Modelling Complex Adaptive Systems

Agent Based Simulations

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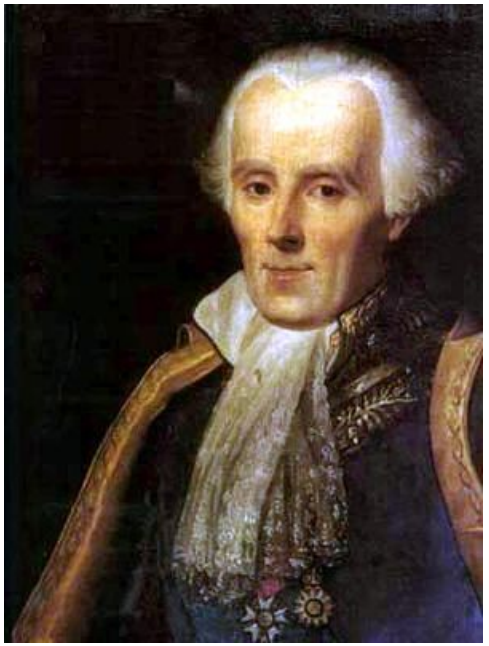
“We may regard the present state of the universe as the effect of its past and the cause of its future. An intellect which at a certain moment would know all forces that set nature in motion, and all positions of all items of which nature is composed, if this intellect were also vast enough to submit these data to analysis, it would embrace in a single formula the movements of the greatest bodies of the universe and those of the tiniest atom; for such an intellect nothing would be uncertain and the future just like the past would be present before its eyes.“



Laplace 1814: Essai philosophique sur les probabilites

Assumptions

- Every observed effect has an observable cause (causality).
- The whole can be understood by taking it apart and studying the pieces (analysis).
- Sufficient analysis of past events can create the capacity to predict future events (predictability).

True?

Yes for many cases

But not always

When does it go wrong?

- many social beings
- many interactions
- decentralised systems
- coupled systems & scales

Complex Adaptive Systems (CAS)

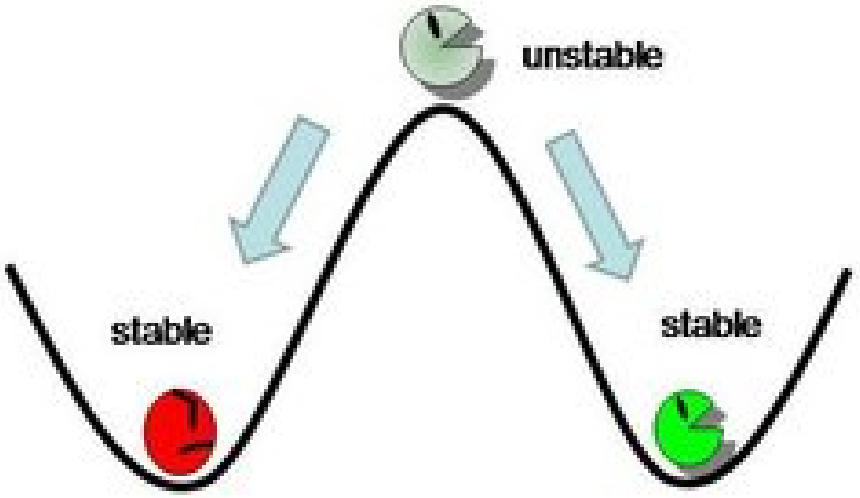
CAS definition

- A system that can adapt itself to the environment
- Large number of interacting components (agents)
- Many different scales (both in space and time)
- Capacity to change and learn from experience
- Interdisciplinary

Sum is more than its parts

What's the problem?

- Open
- Hidden causalities
- Non-linear
- Feedbacks
- Path dependency
- Bi-stability / inherent uncertainty



Adaptive Cycles

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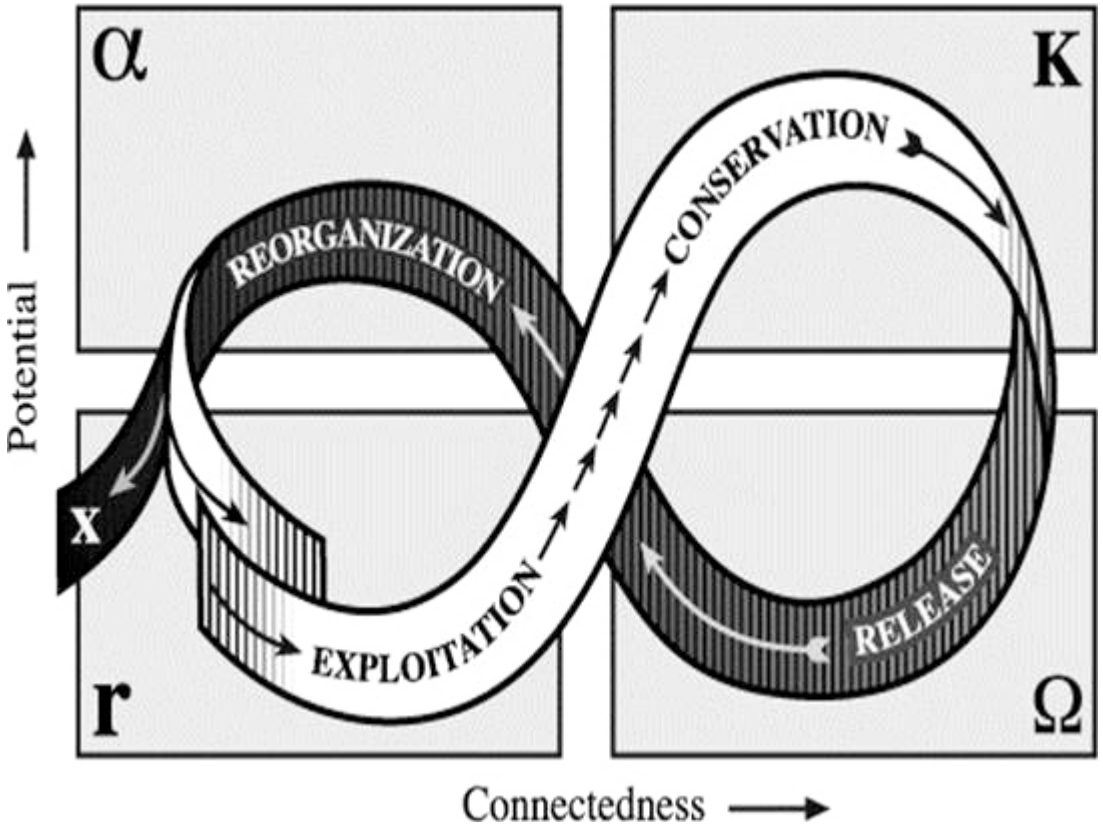
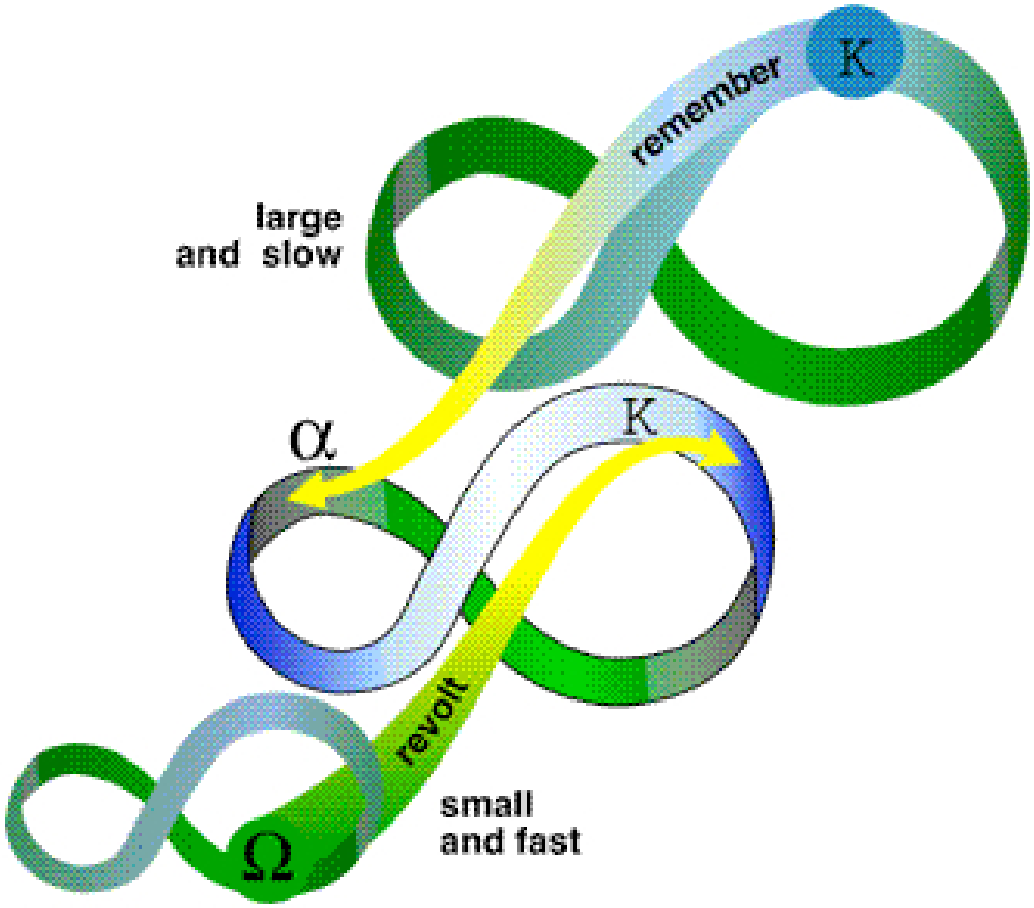


Source: Holling et. al. 2020

Panarchy



Source: resilience alliance

Examples

- Ecologies
- Economies
- Sociologies
- Politics
- Cities

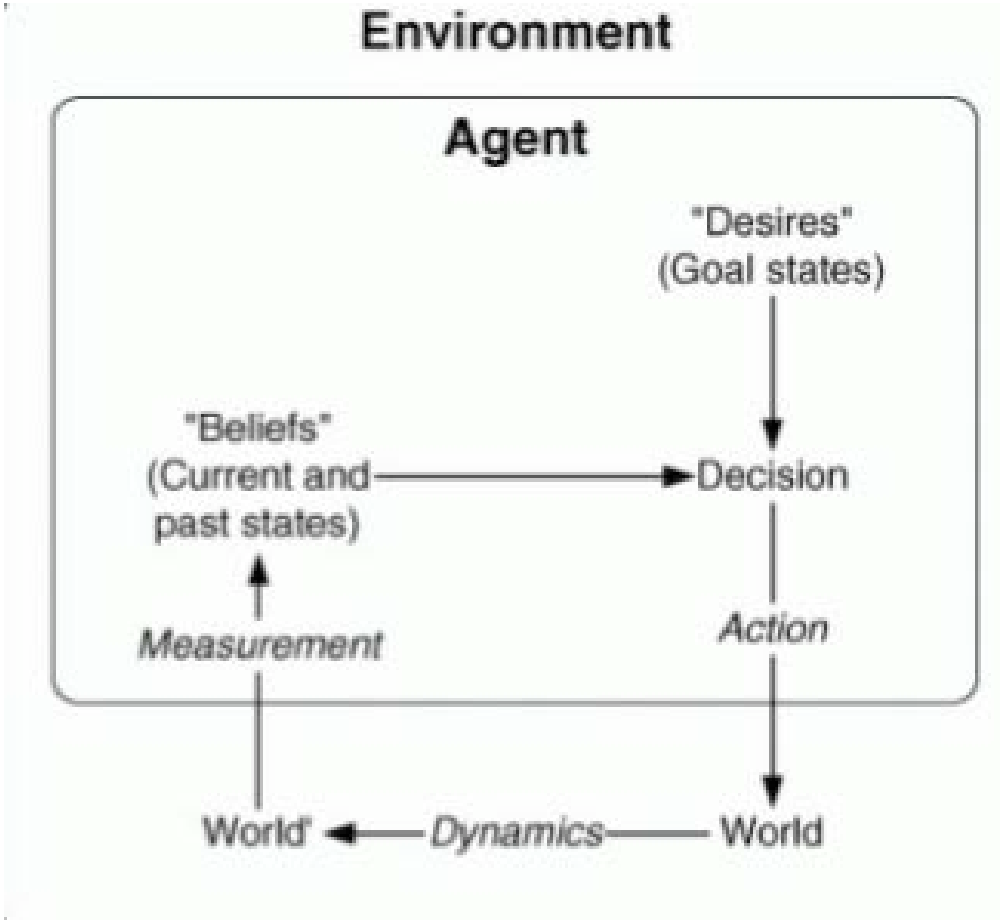
Modelling CAS

- Bottom-up
- No central control
- Individual components
- Interactions & feedback
- Self-organisation and Emergence

Agent Based Models (ABM)

Agents

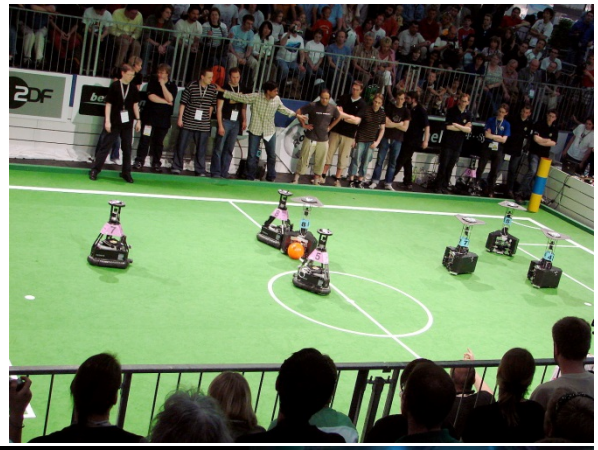
- Decision-making components
- Situated in some environment
- Autonomous and goal directed
- Reactive (pro active)
- Learning
- Partial control; influence environment
- Action steered by pre-conditions



Examples

- Control systems (thermostat, flight control systems, Tesla)
- Software daemons
- Webcrawlers
- Robots

Simulation models



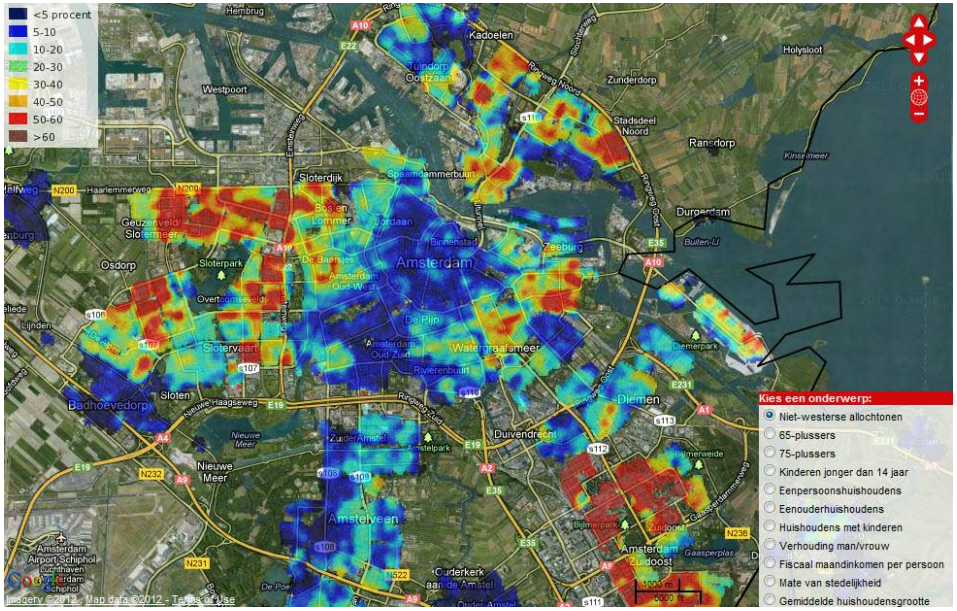
Simulating CAS

- Interactions between social beings and their environment
- Represented as Agents

- Example:

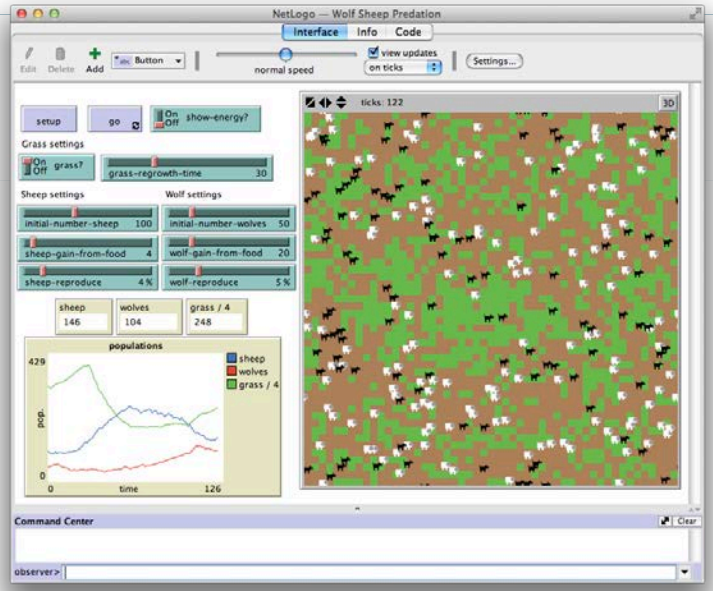
Segregation model

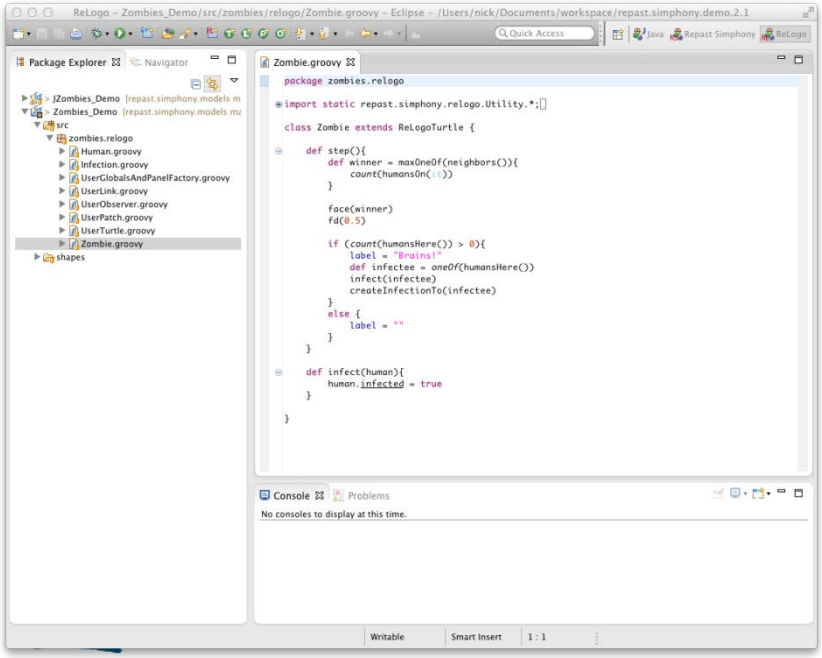
(Schelling)

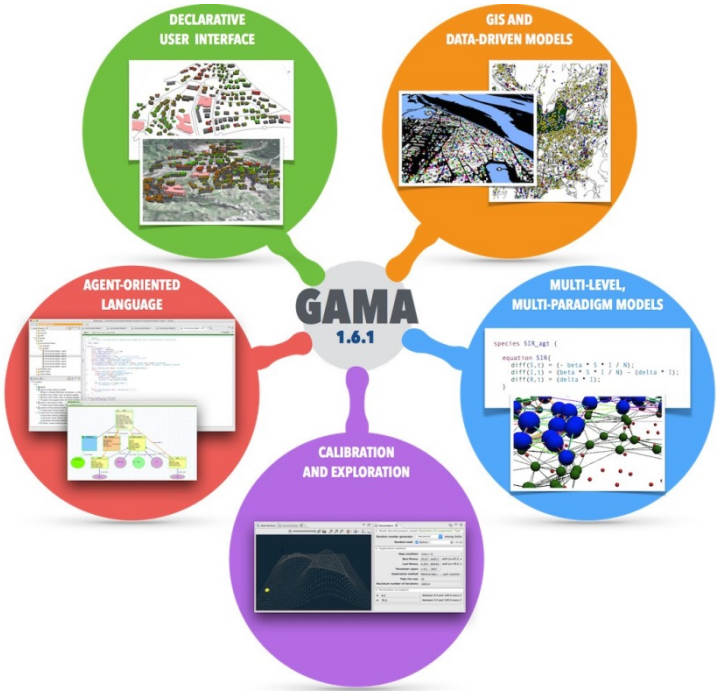


How

- NetLogo
- Repast
- GAMA

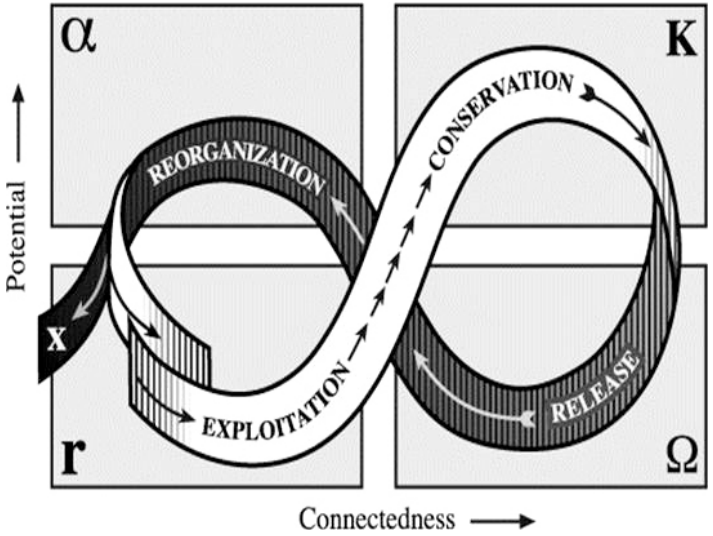






Why

- Learn the systems reactions
- Explore CAS
  - transformations,
  - adaptive capacity
  - robustness and resilience



- Design better policies
- Adaptive Management (≠ best guess management)

Challenges

- **Purpose and theory**
- **Sensitivity analyses, calibration and validation**
- Agent representation and behaviour
- Representation of spatial and social environments

Purpose and theory

Normal: theory ➔ model ➔ validation ➔ acceptance

- Position of ABM not established

- Model as a laboratory
- Use the model to develop theories

- Concern: many assumption remain hidden

Sensitivity Analysis

- Not straight forward for ABMs
- Adaptation and non-linearity is the problem

- Exploring various methods:
  - Local methods
  - Global methods
  - Ergodicity based methods
  - …

Verification, calibration, and validation

- Verification → model matches design
- Calibration → fine tuning model
- Validation → model matches ‘real-world’

Lack of uniqueness in param. estimations.

Assumptions outweigh data availability

Exploring serious gaming as tool

Next

- Olivier: example SES
- Eva: Supply chain

Thank You

Questions