What is Agent-Based Social Simulation?

A talk in the Methods@Manchester Series

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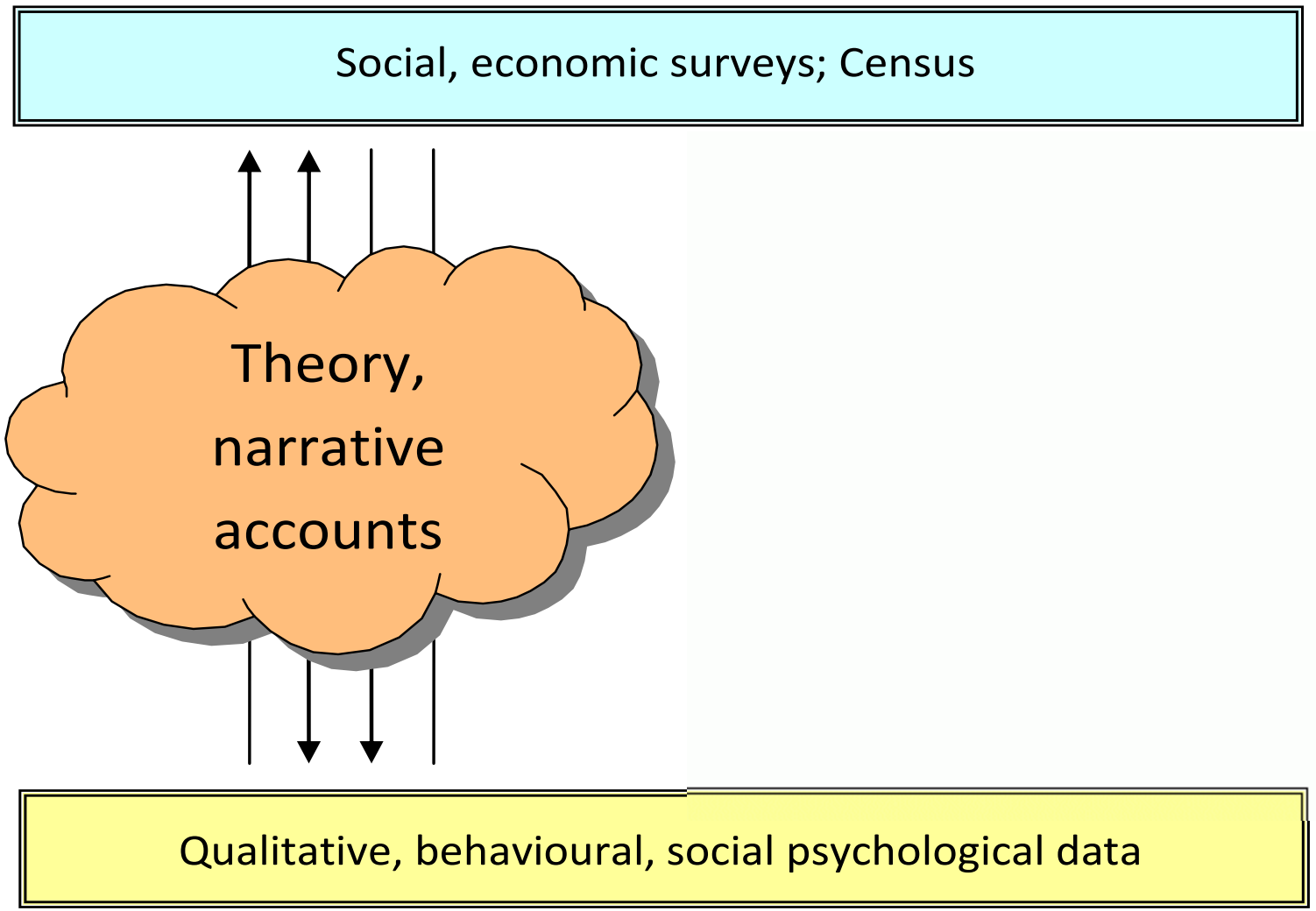
Introduction

An Example: Social Norms

- A social norm emerges partly as a result of the beliefs, self-identity, actions, etc. of individuals
- But, *simultaneously*, the same norm constrains/influences the perceptions, beliefs, self-identity, actions, etc. of those individuals
- What we identify and label as a "social norm" is a dynamic *complex* of upwards "*emergence*" and downwards "*immergence*"
- Like many social phenomena, it has a complex micro-macro relationship/interaction at its core
- *Agent-based simulation allows the representation and exploration of such micro-macro complexes*

Micro-Macro Relationships



Some Key Historical Figures

- Herbert Simon
  - Observed administrative behaviour and described it using algorithms – '*procedural rationality*' (rather than optimisation of utility)
  - Also (with Alan Newell) produced first computational models of aspects of cognition
- Thomas Schelling
  - A simple but effective example of individual-based modelling (in the coming slides)
- Mark Granovetter
  - Distinguished the importance of tracing individual interactions, '*social embeddedness*'
  - Highlighted such processes and structure ('ties')

Origins of ABSS

(Occasionally) Interacting Streams:

- Sociology, including social network analysis
- Distributed Computer Science Programming Languages
- Artificial Intelligence & Machine Learning
- Ecological Modelling

(Strangely) *Not much from*:

- (Mainstream) Economics
- Cognitive Modelling
- Numerical Simulation
- System Dynamics

Method and Examples

Analytic **models**

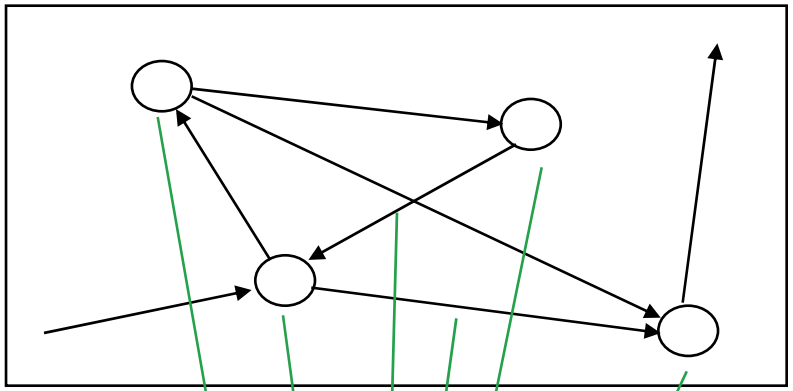
Where the model is expressed in terms that allow for formal inferences about its general properties to be made

- e.g. Mathematical formulae
- Where you don't have to compute the consequences but can *derive* them logically
- Usually requires numerical representation of what is observed (but not always)

Only fairly "simple" mathematical models can be treated analytically – the rest have to be simulated/calculated

Equation-based/statistical/system dynamics modelling

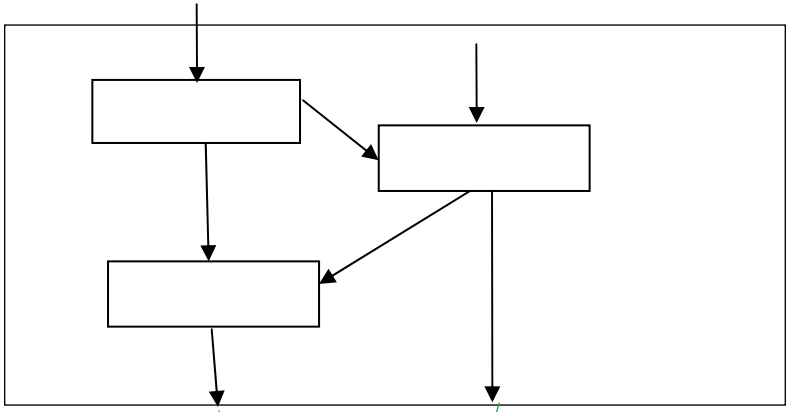
Observed World



Outcomes

Aggregated Outcomes

Equation-based Model



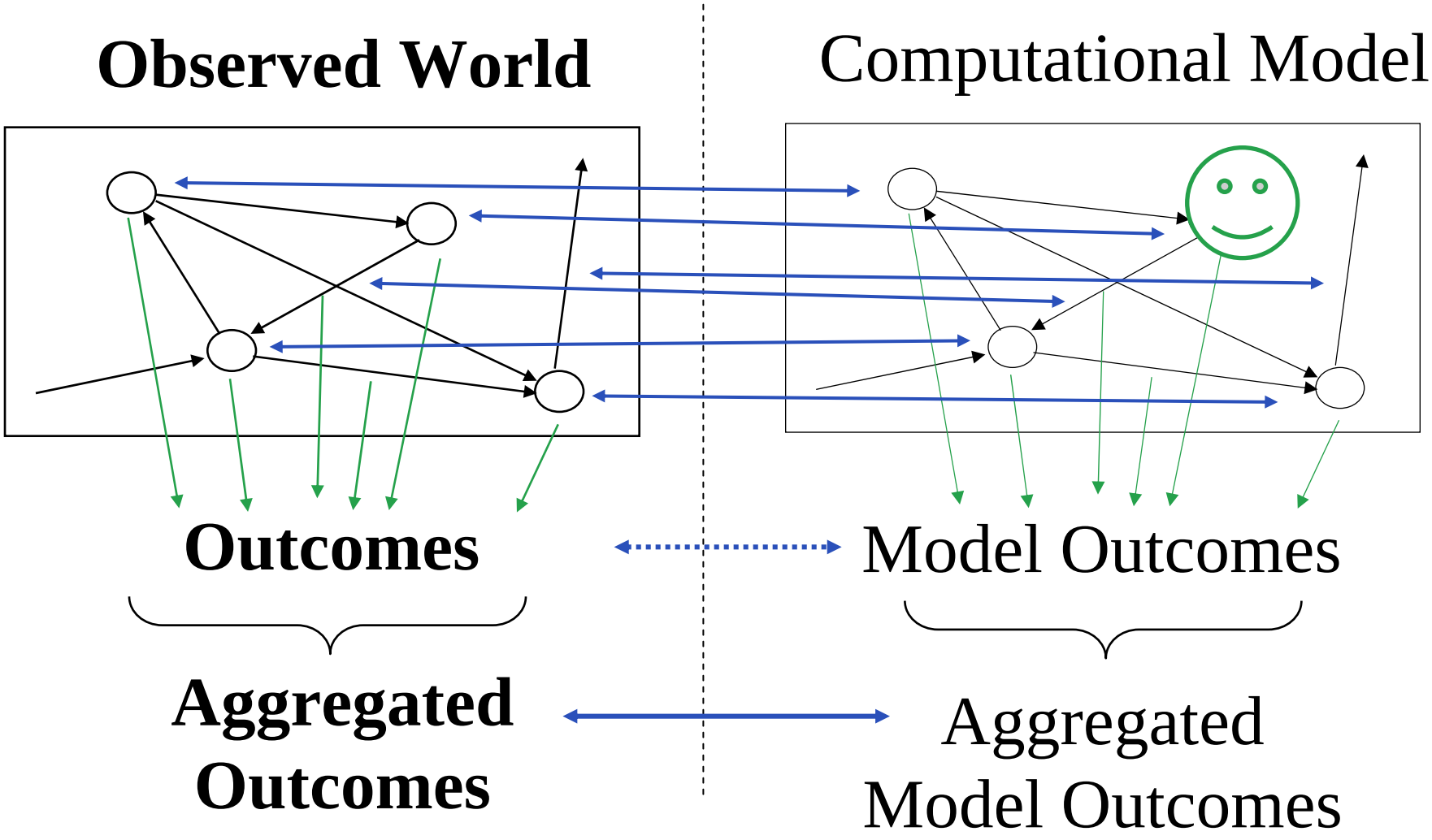
Aggregated Model Outcomes

Computational **models**

Where a process is modelled in a series of precise instructions (the program) that can be "run" on a computer

- The same program always produces the same results (essentially) but...
- ...may use a "random seed" to randomise certain aspects
- Can be simple or very complex
- Often tries to capture more "qualitative" aspects of social phenomena

Agent-based simulation



Characteristics of agent-based modelling

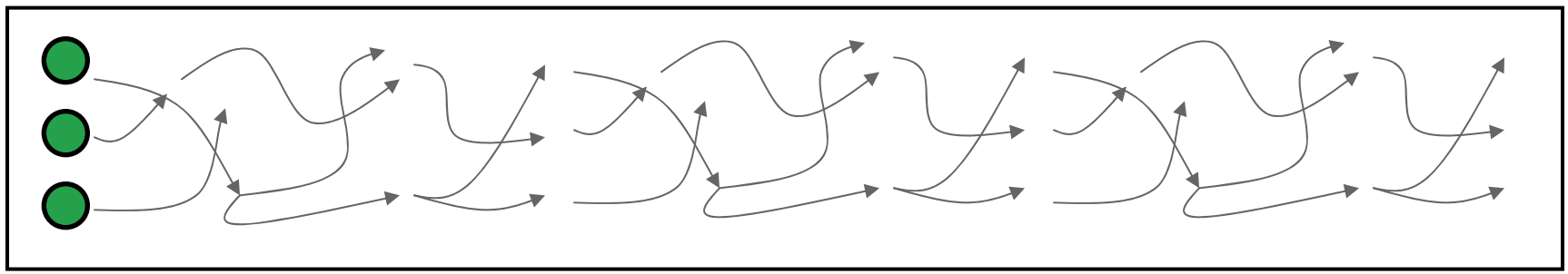
- Computational description of process
- Not usually analytically tractable
- More context-dependent…
- … but assumptions are much less drastic
- Detail of unfolding processes accessible
  - more criticisable (including by non-experts)
- Used to explore inherent possibilities
- Validatable by data, opinion, narrative ...
- Often very complex themselves

What happens in ABSS

- Entities in simulation are decided up
- 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

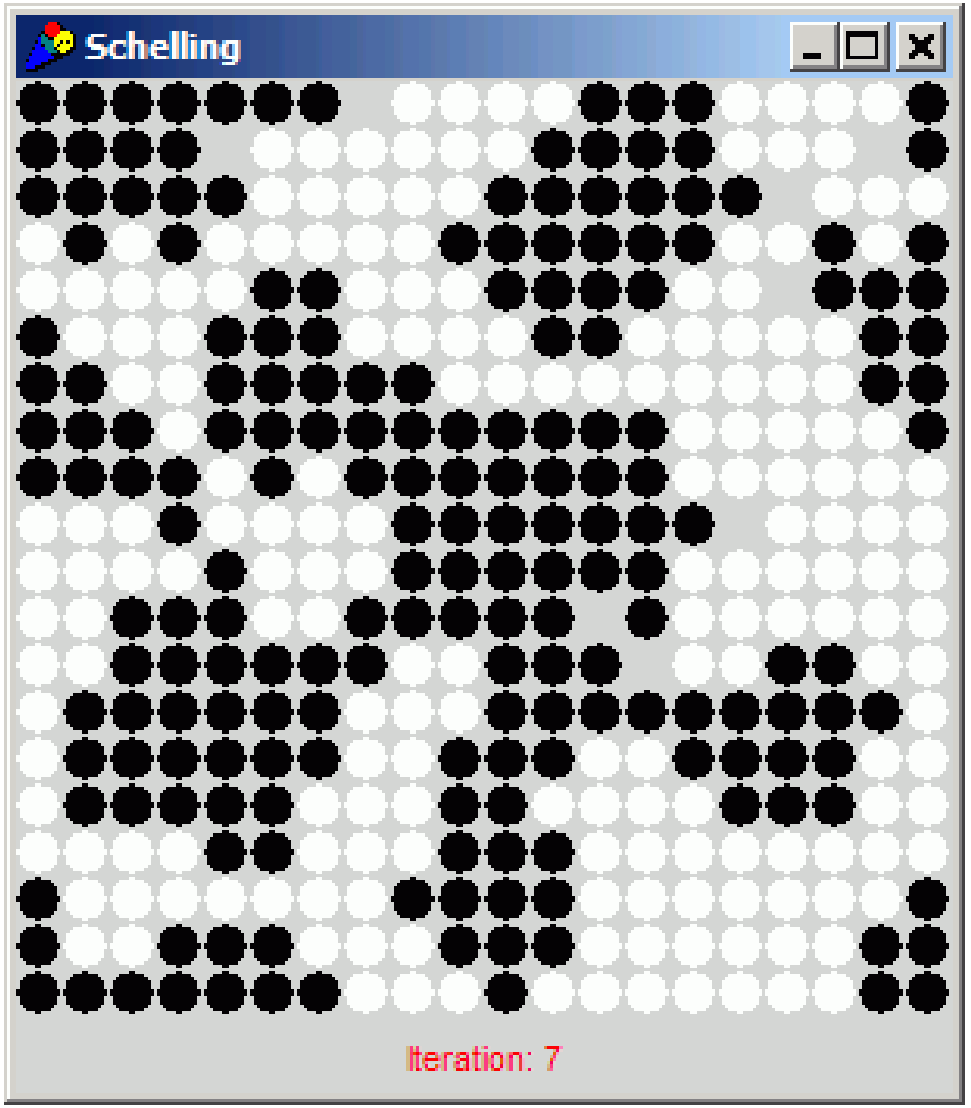
Example 1: *Schelling's Segregation Model*

Schelling, Thomas C. 1971. Dynamic Models of Segregation. *Journal of Mathematical Sociology* **1**:143-186.

Rule: each iteration, each dot looks at its neighbours and if less than 30% are the same colour as itself, it moves to a random empty square

Conclusion:

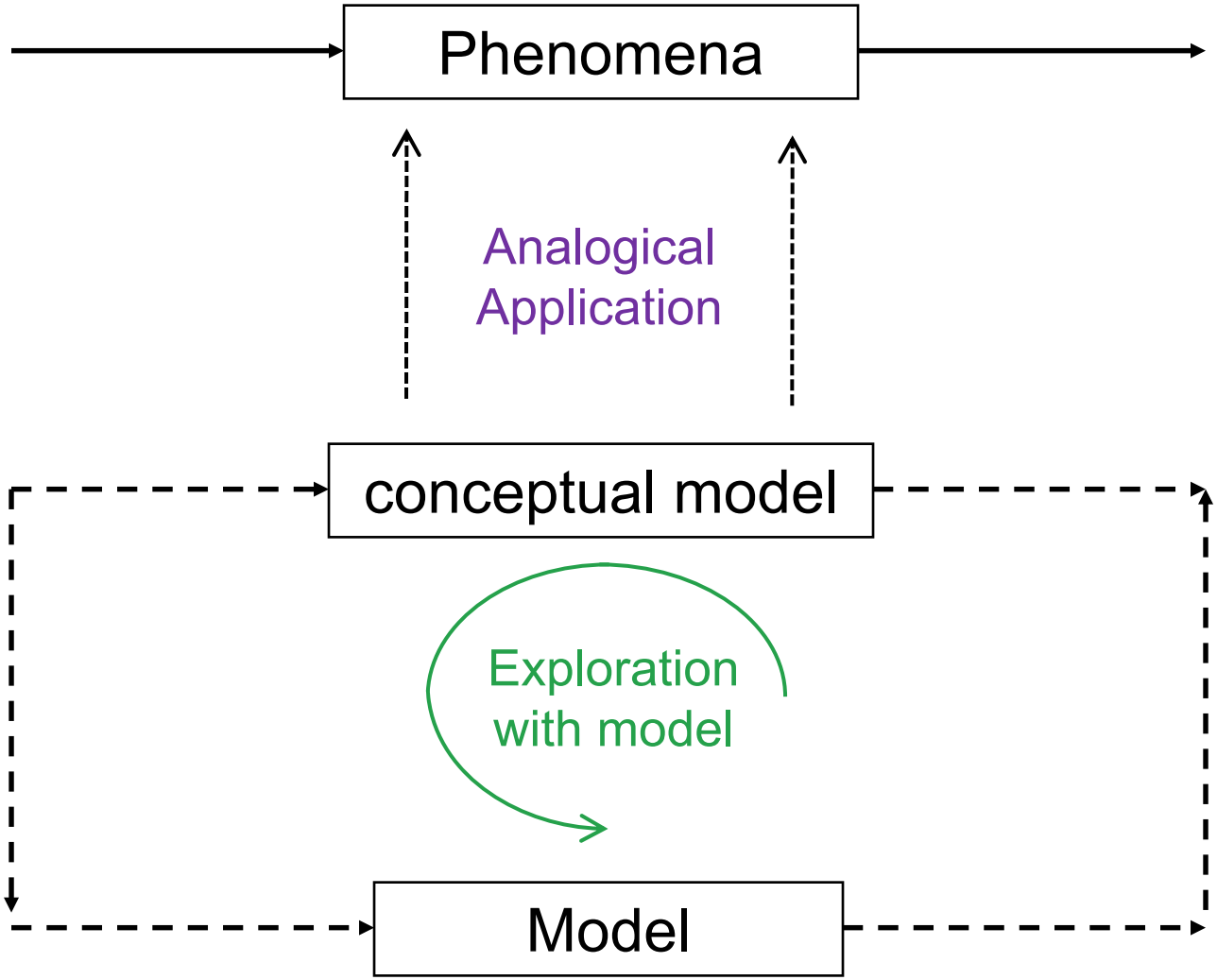
Segregation can result from wanting only a few neighbours of a like colour



Simple, Conceptual Simulations Such as Schelling's

- Are highly suggestive
- Once you play with them, you start to "see" the world in terms of you model – a strong version of Kuhn's *theoretical spectacles*
- They can help persuade beyond the limit of their reliability
- They may well not be directly related to any observations of social phenomena
- Are more a model of an idea than any observed phenomena
- Can be used as a counter-example

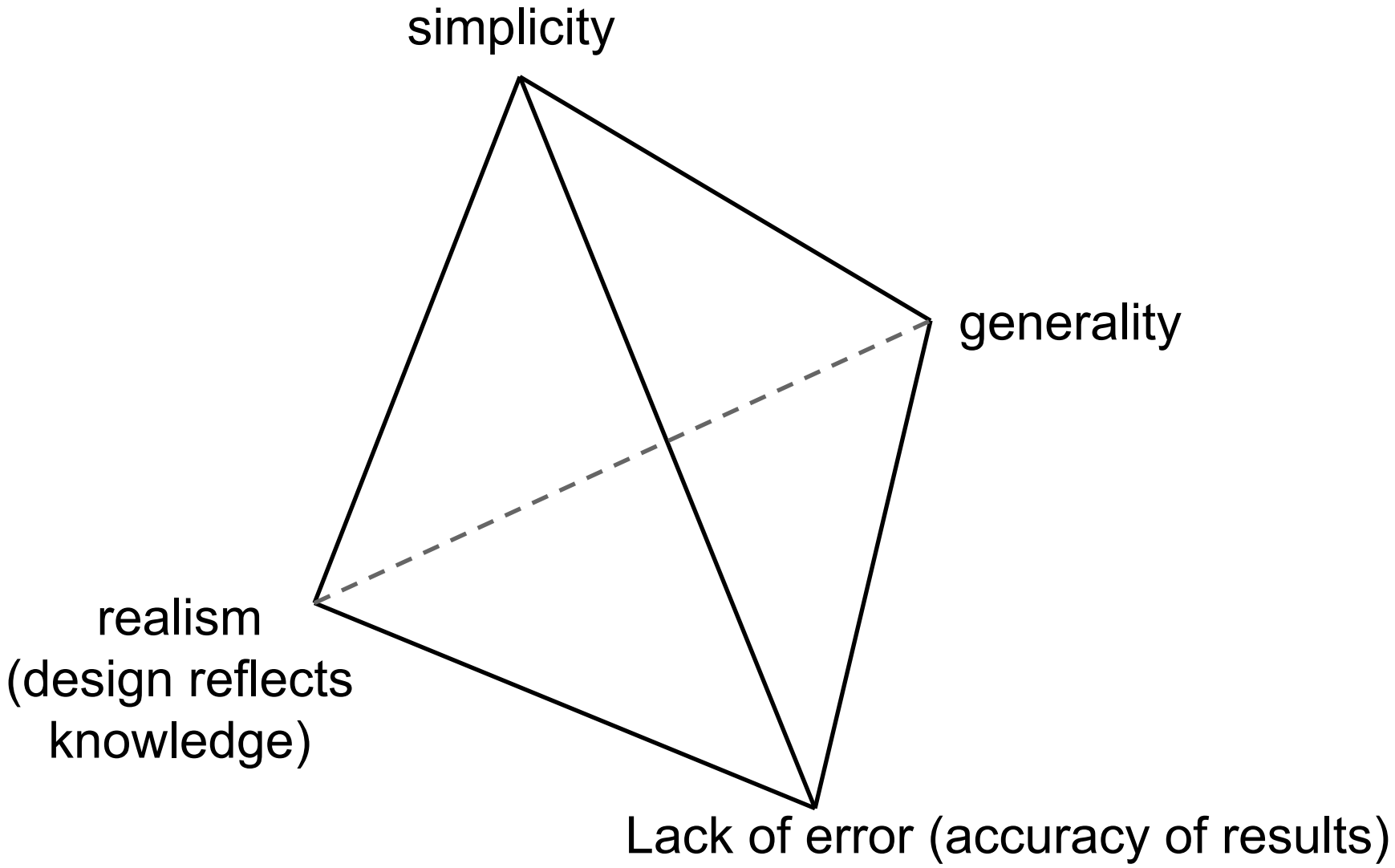
Modelling a concept of something



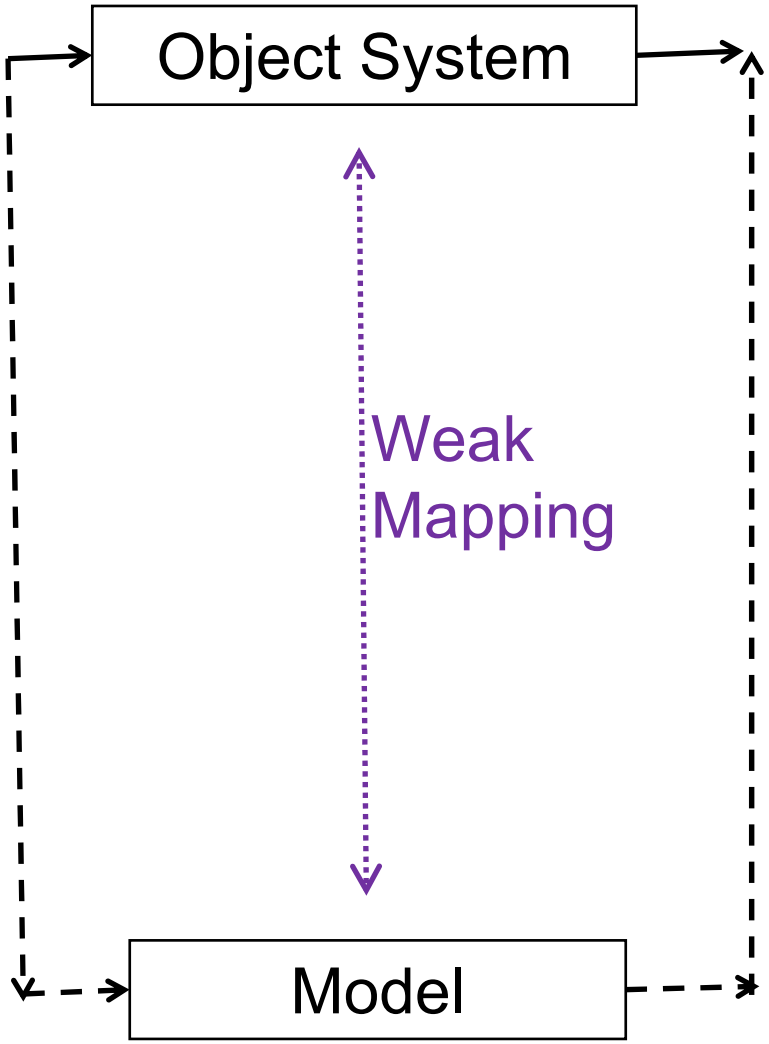
Some Criteria for Judging a Model

- Soundness of design
  - w.r.t. knowledge of how the object works
  - w.r.t. tradition in a field
- Accuracy (lack of error)
- Simplicity (ease in communication, construction, comprehension etc.)
- Generality (when you can safely use it)
- Sensitivity (relates to goals and object)
- Plausibility (of design, process and results)
- Cost (time, effort, etc.)

Some modelling trade-offs

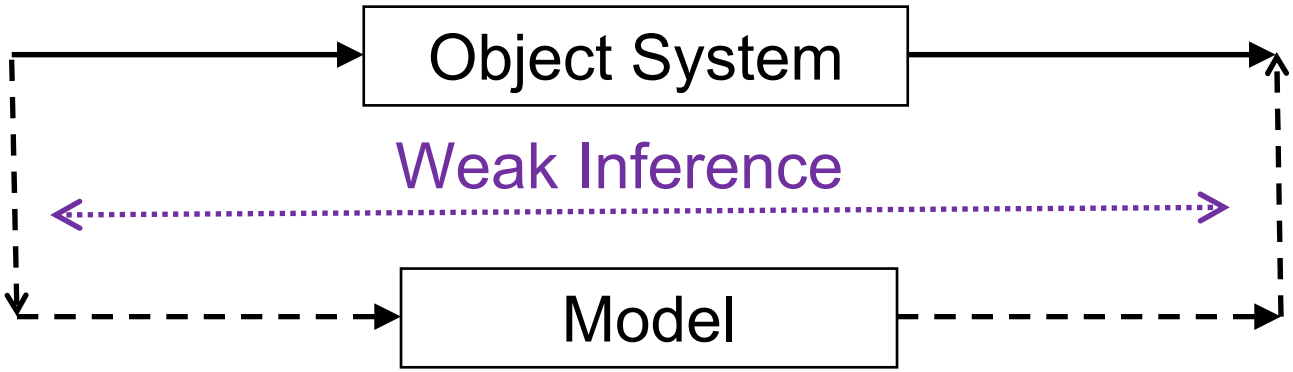


Abstract Theoretical Model



Simple model but abstract – strong inference within model,
but weak mappings to and from the model

Complex Descriptive Model



Complex but directly relevant model –
strong mapping to model,
weak inference within model

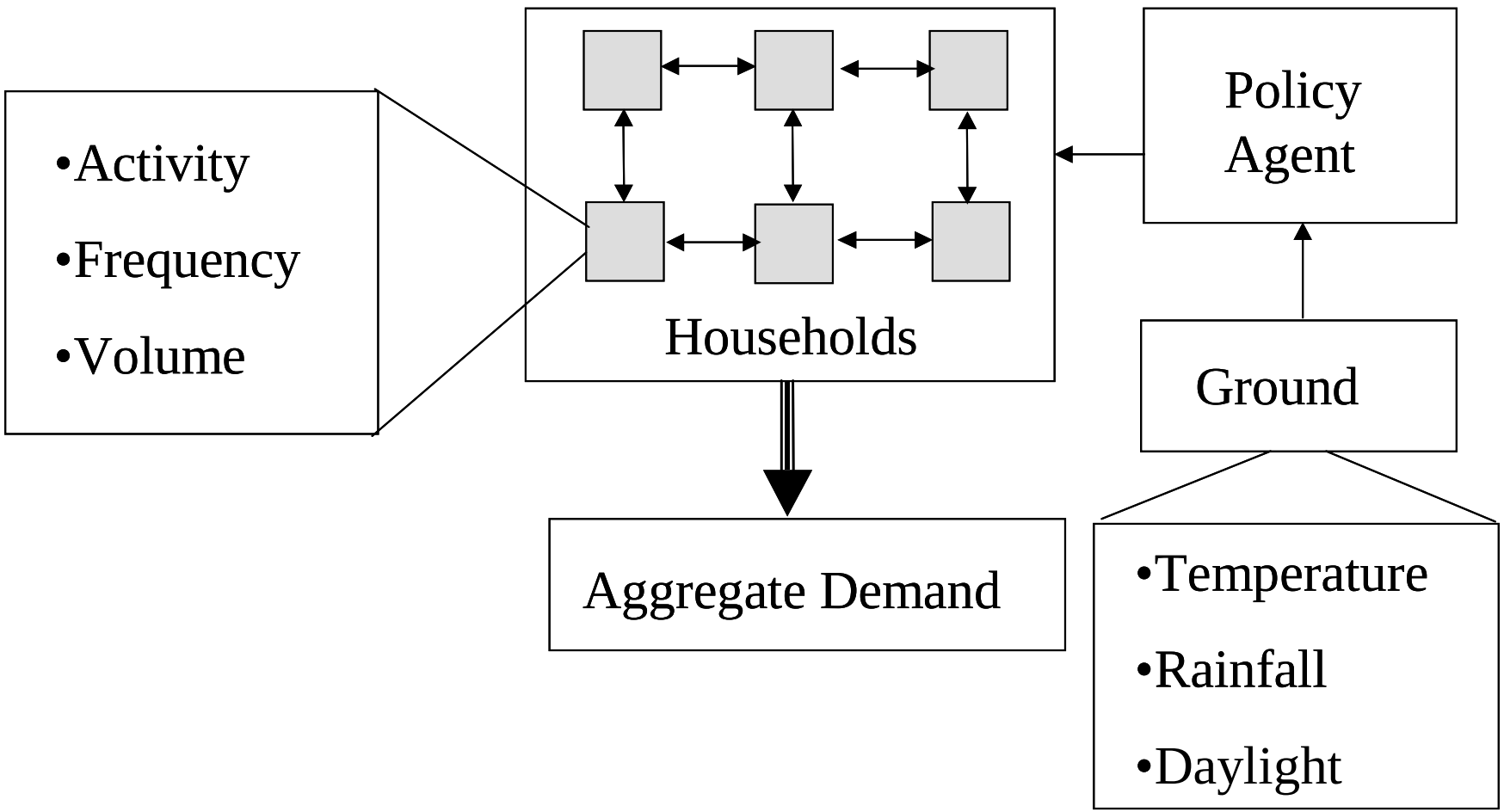
Example 2: *A model of social influence and water demand*

- Investigate the possible impact of social influence between households on patterns of water consumption
- Design and detailed behavioural outcomes 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

Type, context, purpose

- Type: A complex agent-based descriptive simulation integrating a variety of streams of evidence
- Context: statistical and other models of domestic water demand under different climate change scenarios
- Purposes:
  - to critique the assumptions that may be implicit in the other models
  - to demonstrate an alternative

Simulation structure



Household Behaviour – Endorsement on Actions

- Each action might is a particular frequency and use of water
- Action Endorsements: recentAction neighbourhoodSourced selfSourced globallySourced newAppliance bestEndorsedNeighbourSourced
- 3 Weights moderate effective strengths of neighbourhoodSourced selfSourced globallySourced endorsements and hence the bias of households
- Can be simplified as 3 types of households influenced in different ways: *global*-; *neighbourhood*-; and *self*-sourced depending on the dominant weight

History of a particular action from one agent's point of view with respect to one action

Month 1: used, endorsed as **self sourced**

Month 2: endorsed as **recent** (from personal use) and **neighbour sourced** (used by agent 27) and **self sourced** (remembered)

Month 3: endorsed as **recent** (from personal use) and **neighbour sourced** (agent 27 in month 2).

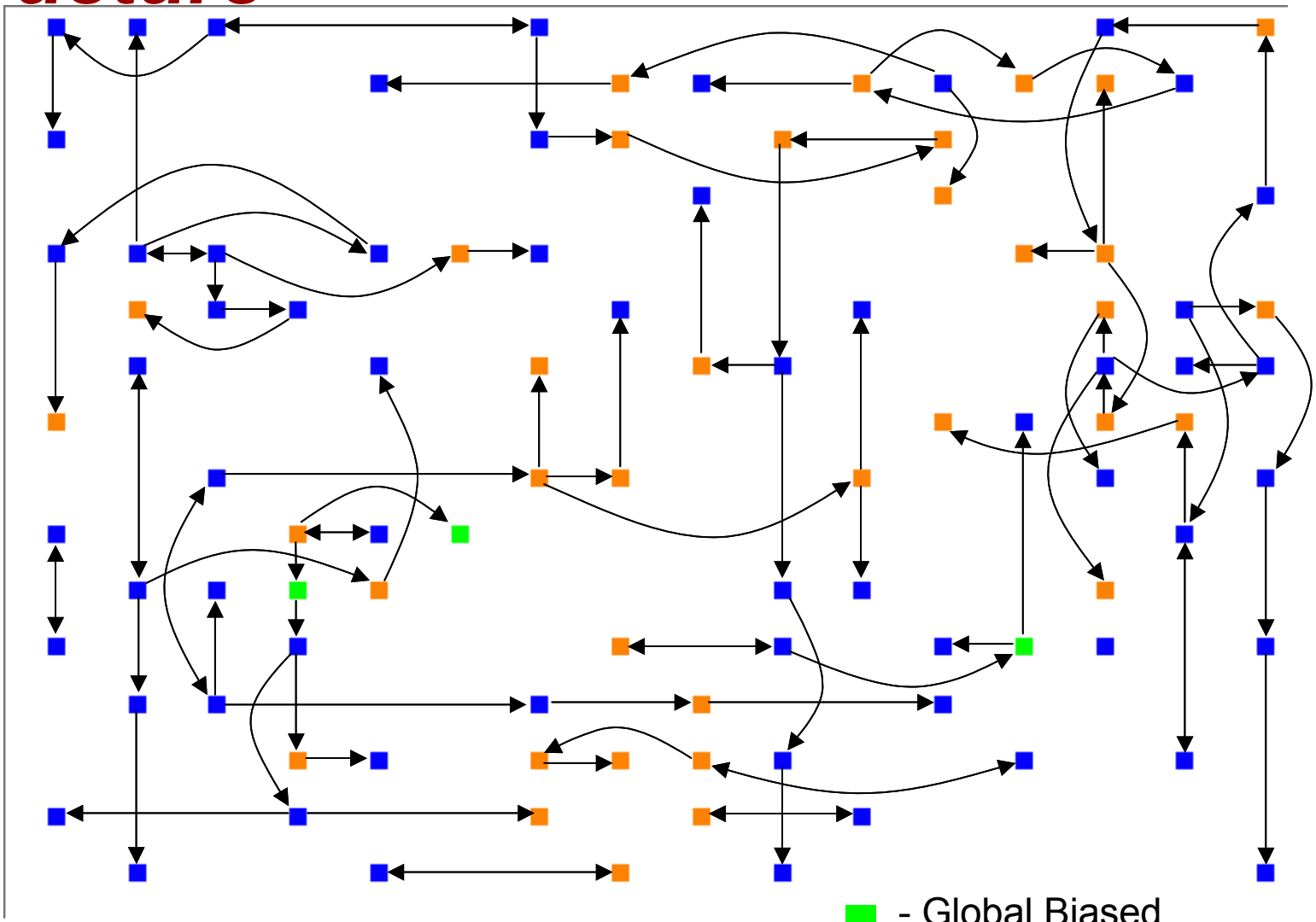
Month 4: endorsed as **neighbour sourced** twice, used by agents 26 and 27 in month 3, also **recent**

Month 5: endorsed as **neighbour sourced** (agent 26 in month 4), also **recent**

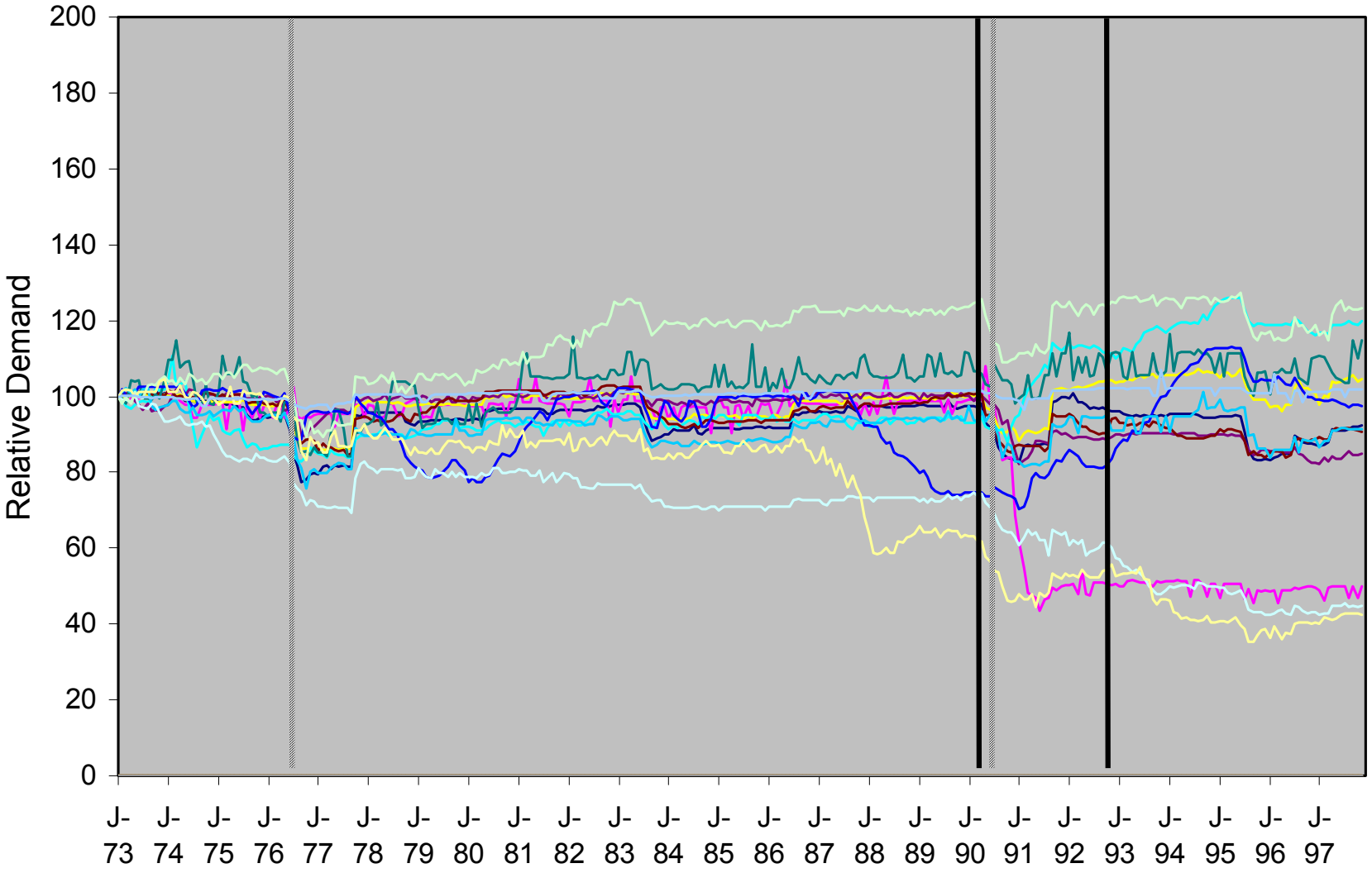
Month 6: endorsed as **neighbour sourced** (agent 26 in month 5)

Month 7: replaced by action 8472 (appeared in month 5 as **neighbour sourced**, now endorsed 4 times, including by the **most alike neighbour** – agent 50)

Some of the household influence structure



Example results



Conclusions from Water Demand Example

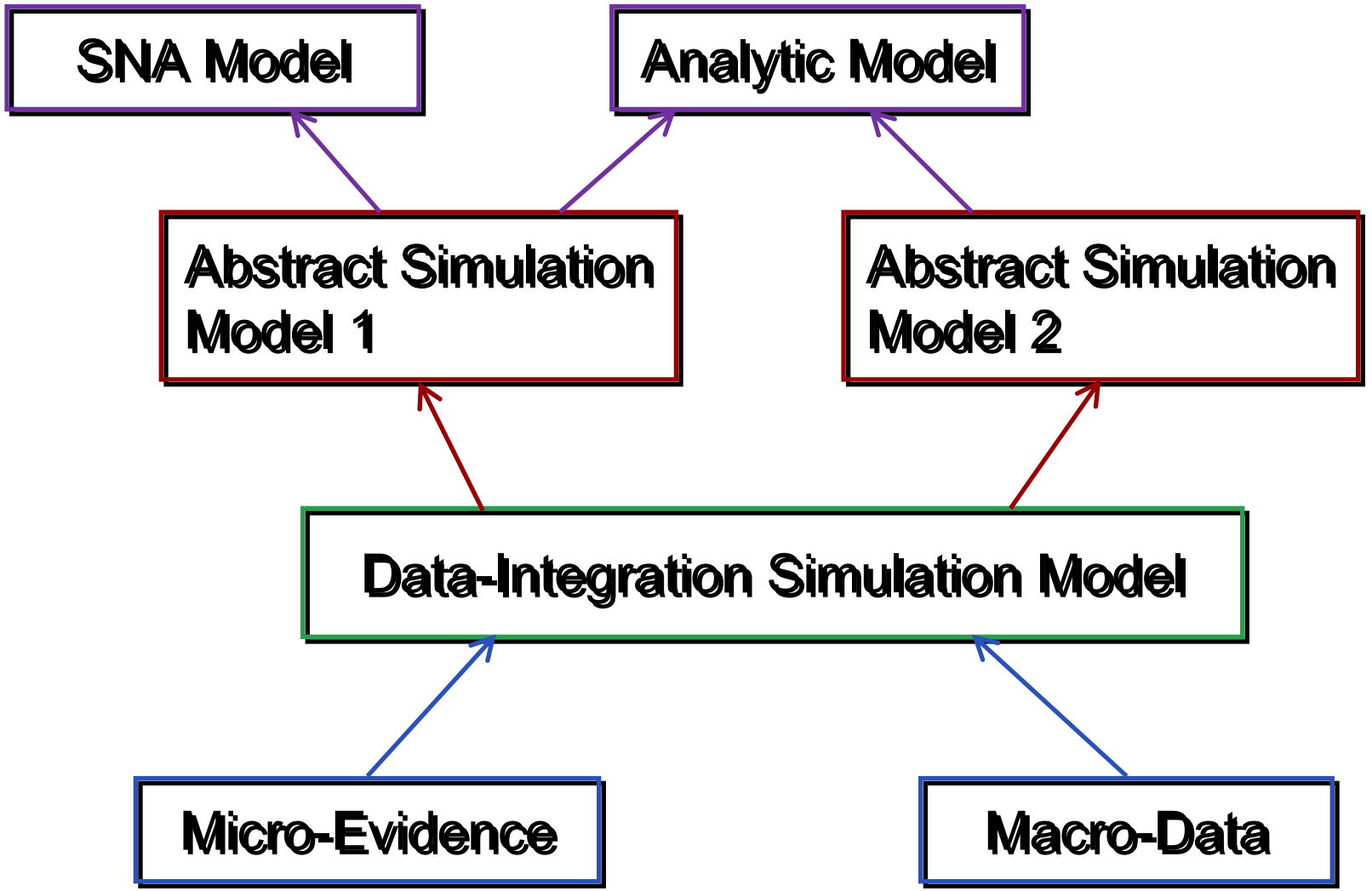
- The use of a concrete descriptive simulation model allowed the detailed criticism and, hence, improvement of the model
- The inclusion of social influence resulted in aggregate water demand patterns with many of the characteristics of observed demand patterns
- The model established how it *was possible that* processes of mutual social influence could result in widely differing patterns of consumption that were self-reinforcing

Comments on Descriptive ABSS

- Is a dynamic and integrated representation of available evidence of many different kinds: narrative, survey, time-series, SNA, etc. (a "*Data-Integration Model*")
- More of a *description* than a general theory
- Allows for experimentation and exploration of possible outcome "trajectories"
- A main benefit is often the discovery of new questions and issues to be researched – it can inform good observational studies
- The simulation was complex and slow, we could not say we fully understand it
- Ideally the DIM should be subject to further analysis and modelling to check and understand aspects

The SCID Project Methodology

(http://scid-project.org)



Conclusion

Discursive vs Simulation Approaches

Natural Language

- Rich, semantic, meaningful, flexible
- But imprecise
- Map to what is observed is often complex and implicit
- Difficult to keep track of complicated interactions and outcomes
- Has “pre-prepared” meaning and referents

Computer Simulation

- Precise, well defined, replicable, flexible
- But brittle
- Semantically thin
- Map to observed *can be* explicit and more direct
- Good at keeping track of complicated interactions and outcomes
- Meaning needs to be established through use

Analytic vs Simulation Approaches

Analytic Modelling

- Precise, well defined, replicable
- Very brittle
- Not Semantic
- Map to observed can be indirect and/or difficult to establish
- Strong checkable inference
- General characterisation of outcomes
- Requires *strong* assumptions to work

Computer Simulation

- Precise, well defined, replicable, flexible
- More expressive descriptive
- Semantically thin
- Map to observed *can be* explicit and more direct
- Inference is more contingent, (sets of) example outcomes
- Can relate more easily to a broader range of evidence

What ABSS Can Do

- ABSS can allow the production and examination of sets of possible complicated processes both emergent and immergent
- Using a precise (well-defined and replicable) language (a computer program)
- But one which allows the tracing of very complicated interactions
- And thus does not need the strong assumptions that analytic approaches require to obtain their proofs
- It allows the indefinite experimentation and examination of outcomes (*in vitro*)
- Which can inform our understanding of some of the complex interactions that may be involved in observed (*in vivo*) social phenomena

To Learn More

- *Simulation for the Social Scientist*, 2nd Edition. Nigel Gilbert and Klaus Troitzsch (2005) Open University Press. http://cress.soc.surrey.ac.uk/s4ss/
- *Journal of Artificial Societies and Social Simulation*, http://jasss.soc.surrey.ac.uk
- *European Social Simulation Association*, http://essa.eu.org
- *NetLogo*, a relatively accessible system for doing ABSS with a big library of example models, http://ccl.northwestern.edu/netlogo

The End

For supporting information follow links:

http://methods.manchester.ac.uk

→ Events → "*What is… ?*"

→ what is agent-base social simulation

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