Agent-Based Modelling & NetLogo

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(using slides from)
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Society is Complex!

• This may not be a surprise to many of you..
• …but in the sense of complexity science it means that significant global outcomes can be caused by the interactions of networks of individuals.
• The outcomes are not modellable if you do not model interactions between individuals or model only the interaction of global variables…
• …and if you try to model it in these ways, you will often be caught out by surprises.
• Agent-based simulation allows the exploration of such surprises but it is still a maturing field.
Equation-based or statistical modelling

Real World

Equation-based Model

Actual Outcomes

Aggregated Actual Outcomes

Aggregated

Model Outcomes
Individual- or Agent-based simulation

Real World

Agent-based Model

Actual Outcomes

Model Outcomes

Aggregated Actual Outcomes

Aggregated Model Outcomes
What happens in ABSS

- Entities in simulation are decided on
- Behavioural Rules for each agent specified (e.g. sets of rules like: if *this has happened* then *do this*)
- Repeatedly evaluated in parallel to see what happens
- Outcomes are inspected, graphed, pictured, measured and interpreted in different ways

**Specification** (incl. rules)

**Representations of Outcomes**

**Simulation**
Characteristics of agent-based modelling

• Computational description of process
• Not usually analytically tractable
• More specific…
• … but assumptions are less ‘brave’
• Detail of unfolding processes accessible
  – more criticisable (including by non-experts)
  – but can be more convincing than is warranted
• Used to explore inherent possibilities
• Validatable by a variety of data kinds…
  – but needs LOTS of data to do this
• Often very complex themselves
Micro-Macro Relationships

Macro/
Social data

Social, economic surveys; Census

Theory,
narrative
accounts

Micro/
Individual data

Qualitative, behavioural, social psychological data
Choosing Simulation Techniques

- Every simulation technique has pros and cons
- The *hardest* decision is when to use which approach (or how to combine approaches)
- Analytic approaches rely on their formulation being simple enough to be solvable (or, in practice, they use simulation anyway)
- Statistical approaches rely (in different and subtle ways) on the representation of *noise* as random – they will miss surprises in their projections
- Agent-based approaches are complex, require lots of data and do not give probability forecasts
- Simplicity is no guarantee of truth or generality
Meaning from intermediate abstraction (often implicit)
In Vitro vs In Vivo

• In biology there is a well established distinction between what happens in the test tube (in vitro) and what happens in the cell (in vivo)

• In vitro is an artificially constrained situation where some of the complex interactions can be worked out…

• ..but that does not mean that what happens in vitro will occur in vivo, since processes not present in vitro can overwhelm or simply change those worked out in vitro

• One can (weakly) detect clues to what factors might be influencing others in vivo but the processes are too complex to be distinguished without in vitro experiments
Some modelling trade-offs

- Simplicity
- Generality
- Realism (design reflects observations)
- Lack of error (accuracy of results)
Example: *A model of social influence and water demand*

- Part of a 2004 study for EA/DEFRA, lead by the Stockholm Environment Institute *(Oxford branch)*
- Investigate the possible impact of social influence between households on patterns of water consumption
- Design and detailed behaviour from simulation validated against expert and stakeholder opinion at each stage
- Some of the inputs are real data
- Characteristics of resulting aggregate time series validated against similar real data
Simulation structure

- Activity
- Frequency
- Volume

Households

Aggregate Demand

Policy Agent

Ground

- Temperature
- Rainfall
- Daylight
Some of the household influence structure
Example results: relative aggregate domestic demand for water (1973 = 100)
Conclusions from Example

• The use of a concrete descriptive simulation model allowed the detailed criticism and, hence, improvement of the model.

• The inclusion of social influence resulted in aggregate water demand patterns with many of the characteristics of observed demand patterns.

• The model established how:
  – processes of mutual social influence could result in differing patterns of consumption that were self-reinforcing.
  – shocks can shift these patterns, but not always in the obvious directions.
  – the importance of introduction of new technologies.
Example 2: Voting behaviour

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Overall Structure of Model

Input

- Underlying data about population composition
- Demographics of people in households
- Social network formation and maintenance (homophily)
- Influence via social networks
  - Political discussions
- Voting Behaviour

Output
Changing personal networks over which social influence occurs

Composed of households of individuals initialised from detailed survey data

Each agent has a rich variety of individual (heterogeneous) characteristics

Including a (fallible) memory of events and influences

An Agent's Memory of Events

Class
Age
Ethnicity
Level-of-Political-Interest
Memory

Discuss-politics-with person-23 blue expert=false
neighbour-network year=10 month=3
Lots-family-discussions year=10 month=2
Etc.
Example Output: why do people vote (if they do)

**Effect:** on civic duty norms

**Effect:** on habit-based behaviour

**Intervention:** voter mobilisation
Possibilistic vs Probabilistic

• The idea is to map out some of the possible social processes that may happen
• Including ones one would not have thought of or ones that have already happened
• The global coupling of context-dependent behaviours in society make projecting probabilities problematic
• Increases understanding of why processes (such as the spread of a new racket) might happen and the conditions that foster them
• Complementary to statistical models
Role of ABM in Policy Assessment

• ABMs are good for analysing risk – how a more standard model/prediction might go/be wrong
• That is, testing the assumptions behind simpler models (statistical, discrete event, system dynamic, etc.)…
• …so exploring the possible deviations from their forecasts
• In other words, showing some of the possible surprises that could occur (but not all of them)
• To inform a risk analysis that goes with a forecast
• Can be used for designing early-warning indicators of newly emergent trends
ABSS Advantages

• ABSS allows the production and examination of possible complex outcomes that might emerge
• It does not need such strong assumptions (that analytic approaches require) to obtain results
• It allows the indefinite experimentation and examination of outcomes (*in vitro*)
• It aids the integration and use of a wider set of evidence, e.g. very open to stakeholder critique
• It suggests hypotheses about the complex interactions in observed (*in vivo*) social phenomena
• So allowing those ‘driving’ policy to be prepared, e.g. by implementing ‘early warning systems’
• Can be complementary to other techniques
ABSS Disadvantages

- It does not magically tell you what will happen
- Are relatively time-consuming to construct
- It can look more convincing that is warranted
- Understanding of the model itself is weaker
- It needs truck loads of data for its validation
- It gives possibilities rather than probabilities
- Fewer good practitioners around
- Not such a mature field
To Learn More


• *Journal of Artificial Societies and Social Simulation*, [http://jasss.soc.surrey.ac.uk](http://jasss.soc.surrey.ac.uk)

• *European Social Simulation Association*, [http://essa.eu.org](http://essa.eu.org)

• *NetLogo*, a relatively accessible system for doing ABM [http://ccl.northwestern.edu/netlogo](http://ccl.northwestern.edu/netlogo)

• *OpenABM.org*, an open archive of ABMs, including code and documentation