Agent-based modelling *design and construction*

Ken Kahn
Howard Noble

All slides available as
http://tinyurl.com/abm-sessions

Plan for today

- ABM - what it is and what it is good for
- Simple examples illustrating different techniques and ideas
- A case studies: religion model and counter-factual history
- Agent-based modelling design exercises
- Build predator prey models
- Running experiments with models
- Theory and methodology
- Tools and communities

What is agent-based modelling?

Computer models of *interacting* individuals

Typically the agents are

- heterogenous
- autonomous
- inhabit space and time
- stochastic (path dependent)

Often they have

- limited perception
- limited memory and learning
- limited cognition and rationality
- limited knowledge of the state of the entire model

Two approaches to computer modelling

Agent or individual based

E.g., predators and prey move, consume energy, acquire energy from eating, reproduce, ...

Aggregate models

E.g. Lotka-Volterra equations

$$\frac{dx}{dt} = x(\alpha - \beta y) \qquad \frac{dy}{dt} = -y(\gamma - \delta x)$$

More kinds of computer simulations

- Cellular Automata
- Monte Carlo Simulation
- Discrete Event Simulation
- Micro-simulation
- System dynamics
- And more...

Why Model? (Epstein #1)

Joshua M. Epstein, *Journal of Artificial Societies and Social Simulation* vol. 11, no. 4 12, 2008.

> *"Why model" ... my favorite retort is, "You are a modeler." Anyone who ventures a projection, or imagines how a social dynamic - an epidemic, war, or migration - would unfold is running some model.*

Why Model? (Epstein #2)

But typically, it is an implicit model in which the assumptions are hidden, their internal consistency is untested, their logical consequences are unknown, and their relation to data is unknown. But, when you close your eyes and imagine an epidemic spreading, or any other social dynamic, you are running some model or other.

Richard Dawkins on this topic

We all know, from the inside, what it is like to run a simulation of the world in our heads. We call it imagination, and we use it all the time to steer our decisions in wise and prudent directions...

Having built in the capacity to simulate models of things as they are, natural selection found that it was but a short step to simulate things as they are not quite yet—to simulate the future.

"The Evolved Imagination: Animals as models of their world", *Natural History magazine*, 104 (September 1995): 8-11, 22-23.

A few of the "Sixteen Reasons Other Than Prediction to Build Models"

1. Explain (very distinct from predict)
2. Guide data collection
3. Illuminate core dynamics
4. Suggest dynamical analogies
5. Discover new questions
6. Promote a scientific habit of mind
7. Bound (bracket) outcomes to plausible ranges
8. Illuminate core uncertainties
9. Offer crisis options in near-real time
10. Demonstrate tradeoffs / suggest efficiencies
11. Challenge the robustness of prevailing theory through perturbations
12. Expose prevailing wisdom as incompatible with available data
13. Train practitioners
14. Discipline the policy dialogue
15. Educate the general public
16. Reveal the apparently simple (complex) to be complex (simple)

Why Model? (Epstein #3)

Simple models can be invaluable without being "right," in an engineering sense. Indeed, by such lights, all the best models are wrong. But they are fruitfully wrong. They are illuminating abstractions. I think it was Picasso who said, ***"Art is a lie that helps us see the truth."***

As George Box famously put it,
"All models are wrong, but some are useful."

Why Model? (Epstein #4)

It is a startling and wonderful fact that a huge variety of seemingly unrelated processes have formally identical models (i.e., they can all be seen as interpretations of the same underlying formalism)...

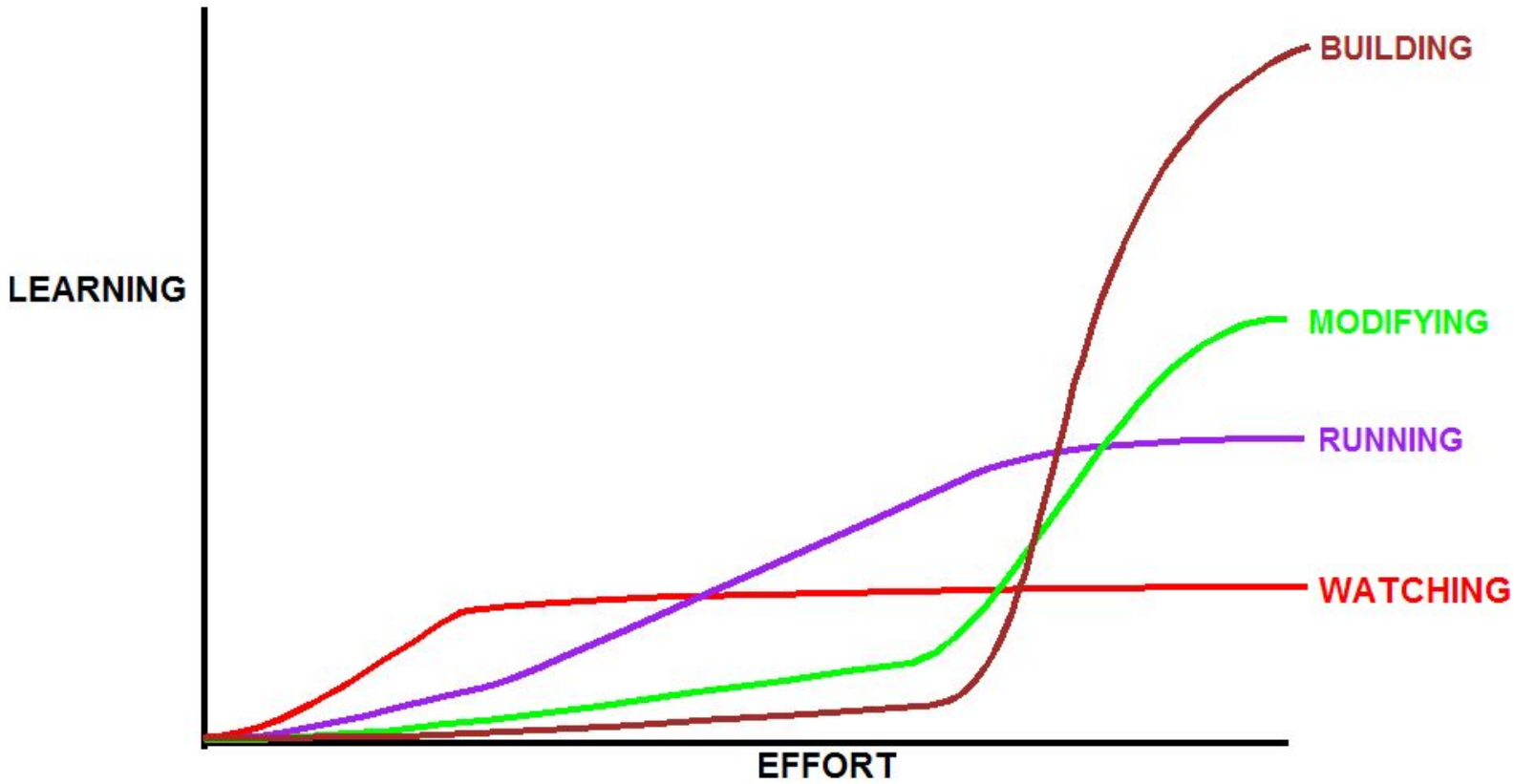
Models can surprise us, make us curious, and lead to new questions.

Examples illustrating different techniques and ideas

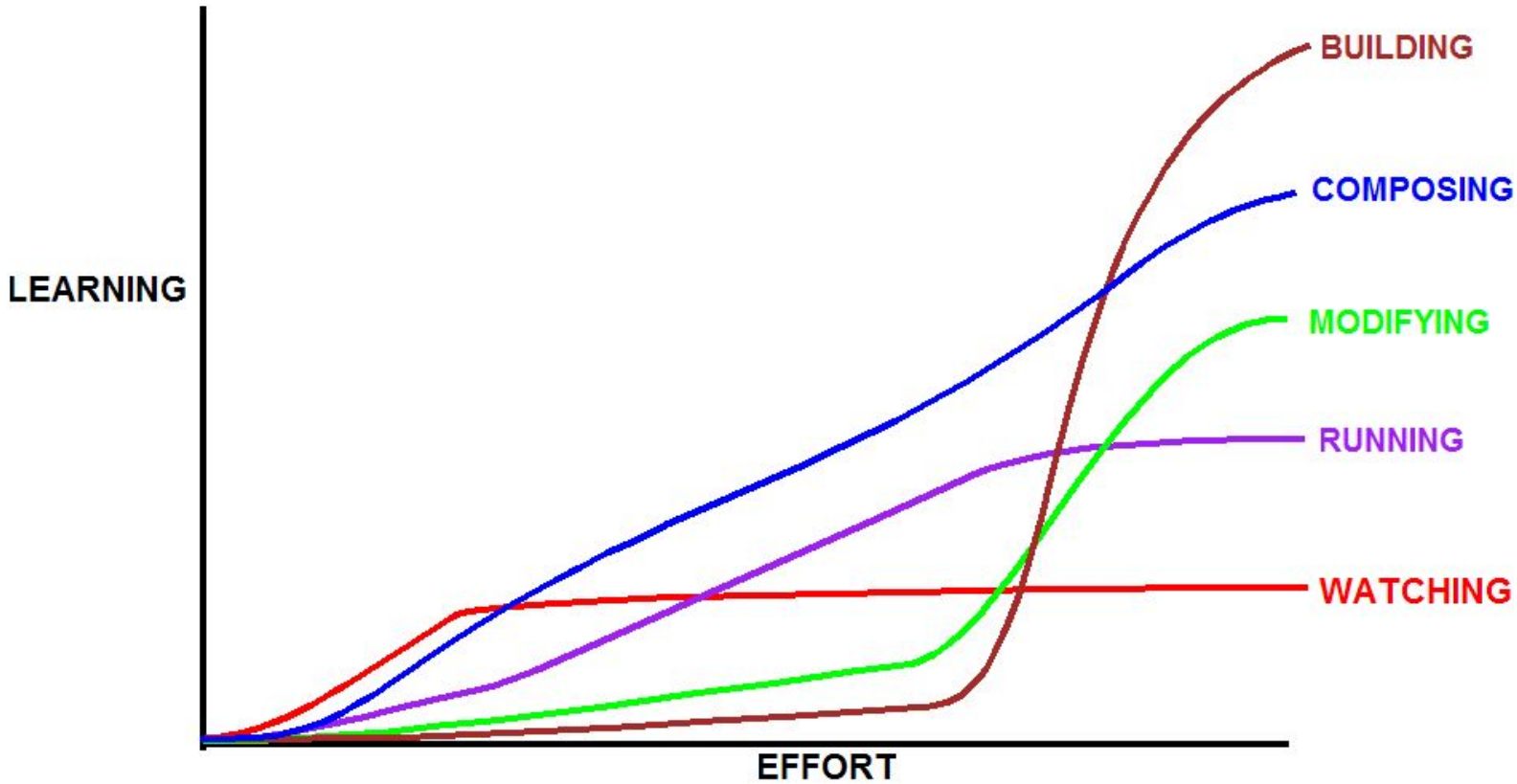
1. Ants (emergent collective behaviour)
2. Cooperation (simple but surprising)
3. Fire (non-linear threshold, process like strikes)
4. Preferential attachment (power law - network formation) Scale-free networks, power law
5. Segregation (a classic) Parable of the Polygons

Very many more in the NetLogo Library

Christmas models: reindeer, stockings, snowflakes



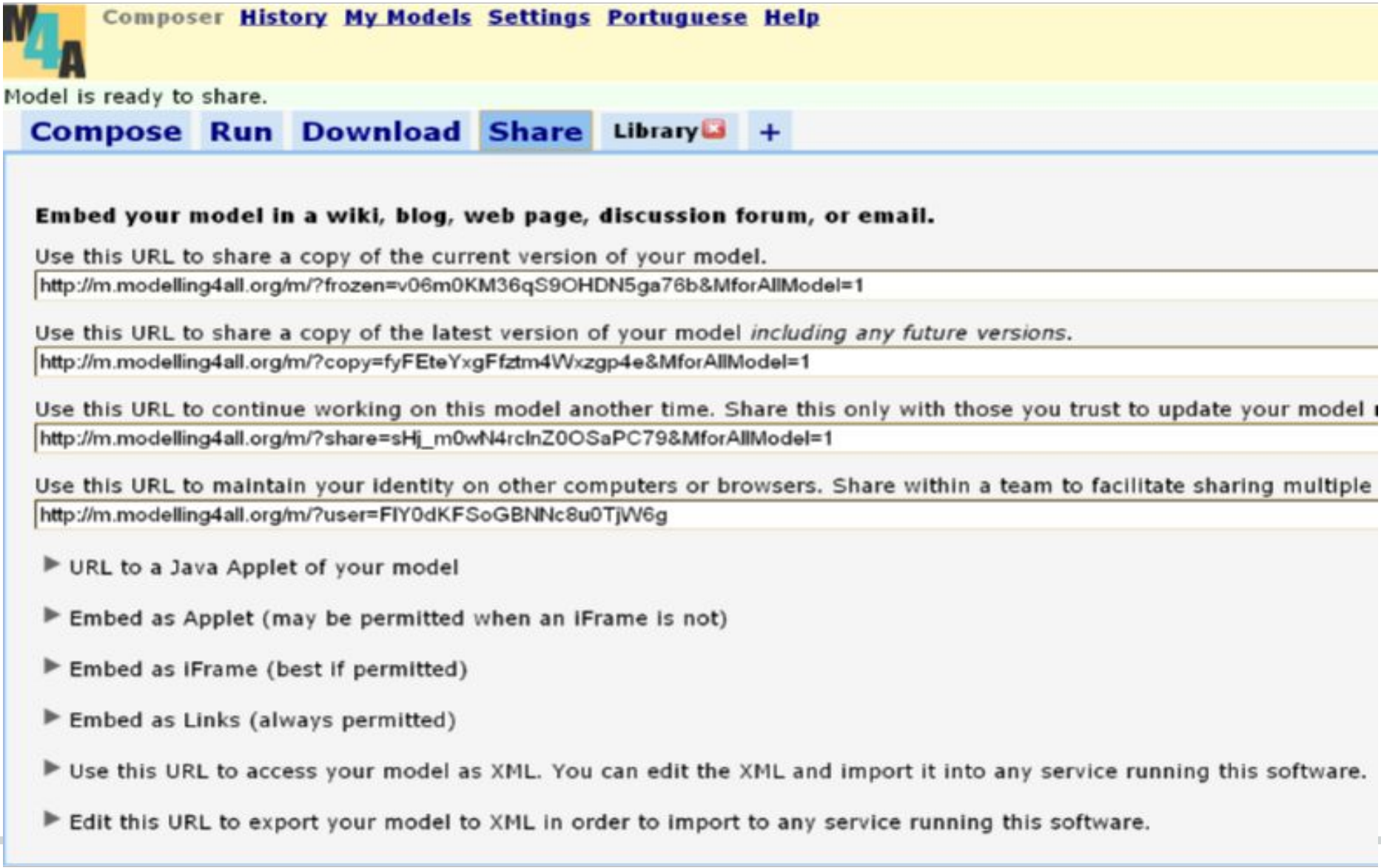
My view of learning ABM from ABM models



The idea behind the Behaviour Composer

Opening up the modelling process?

Models and micro-behaviours are web links in an open Wikipedia-like platform. We hope this makes it easier for programmers to work with domain experts to create models that are interesting to academia and the general public.



The Behaviour Composer

Middle-up tool for making NetLogo models

Compose and customise “micro-behaviours”

Journal of Mathematical Sociology
1971, Vol. 1, pp 143–186

Printed in Birkenhead, England

DYNAMIC MODELS OF SEGREGATION†

THOMAS C. SCHELLING
Harvard University

Some segregation results from the practices of organizations, some from specialized communication systems, some from correlation with a variable that is non-random; and some results from the interplay of individual choices. This is an abstract study of the interactive dynamics of discriminatory individual choices. One model is a simulation in which individual members of two recognizable groups distribute themselves in neighborhoods defined by reference to their own locations. A second

Watch me build the Segregation Model

Thomas C. Schelling (1971). "Dynamic Models of Segregation," Journal of Mathematical Sociology, 1(2), pp. 143–186

Large models

Model library has “toy” (conceptual?) models

Examples of non-toy models I’ve built:

Modelling Modes of Religiosity

Spanish Flu Pandemic model

Cancer cells and genes

The Segregation Model

Agents	People/households
World	Houses
Behaviours	Move if unhappy with the neighbourhood
Attributes	colour/kind, tolerance-threshold, location
Questions	Can a reasonably tolerant population become very segregated?

Agents *The things in the system*	
World *The environment the agents move about in*	
Behaviours *How agents interact with the world and each other*	
Attributes *The values the agent behaviours need to work*	
Questions *What do you want to understand?*	

2 NetLogos and 3 Behaviour Composer Interfaces

NetLogo is a desktop application that runs in Windows, Mac OS, and Linux.

Recently the Northwestern University NetLogo team introduced NetLogo Web

The Behaviour Composer can

1. embed the web version
2. download NetLogo files to open in NetLogo
3. connect directly to a modified NetLogo

Starting BC2NetLogo in this classroom

- Open the Computer icon
- Open the first Network drive
- Open the BC2NetLogo folder
- Double click on the StartBC2NetLogo.jar file

If you want to use your own laptop download the Behaviour Composer to NetLogo tool from modelling4all.org

Why does the model differ from the empirical data below?

- Why do extinctions happen so often in the model?
- Why are natural systems more robust?

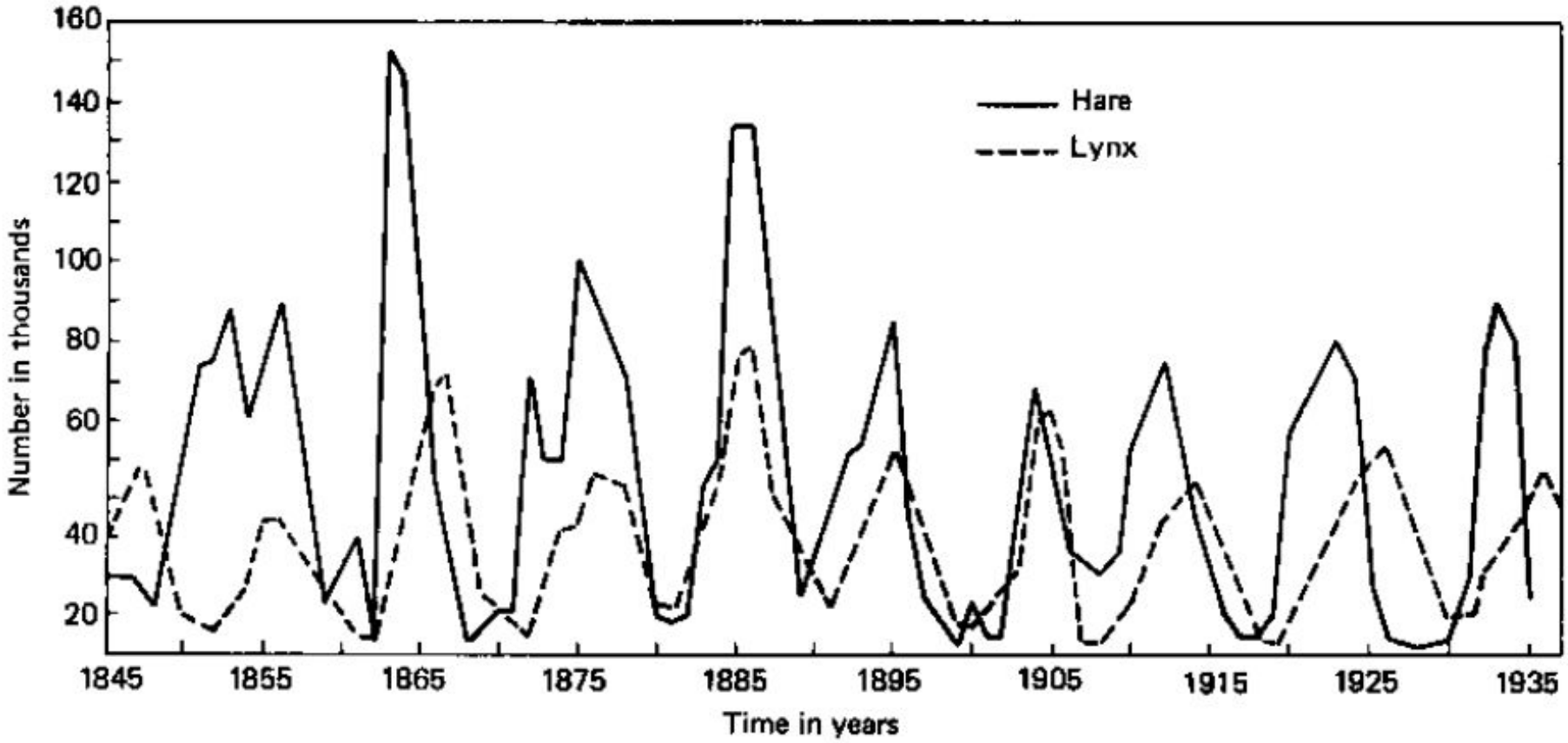
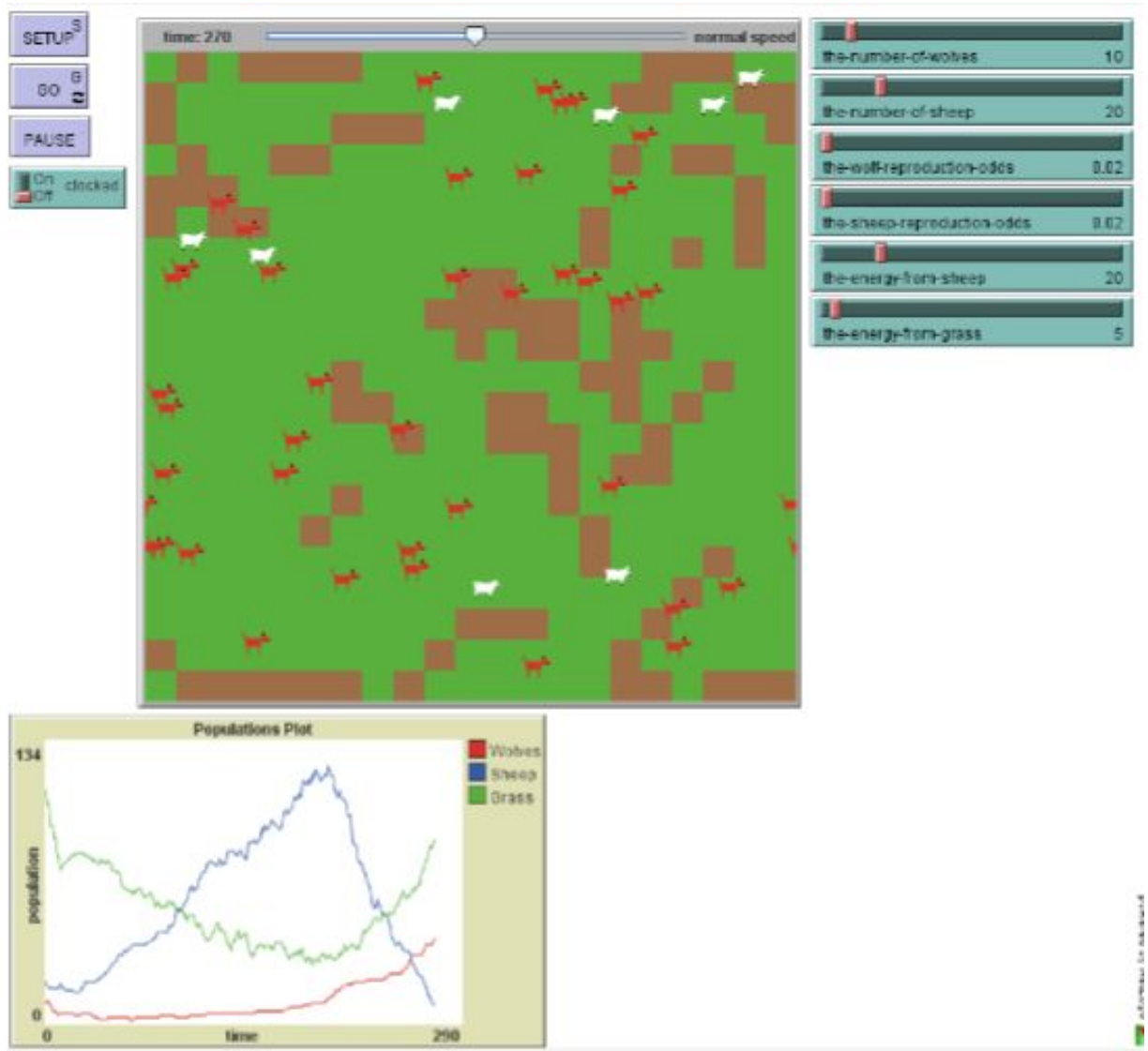


Figure 9-3. Changes in the abundance of the lynx and the snowshoe hare, as indicated by the number of pelts received by the Hudson's Bay Company. This is a classic case of cyclic oscillation in population density. (Redrawn from MacLulich 1937.)

Any ideas for how to change the model i.e. new agents, behaviours, attributes and questions?



Two model enhancements

Young and old sheep more likely to be predated

Nearly isolated regions

Sample model

BehaviorSpace and BehaviorSearch.org

BehaviorSpace - parameter sweeps

How thoroughly to explore this multi-dimensional space?

BehaviorSearch.org - automated search for 'best' parameter values

What fitness function to use?

Or program your own search

Things to look for

Sensitivity -- *Do changes in a parameter change the aggregate dynamics?*

Robustness -- *Do patterns in aggregate dynamics depend upon particular values of parameters?*

Uncertainty - *Do patterns in aggregate dynamics depend upon particular probability distributions of parameter values?*

ABM Tools

1. NetLogo (low threshold, high ceiling; moderately wide walls)
2. Mason (high threshold; higher ceiling; wide walls)
3. RePast (high threshold; higher ceiling; wide walls; HPC)
4. RePast Simphony (mixed threshold; higher ceiling; wide walls)
5. Gama (mixed threshold; higher ceiling; wide walls)
6. AnyLogic (commercial, multi-paradigm)
7. Many more
8. Any modern programming language (highest threshold; highest ceiling; widest walls; HPC)

ABM Communities

OpenABM -- Open library of models

SIMSOC -- Discussion of social simulation

NetLogo Users -- Very active and supportive discussion group

CABDyN -- Oxford University Complex Agent-based Dynamic Networks

Modelling Commons -- a Web-based application designed to make it easy to share NetLogo models with other people

Recommended books

- Joshua Epstein and Robert Axtell, *Growing Artificial Societies: Social Science From the Bottom Up*, MIT Press/Brookings Institution, 1996.
- Joshua Epstein, *Generative Social Science*, Princeton University Press, 2006.
- Nigel Gilbert and Klaus Troitzsch, *Simulation for the Social Scientist*, Open University Press, 1999; second edition, 2005.
- Volker Grimm and Steven F. Railsback, *Individual-based Modeling and Ecology*, Princeton University Press, 2005.
- Volker Grimm and Steven F. Railsback, *Agent-based and Individual-based Modeling: A Practical Introduction,* Princeton University Press, 2011.
- Uri Wilensky and William Rand, An Introduction to Agent-Based Modeling - Modeling Natural, Social, and Engineered Complex Systems with NetLogo, MIT Press 2015.

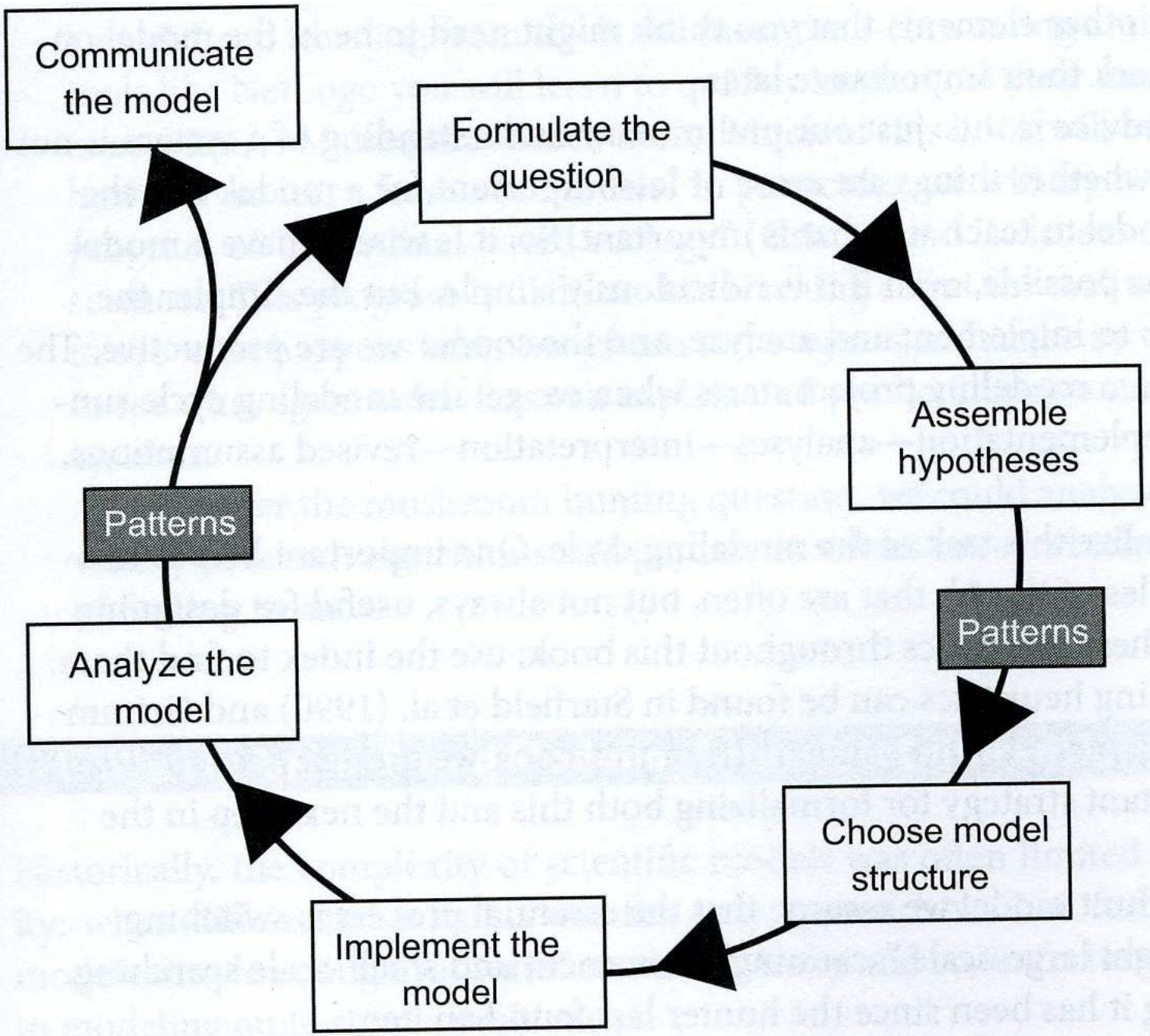
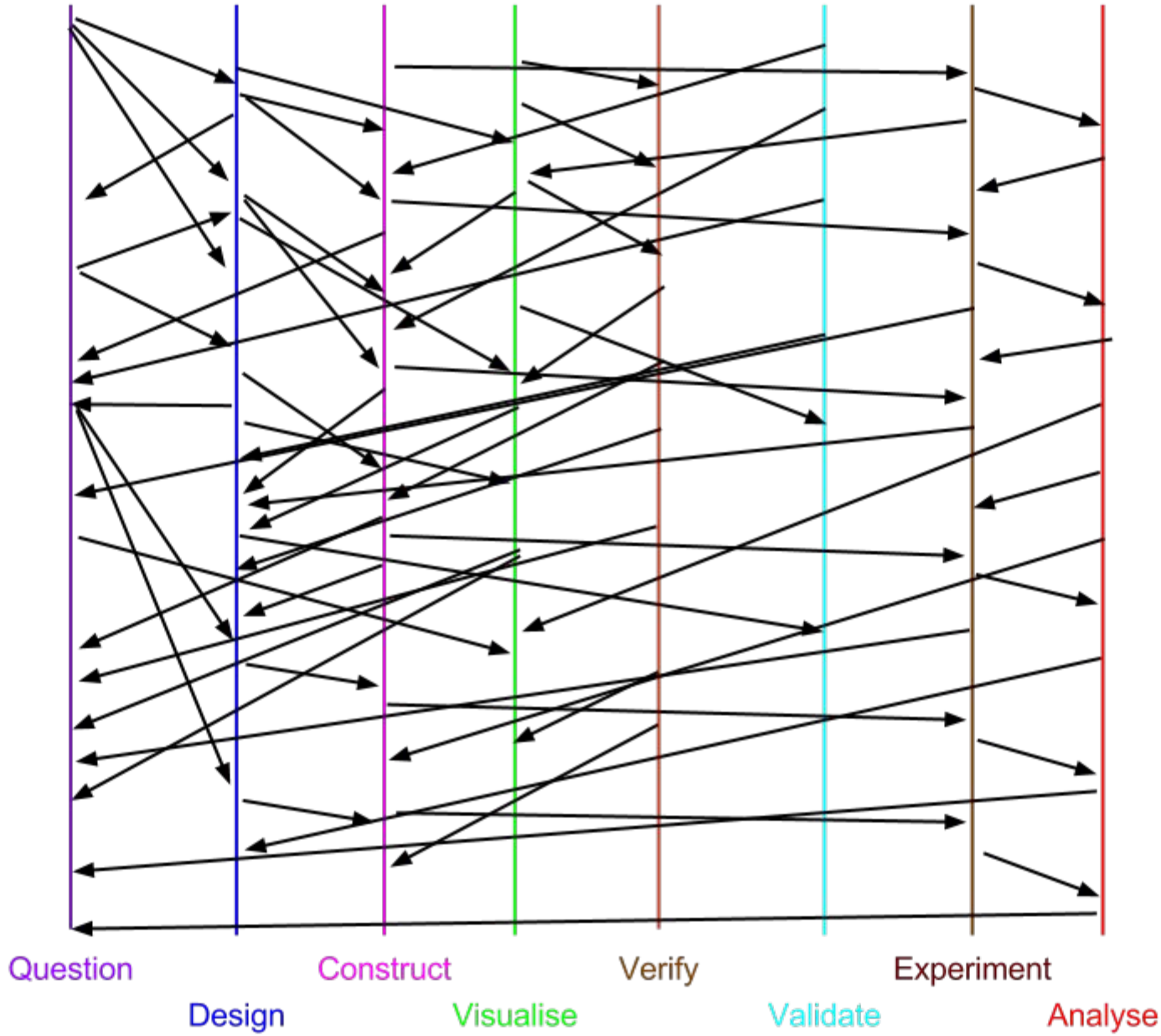


Figure 1.3
The modeling cycle (from Grimm and Railsback 2005).

Methodology

1. Decide what **questions** you are trying to answer
2. **Design** agents (attributes and rules) and their environment
3. Possibly revise 1 and 2
4. **Implement** and **test** successive subsets of #2
5. Possibly revise 1, 2, and 4
6. *Ongoing* **verification** that the model is bug-free
7. *Sometimes* need to **validate** micro level against data; *sometimes* need to **validate** macro level against data; *sometimes* both
8. Possibly revise 1, 2, and 4; redo 7
9. **Experiment** and **analyse** output
10. **Analyse sensitivity** of results to design elements

One size does not fit all and process is rarely sequential


Question
Design
Construct
Visualise
Verify
Validate
Experiment
Analyse

Relationship between ABM and science

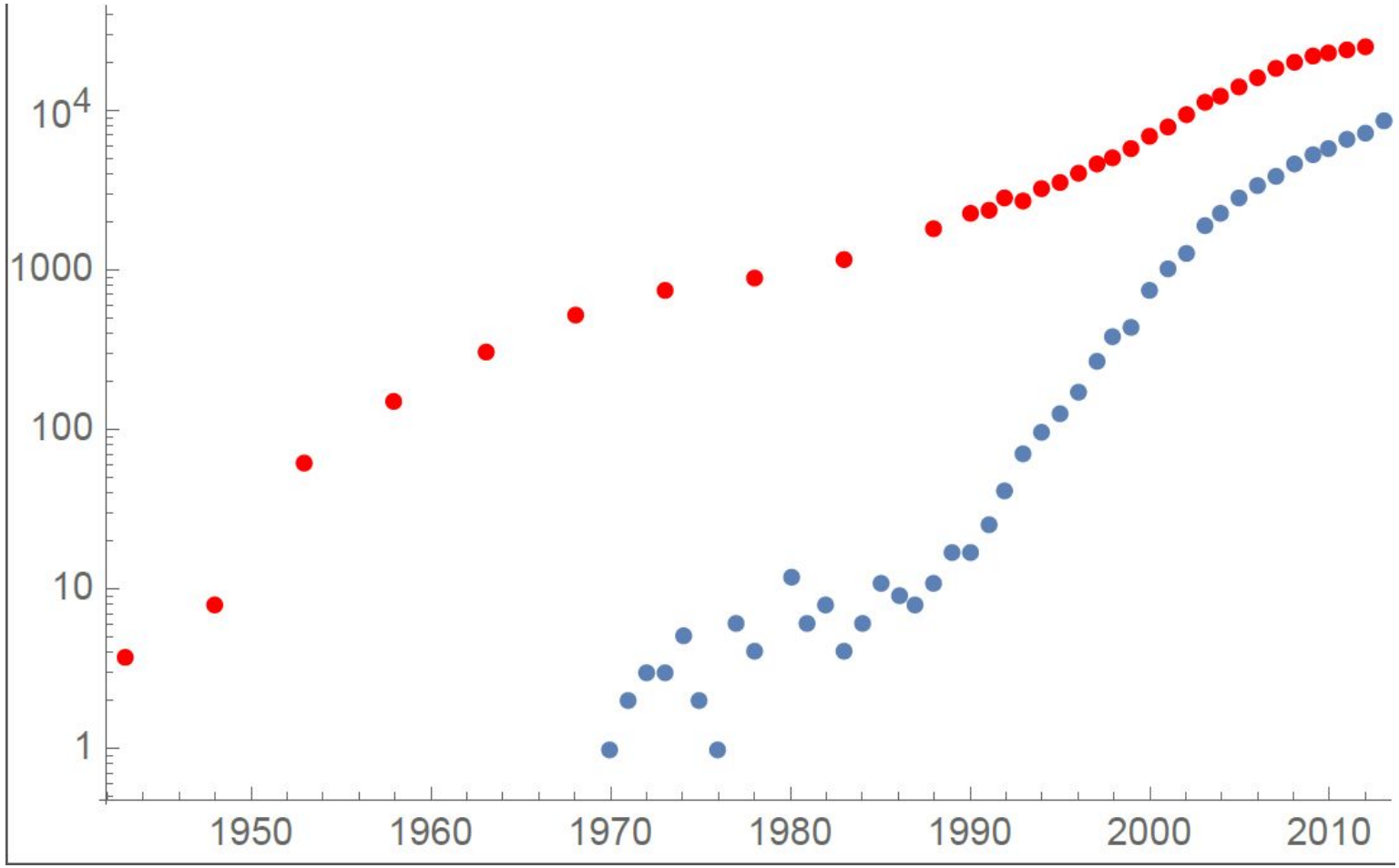
Lots of debate and discussion

- Agent-based models are another kind of scientific theory
- Agent-based models are virtual laboratories
- Great for intuitive understanding, discovering good questions, and generating hypotheses, but problematic for doing science
- A New Kind of Science (Wolfram); A third way of doing science (Alexrod)
- Restructuration

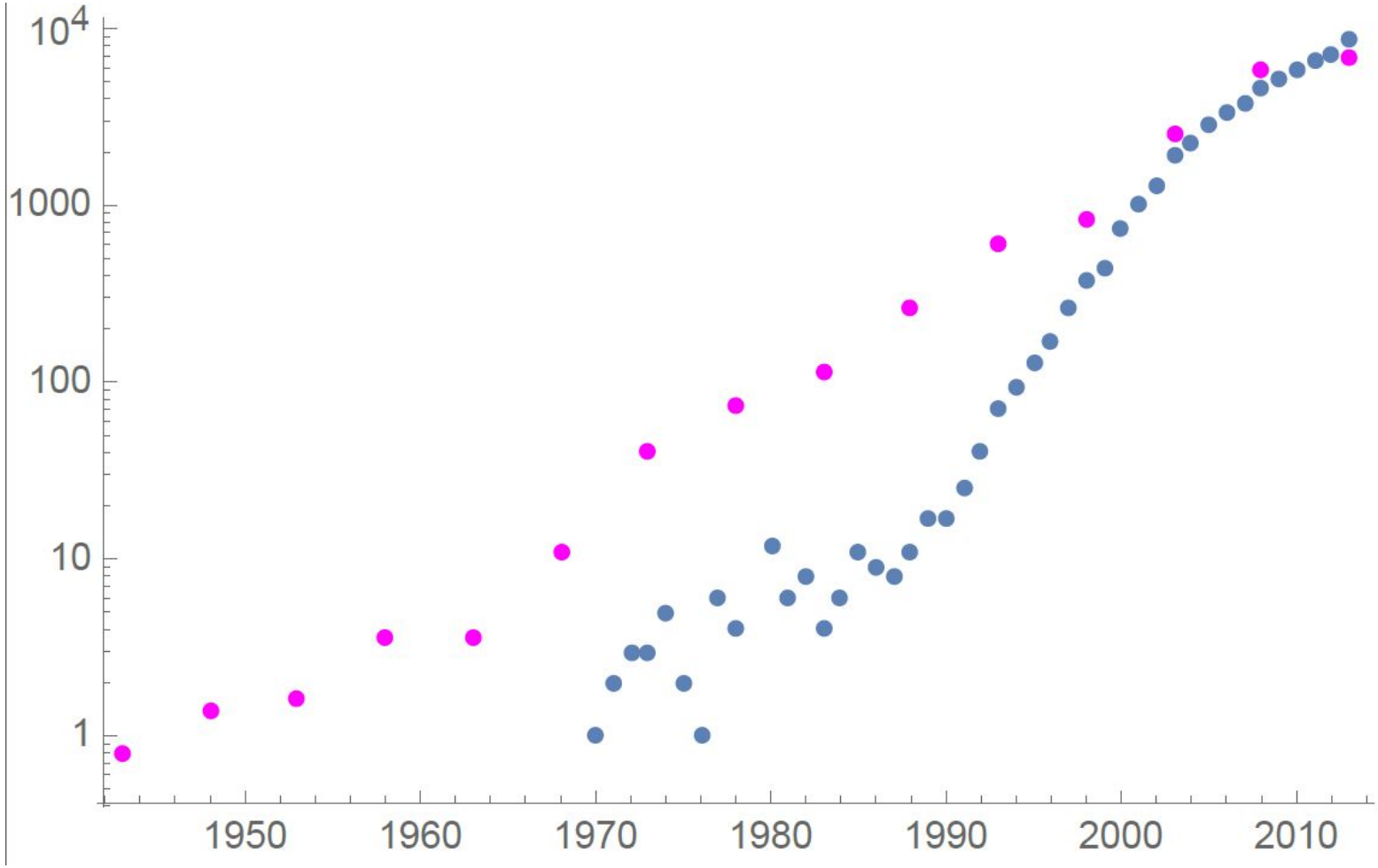
ABM in Research

Huge variety of fields

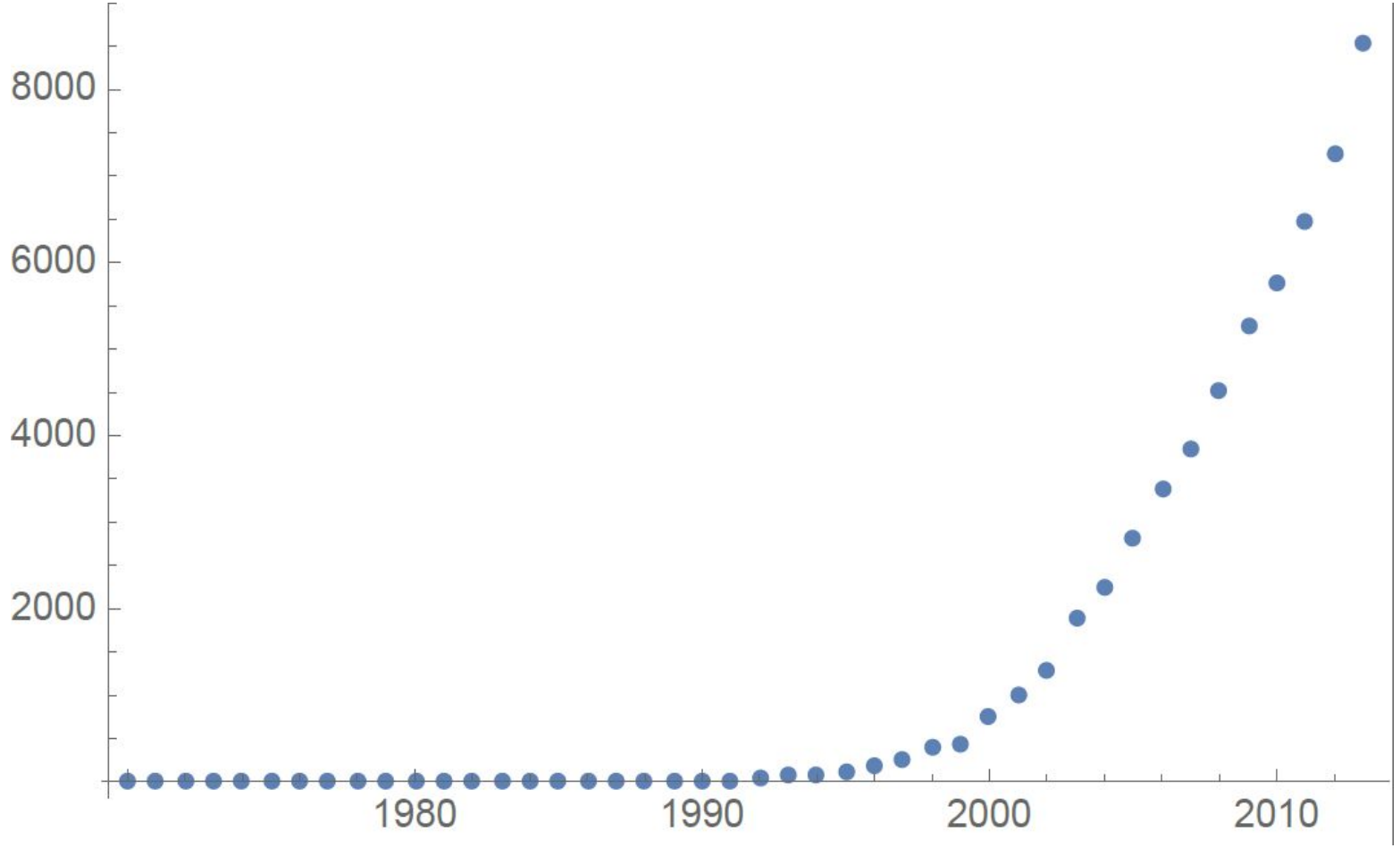
Ecology, collective animal behaviour, epidemiology, economics, sociology, land use, urban studies, history, religion, linguistics, philosophy, archeology, anthropology, ...



Agent-based modelling versus game theory



Agent-based versus behavioural/experimental economics



ABM publications

ABM Research in Oxford

The CABDyN Complexity Centre

Complexity Economics

Many others including modelling cancer cells, medieval populations, religions, rebellions, malaria, insurance risk, ...

ABM get-togethers

ABM get-togethers each term

26 October 14:30-16:30

Seminar room, Oxford Martin School

34 Broad Street, Oxford OX1 3BD

To be notified of future get-togethers contact kenneth.kahn@it.ox.ac.uk

How to install BC2NetLogo

Go to modelling4all.org

And click on the link that says:

the Behaviour Composer to NetLogo tool

After clicking on StartBC2NetLogo.jar on a Mac you may need to go to System Preferences then Security and Privacy and allow it to run. Or control-click it.

Installing and using NetLogo

http://ccl.northwestern.edu/netlogo/

Note that the **Behaviour Composer to NetLogo** tool already includes an installation of NetLogo

How to learn more

Santa Fe Institute MOOC

University of Michigan MOOC

Centre for Research in Social Simulation

NetLogo online tutorials

Text books - I recommend

Uri Wilensky and William Rand, An Introduction to Agent-Based Modeling - Modeling Natural, Social, and Engineered Complex Systems with NetLogo, MIT Press 2015.

I'm happy to help this term - email kenneth.kahn@it.ox.ac.uk

The following slides are extras

Plan for today

Last week

- ABM - what it is and what it is good for
- Simple examples illustrating different techniques and ideas
- Case studies: companion modelling and counter-factual history
- Agent-based modelling design exercises
- Build predator prey models

Today

- Guest presentation by Wybo Wiersma
- Running experiments with models
- Theory and methodology
- Tools and communities
- Guest presentation by Andreas Duering

Next week

A small but very useful subset of NetLogo

Connecting models together

ABM support from Academic IT Services

We are available to help

- research
- teaching (ITLP, departmental courses, bespoke)
- public engagement

kenneth.kahn@it.ox.ac.uk

Practical: build a predator-prey model

Open http://tinyurl.com/m4a-predator-prey

Or

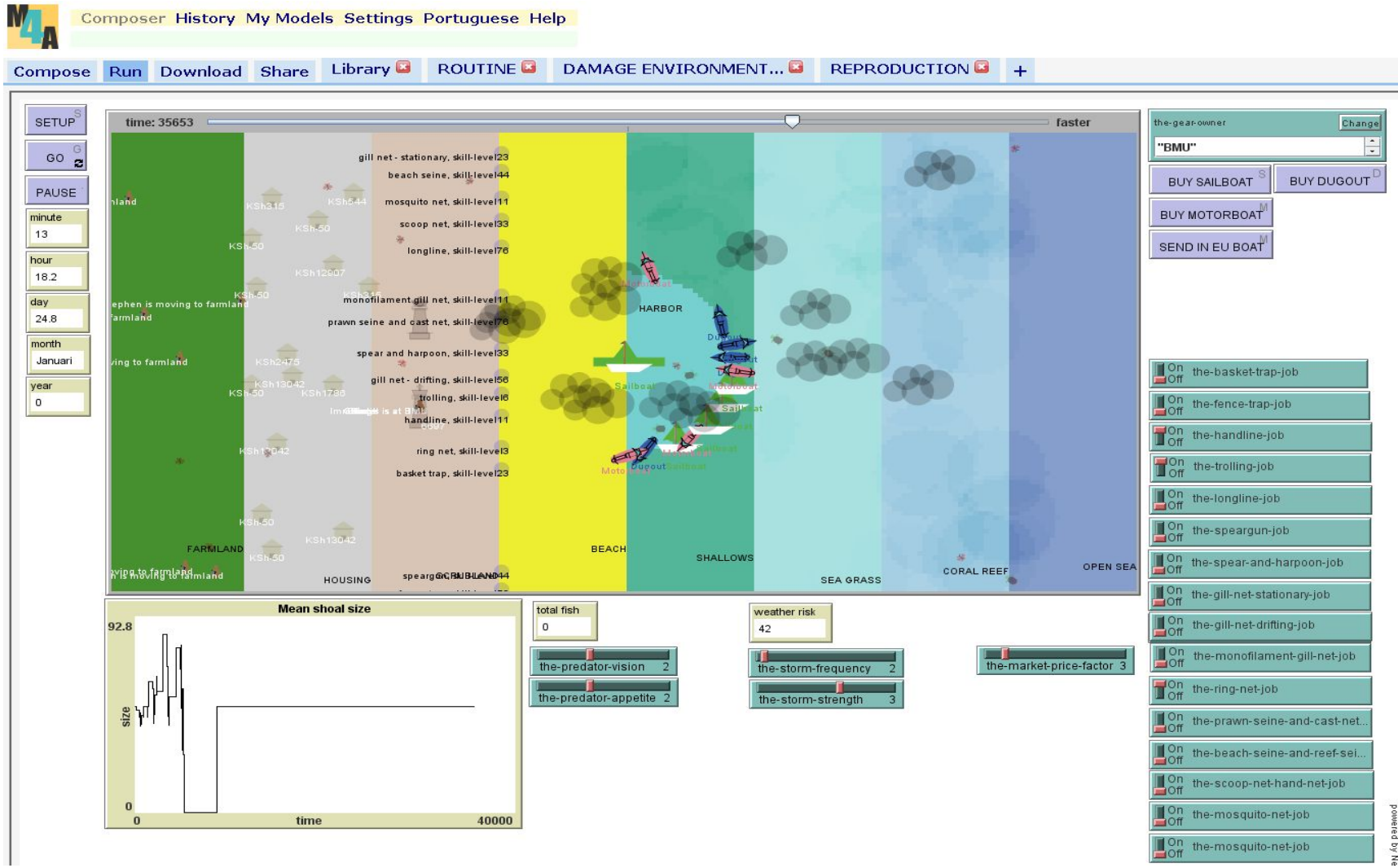
1. Launch BC2NetLogo
2. Go to help tab (if not already there)
3. Click on the step-by-step guide to building an ecosystem link

Please take up to 60 minutes to try to get through the guide and then experiment with your model and the *finished* model we provide.

If you have already built the predator prey model then choose either the epidemic or Sugarscape guides.

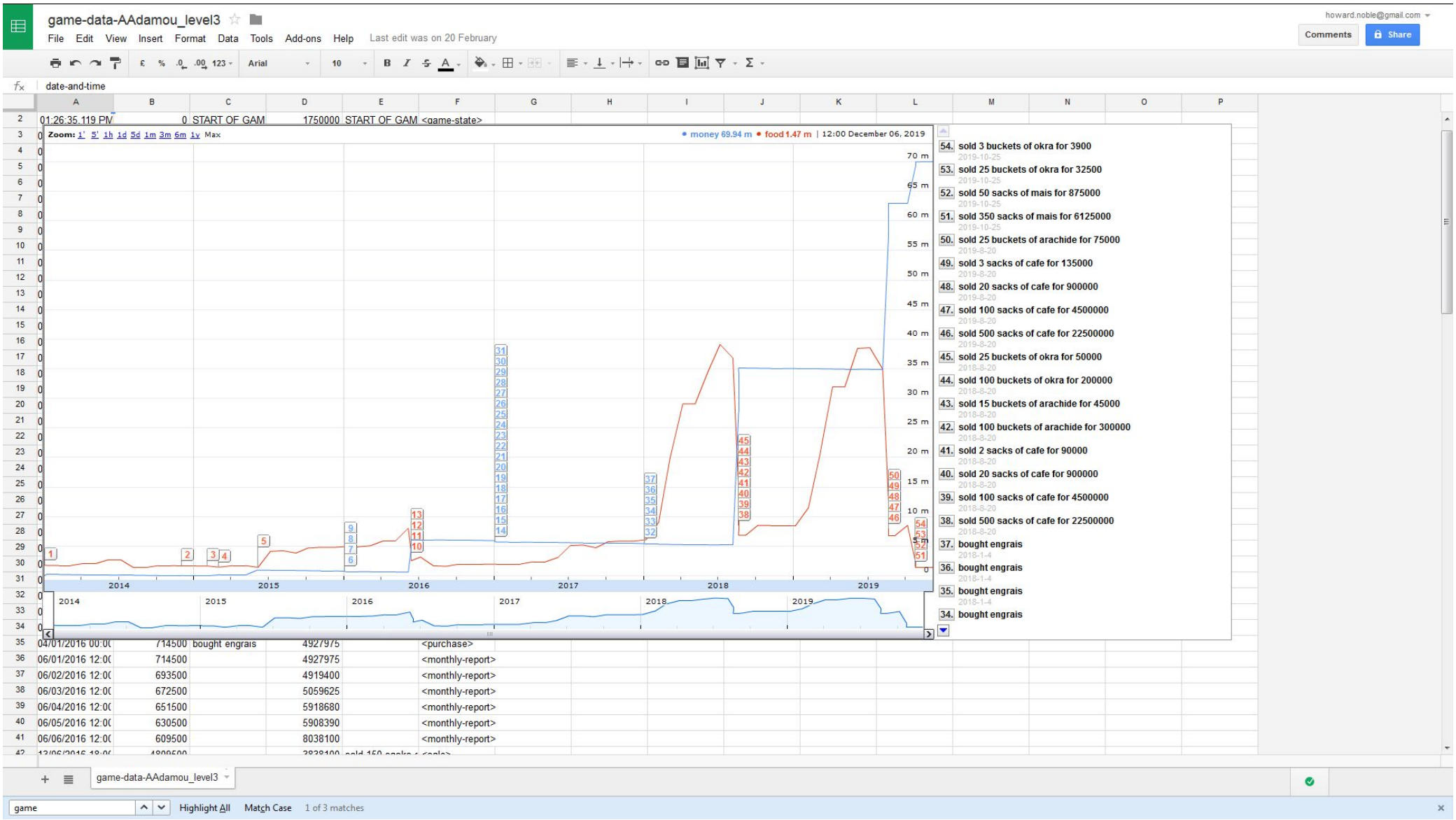
Any questions? Please ask!

Participatory research with the Stockholm Environment (SEI)



http://m.modelling4all.org/m/?frozen=c8Y1ruJ9lSQuG5gcnS_r6c&MforAllModel=1

Building models not asking questions with Prof. David Zeitlyn of the Anthropology department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54. sold 3 buckets of okra for 3900
2019-10-25
53. sold 25 buckets of okra for 32500
2019-10-25
52. sold 50 sacks of mais for 875000
2019-10-25
51. sold 350 sacks of mais for 6125000
2019-10-25
50. sold 25 buckets of arachide for 75000
2019-8-20
49. sold 3 sacks of cafe for 135000
2019-8-20
48. sold 20 sacks of cafe for 900000
2019-8-20
47. sold 100 sacks of cafe for 4500000
2019-8-20
46. sold 500 sacks of cafe for 22500000
2019-8-20
45. sold 25 buckets of okra for 50000
2018-8-20
44. sold 100 buckets of okra for 200000
2018-8-20
43. sold 15 buckets of arachide for 45000
2018-8-20
42. sold 100 buckets of arachide for 300000
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41. sold 2 sacks of cafe for 90000
2018-8-20
40. sold 20 sacks of cafe for 900000
2018-8-20
39. sold 100 sacks of cafe for 4500000
2018-8-20
38. sold 500 sacks of cafe for 22500000
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2018-1-4
34. bought engrais
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04/01/2016 00:0(714500 bought engrais 4927975 <purchase>
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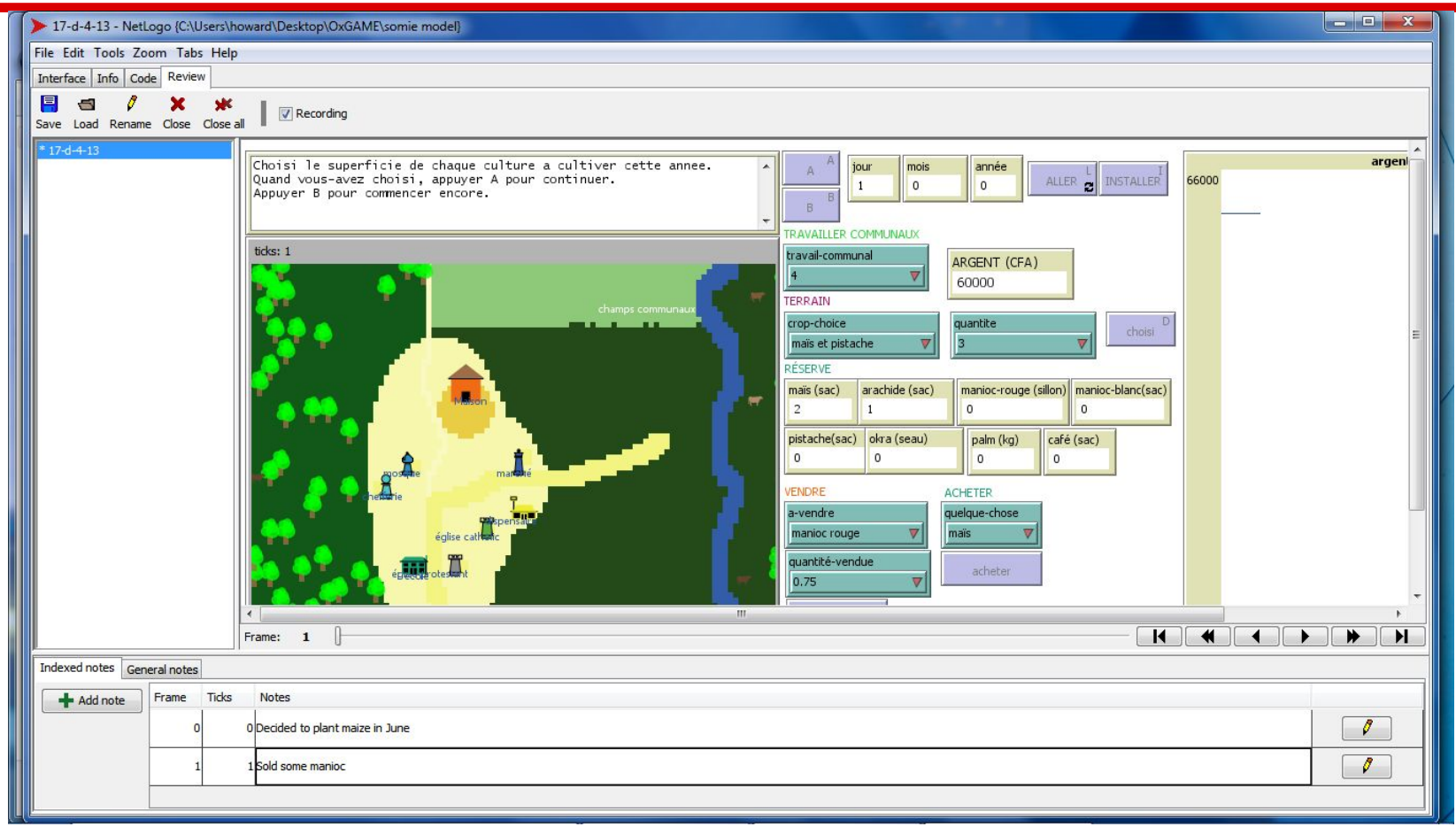
06/02/2016 12:0(693500 4919400 <monthly-report>
06/03/2016 12:0(672500 5059625 <monthly-report>
06/04/2016 12:0(651500 5918680 <monthly-report>
06/05/2016 12:0(630500 5908390 <monthly-report>
06/06/2016 12:0(609500 8038100 <monthly-report>
game-data-AAdamou_level3
game
Highlight All
Match Case
1 of 3 matches

NetLogo Runs extension (Review Tab)



Project blog: http://blogs.it.ox.ac.uk/modelling4all/oxgame/

Next week

Running experiments with models

Theory and methodology

Tools and communities

Plan for the 6 sessions

Sessions will be hands on with some lecturing

1. Introduction to tools and concepts
2. Aspects of ABM – predator prey modelling
3. The NetLogo language and environment
4. Designing models and model components
5. Data, GIS, and ODD
6. Debugging, verifying, experimenting and validating

What do you want?

Plan for today

- Plan for the 6 weekly sessions
- ABM - what it is and what it is good for
- Simple examples illustrating different techniques and ideas
- Exploration of NetLogo models
- Exploration of the Behavior Composer
- Theory and methodology
- Tools and communities

Social science ABM survey paper

THE IMPACT OF AGENT-BASED MODELS IN THE SOCIAL SCIENCES AFTER 15 YEARS OF INCURSIONS

Flaminio Squazzoni, published in "History of Economic Ideas", XVIII, 2010/2

Create a predator-prey model

Launch the Behaviour Composer

On the ‘help’ tab click on the link in this sentence:

A good beginning tutorial is this step-by-step guide to building an ecosystem of predators and prey.

2 ways to run the Behaviour Composer

1. Using the new BC2NetLogo tool.
2. ~~In the browser relying upon Java applets~~

Take our advanced ABM course

Seven sessions focussed on supporting the design and construction of models that class participants care about

http://courses.it.ox.ac.uk/detail/TPAM

Sixteen Reasons Other Than Prediction to Build Models

1. Explain (very distinct from predict)
2. Guide data collection
3. Illuminate core dynamics
4. Suggest dynamical analogies
5. Discover new questions
6. Promote a scientific habit of mind
7. Bound (bracket) outcomes to plausible ranges
8. Illuminate core uncertainties

...

The other eight reasons

9. Offer crisis options in near-real time
10. Demonstrate tradeoffs / suggest efficiencies
11. Challenge the robustness of prevailing theory through perturbations
12. Expose prevailing wisdom as incompatible with available data
13. Train practitioners
14. Discipline the policy dialogue
15. Educate the general public
16. Reveal the apparently simple (complex) to be complex (simple)

Case Studies

1. Modelling4All epidemics (social network & commuting)
2. Modelling of social norms (Epstein)
3. Mobile version of prisoners dilemma (Epstein)
4. Ethnocentrism
5. Multi-Agent Religion Simulation (twist on segregation model)
6. Axelrod's model of cultural dissemination[1]
7. Balinese Water Temples[2,3]
8. Artificial Anasazi (Epstein videos or live)
9. Using simulation to develop testable functionalist explanations: a case study of church survival

Simple examples illustrating different techniques and ideas

1. Segregation (a classic)
2. Termites (so simple but something interesting happens)
3. Traffic (simple but interesting emergence) Real video
4. Ants foraging (a distributed "mind")
5. Cooperation (are greedy cows a good idea?)
6. Diffusion-limited aggregation (too simple to call agents?)
7. Maxwell's Demon (nice example of imaginary simulation)
8. Preferential Treatment (power law - network formation)
9. Climate Change (complexity and performance balance)
10. Echo (very abstract evolution & ecology model)

Setting up an experiment with the BehaviorSpace tool in NetLogo

These slides can be found at

http://tinyurl.com/abm-introduction

For help with ABM or to be informed of Oxford ABM get-togethers send email to

kenneth.kahn@it.ox.ac.uk

And some additional resources are on the following slides.

Journals and ABM

JASSS

SIMSOC discussion of this

Modelling an historical event

What can one learn from modelling the past?

Spanish Flu Pandemic model

Part of a larger Open Educational Resources project.

Plan for today

- Agent-based modelling design exercises
- Build predator prey models
- Discussion of predator prey model
- Running experiments with models

Plan for Session 2

- Design exercise
- Learn about participatory modelling
- Practical building a predator-prey model
- Discussion of model
- Run experiments with model
- Your designs