Agent Based Modelling with Applications in Economics

M Czupryna

Cracow University of Economics

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Overview

Agent based modelling phenomena

Two types of modelling approaches:

- phenomenon-based modelling (we try to explain patterns)
- exploratory modelling (we analyse the consequences)

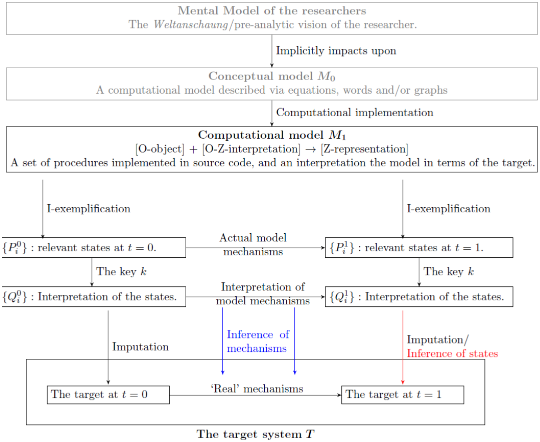
Typically observed phenomena:

- Simple rules can be used to generate complex phenomena.
- Randomness in individual behaviour can results in a consistent patterns of population behaviour
- Complex patterns "self-organise" without any leader
- Different models emphasise different aspects of the world

One must be careful about:

- verification
- validation

Agent based modelling verification and validation



Graebner, Claudius (2018) 'How to Relate Models to Reality? An Epistemological Framework for the Validation and Verification of Computational Models' Journal of Artificial Societies and Social Simulation 21 (3) 8

Agent based modelling verification and validation

Verification – testing whether the model does what it is supposed to be doing, i.e. whether it adequately implements the conceptual model, foe example whether it is free of bugs

Validation – testing whether the model is actually a reasonable representation of the target

Agent based modelling verification and validation

Validation:

1. Input validation
2. Process validation
3. Descriptive output validation
4. Predictive output validation

Virus transmission

The basic SIR model has three groups:

- susceptible (S)
- infectious (I)
- recovered (R)

Total population size $N = S + I + R$

$$\frac{\mathrm{d}S}{\mathrm{d}t} = -\underbrace{\beta IS/N}_{\text{infection}}$$

$$\frac{\mathrm{d}I}{\mathrm{d}t} = \underbrace{\beta IS/N}_{\text{infection}} - \underbrace{\gamma I}_{\text{recovery}}$$

$$\frac{\mathrm{d}R}{\mathrm{d}t} = \underbrace{\gamma I}_{\text{recovery}}$$

Virus transmission

The SEIRS model has four groups:

- susceptible (S)
- infectious (I)
- exposed (E)
- recovered (R)

$$\frac{\mathrm{d}S}{\mathrm{d}t} = \underbrace{\mu N}_{\text{birth}} - \underbrace{\beta IS/N}_{\text{infection}} + \underbrace{\omega R}_{\text{lost immunity}} - \underbrace{\mu S}_{\text{death}}$$

$$\frac{\mathrm{d}E}{\mathrm{d}t} = \underbrace{\beta IS/N}_{\text{infection}} - \underbrace{\sigma E}_{\text{latency}} - \underbrace{\mu E}_{\text{death}}$$

$$\frac{\mathrm{d}I}{\mathrm{d}t} = \underbrace{\sigma E}_{\text{latency}} - \underbrace{\gamma I}_{\text{recovery}} - \underbrace{(\mu + \alpha) I}_{\text{death}}$$

$$\frac{\mathrm{d}R}{\mathrm{d}t} = \underbrace{\gamma I}_{\text{recovery}} - \underbrace{\omega R}_{\text{lost immunity}} - \underbrace{\mu R}_{\text{death}}$$

Bjørnstad, O.N., Shea, K., Krzywinski, M. et al. The SEIRS model for infectious disease dynamics. Nat Methods 17, 557–558 (2020).

Virus transmission

Models library $\rightarrow$ Biology $\rightarrow$ Virus

Problem: The model simulates the transmission and perpetuation of a virus in a human population.

John Conway's Game of Life

Models library $\rightarrow$ IABM Textbook $\rightarrow$ chapter 2 $\rightarrow$ Life simple

Example: A cellular automaton is a computational machine that performs actions based on certain rules.

Forest fire simple model

Models library $\rightarrow$ IABM Textbook $\rightarrow$ chapter 3 $\rightarrow$ Fire extensions $\rightarrow$ Fire simple

Problem: If you start with some burning trees on one side how likely is that the fire will spread to the other side?

Forest fire extensions

- Probabilistic transition: Models library → IABM Textbook → chapter 3 → Fire extensions → Fire simple Extension 1
- Wind: Models library → IABM Textbook → chapter 3 → Fire extensions → Fire simple Extension 2
- Long distance transmission: Models library → IABM Textbook → chapter 3 → Fire extensions → Fire simple Extension 3

Genetic drift model

Models library → Sample models → Biology → Evolution → Genetic drift → GenDrift P global

Problem: The idea, explained in more detail in Dennett's "Darwin's Dangerous Idea", is that trait drifts can occur without any particular purpose or 'selecting pressure'.

Genetic drift extensions

- Local exchange: Models library → Sample models → Biology → Evolution → Genetic drift → GenDrift P local
- Local interaction: Models library → Sample models → Biology → Evolution → Genetic drift → GenDrift T interact
- Reproduction: Local interaction: Models library → Sample models → Biology → Evolution → Genetic drift → GenDrift T reproduce

Segregation models

Models library $\rightarrow$ IABM Textbook $\rightarrow$ chapter 3 $\rightarrow$ Segregation extensions $\rightarrow$ Segregation simple

Problem: "macro-behaviour" from "micro-preferences"

Segregation models extensions

- Multiple ethnicities: Models library → IABM Textbook → chapter 3 → Segregation extensions → Segregation simple Extension 1
- Diverse thresholds: Models library → IABM Textbook → chapter 3 → Segregation extensions → Segregation simple Extension 2
- Diversity seeking individuals: Models library → IABM Textbook → chapter 3→ Segregation extensions → Segregation simple Extension 3

Wolf sheep model

Models library $\rightarrow$ Biology $\rightarrow$ Wolf sheep predation

Problem: How do the population levels of two species change over time when they coexists in the shared habitat?

EBM – "Equation Based Modelling" – Lotka-Volterra differential equations, where x is the number of prey and y is the number of predators.

$$\frac{dx}{dt} = \alpha x - \beta xy$$

$$\frac{dy}{dt} = \delta xy - \gamma y$$

Flocking models

Models library → Biology → Flocking

Models library → Biology → Flocking Vee Formations

Problem: to mimic the flocking of birds
The birds follow three rules: alignment, separation, and cohesion.

- "Alignment" means that a bird tends to turn so that it is moving in the same direction that nearby birds are moving.
- "Separation" means that a bird will turn to avoid another bird which gets too close.
- "Cohesion" means that a bird will move towards other nearby birds (unless another bird is too close).