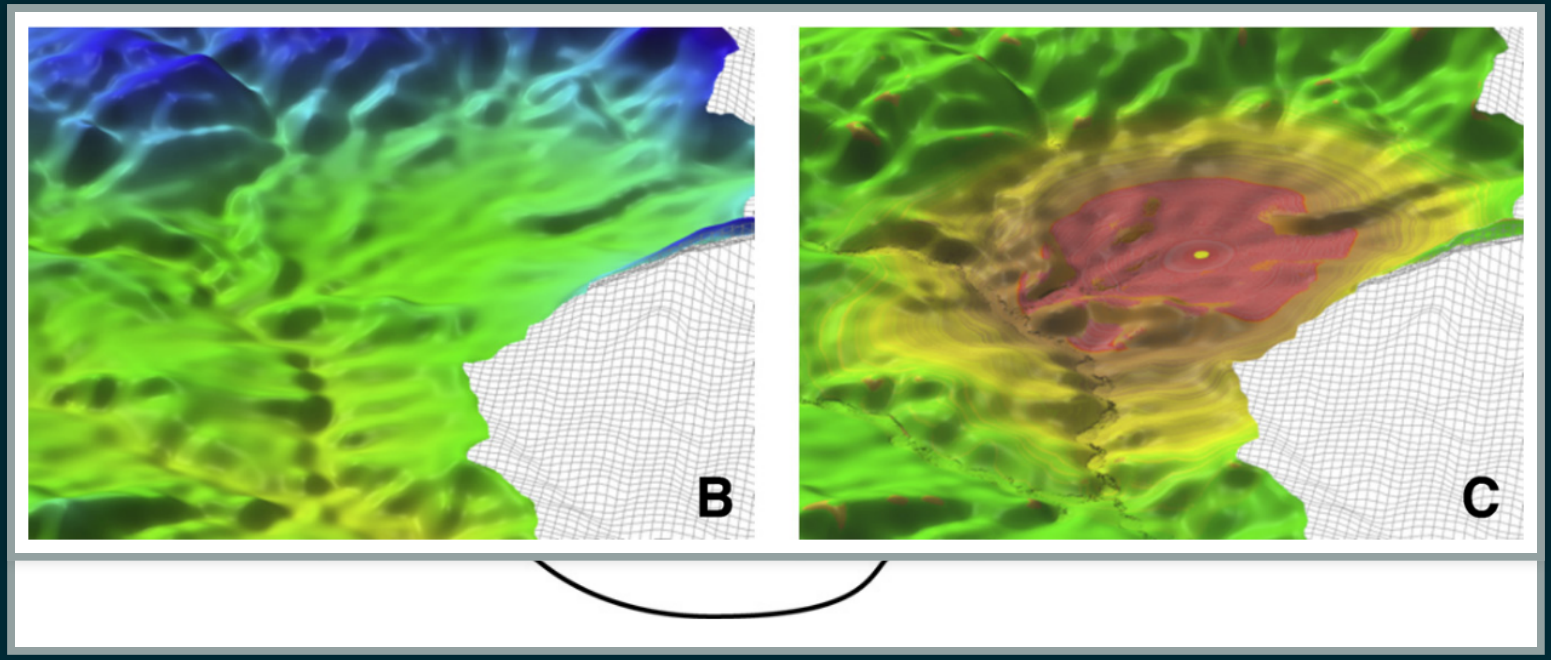
Barton, C. M., Ullah, I. I. T., Bergin, S. M., Mitasova, H., and Sarjoughian, H. (2012). Looking for the future in the past: Long-term change in socioecological systems. Ecological Modelling, 241, 42–53. https://doi.org/10.1016/J.ECOLMODEL.2012.02.010



EXAMPLES

MEDLAND

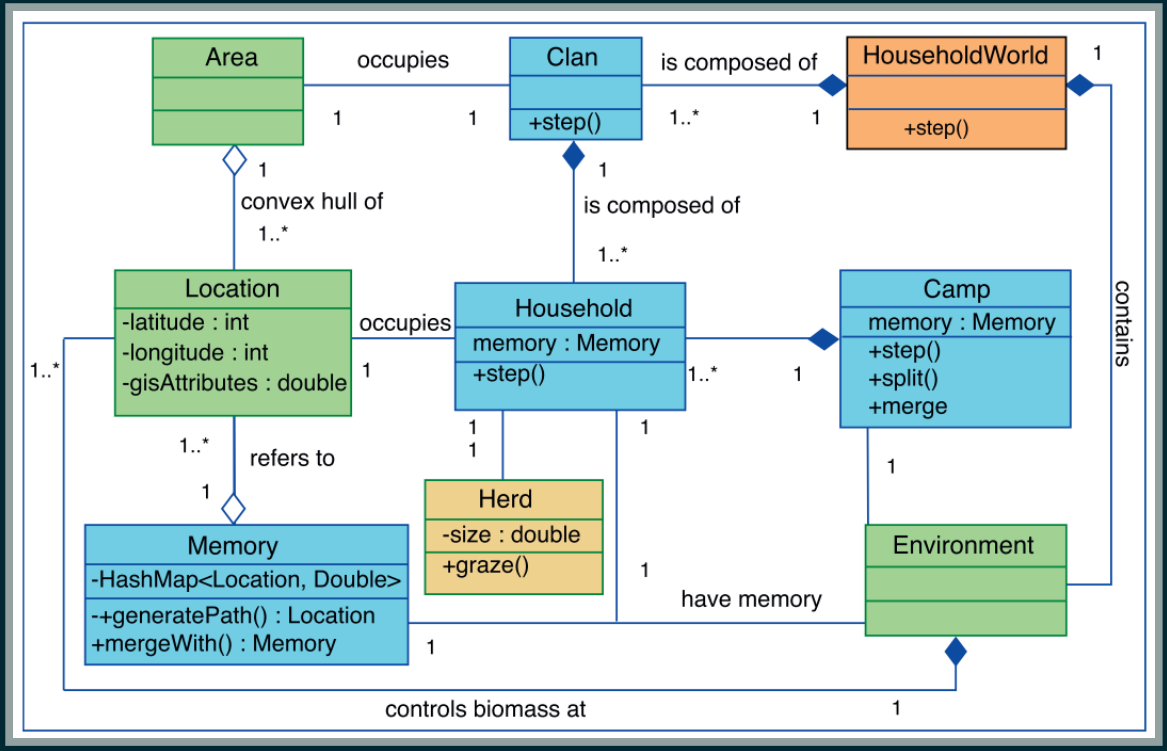
Barton, C. M., Ullah, I. I. T., Bergin, S. M., Mitasova, H., and Sarjoughian, H. (2012). Looking for the future in the past: Long-term change in socioecological systems. Ecological Modelling, 241, 42–53. https://doi.org/10.1016/J.ECOLMODEL.2012.02.010



EXAMPLES

HOUSEHOLDSWORLD

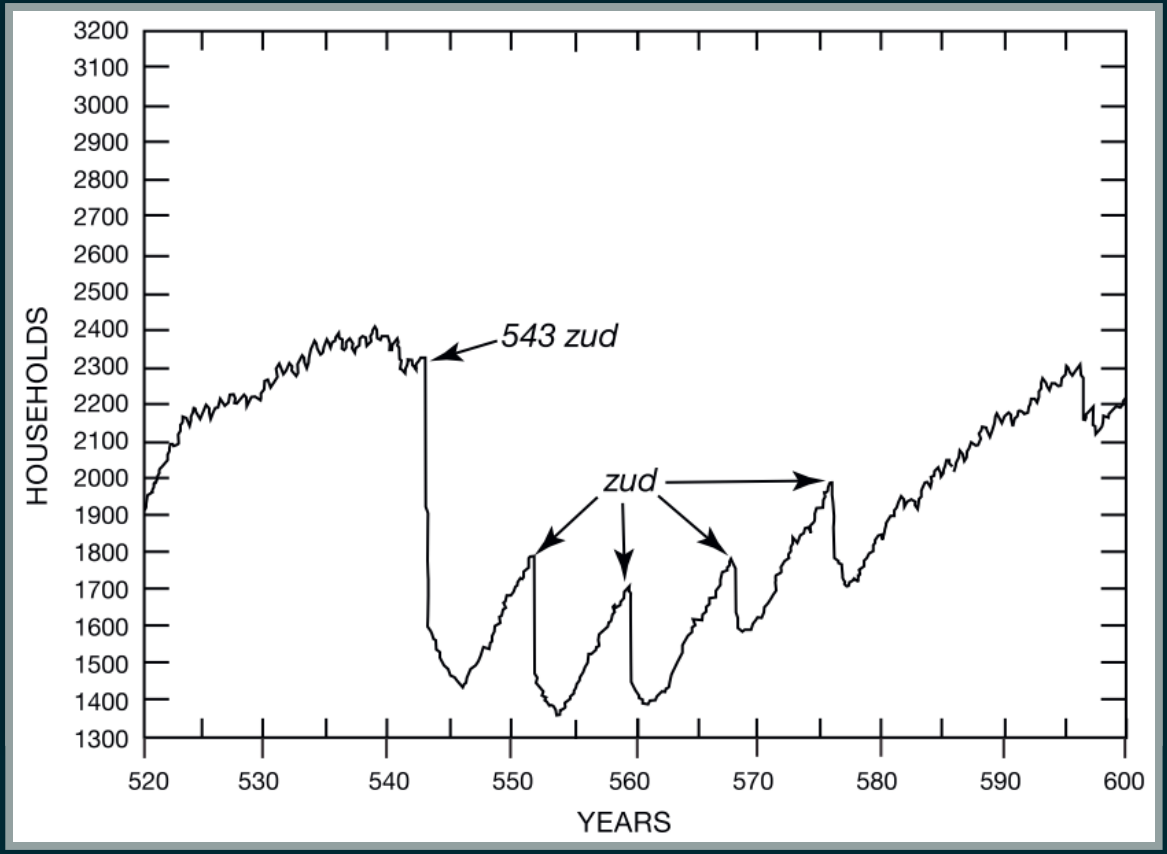
Rogers, J. D., Nichols, T., Emmerich, T., Latek, M., and Cioffi-Revilla, C. (2012). Modeling scale and variability in human–environmental interactions in Inner Asia. Ecological Modelling, 241, 5–14. https://doi.org/10.1016/J.ECOLMODEL.2011.11.025



EXAMPLES

HOUSEHOLDSWORLD

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



EXPECTATIONS

GRAND CHALLENGES (METHOD)

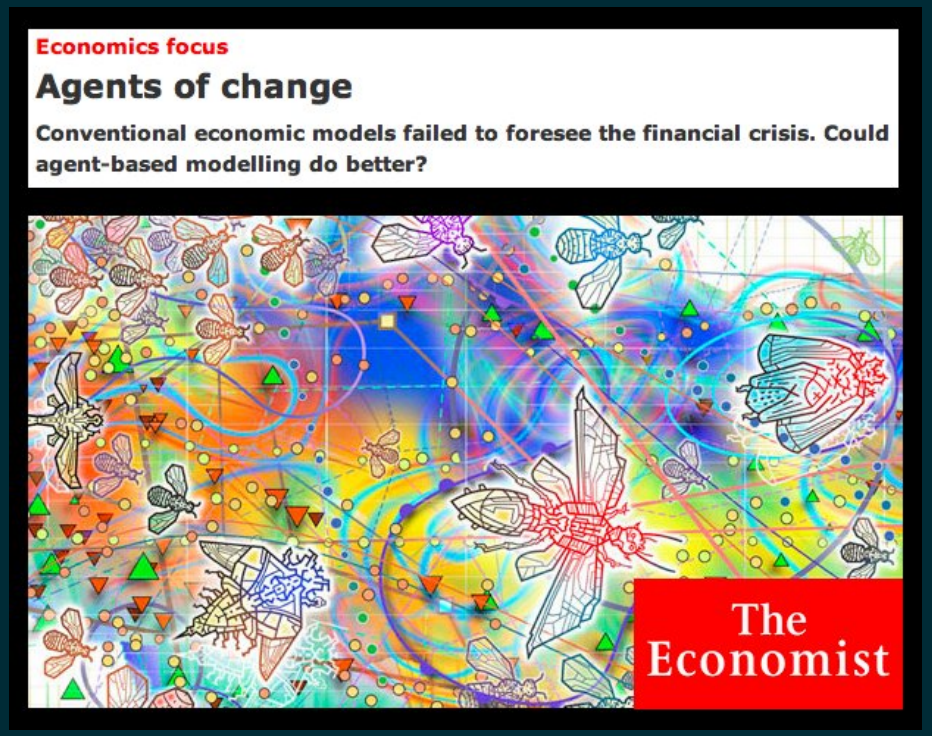
- Disambiguation
- Consolidation of shared models
- Virtual laboratory
- Interdisciplinary approach

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



- 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

AGENT-BASED MODELLING IN ARCHAEOLOGY

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

Andreas **Angourakis** *@AndrosSpica*

THANK YOU!

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

click on images to consult source

FURTHER REFERENCES

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