Simulation in the social sciences

Introduction

- What is simulation?
- The uses of simulation?
- History of simulation
- The special features of social simulation
- The stages of simulation-based research

Simulation in the social sciences

- References
  - Gilbert, N. and Troitzsch, K.G. (1999), *Simulation for the Social Scientist,* Buckingham, Philadelphia: Open University Press (http://www.uni-koblenz.de/~kgt/Learn/Textbook/Book.html)
  - Davidson, P. (2002), "Agent Based Social Simulation: A Computer Science View", *JASSS*, vol 5, n.1 (http://jasss.soc.surrey.ac.uk/5/1/7.html)
  - Goldspink, C. (2002), "Methodological Implications of Complex Systems Approaches to Sociality: Simulation as a Foundation for Knowledge", *JASSS*, vol 5, n.1 (http://jasss.soc.surrey.ac.uk/5/1/3.html)

Models

- There is some “real world” phenomenon which we are interested in. Example, the persistence of inflation in Turkey.
- If the “real world” phenomenon (“target”) is very complex, create a model which is simpler to study.
- A model is a simplification – smaller, less detailed, less complex of a system.
- If the model and the target are sufficiently similar, the conclusions drawn about the model will also apply to the target.

Models

- Model aeroplanes
- Statistical/econometric models
- Natural science models (DNA models)
- Analytical/mathematical models
- Computational models
  - CGE models, simulation models, etc.

Why simulate?

- Verbal descriptions
  - Easy, allow gaps and inconsistencies
- Mathematical descriptions
  - Difficult, precise, rigorous, homogeneous
- Computational models
  - Rigorous, allow complexity, allow experiments

Simulation as a paradigm

- Process analysis
  - Easy, allow not just at one moment in time
- Abstraction
  - Not descriptive
- Macro *and* micro
- Experimental

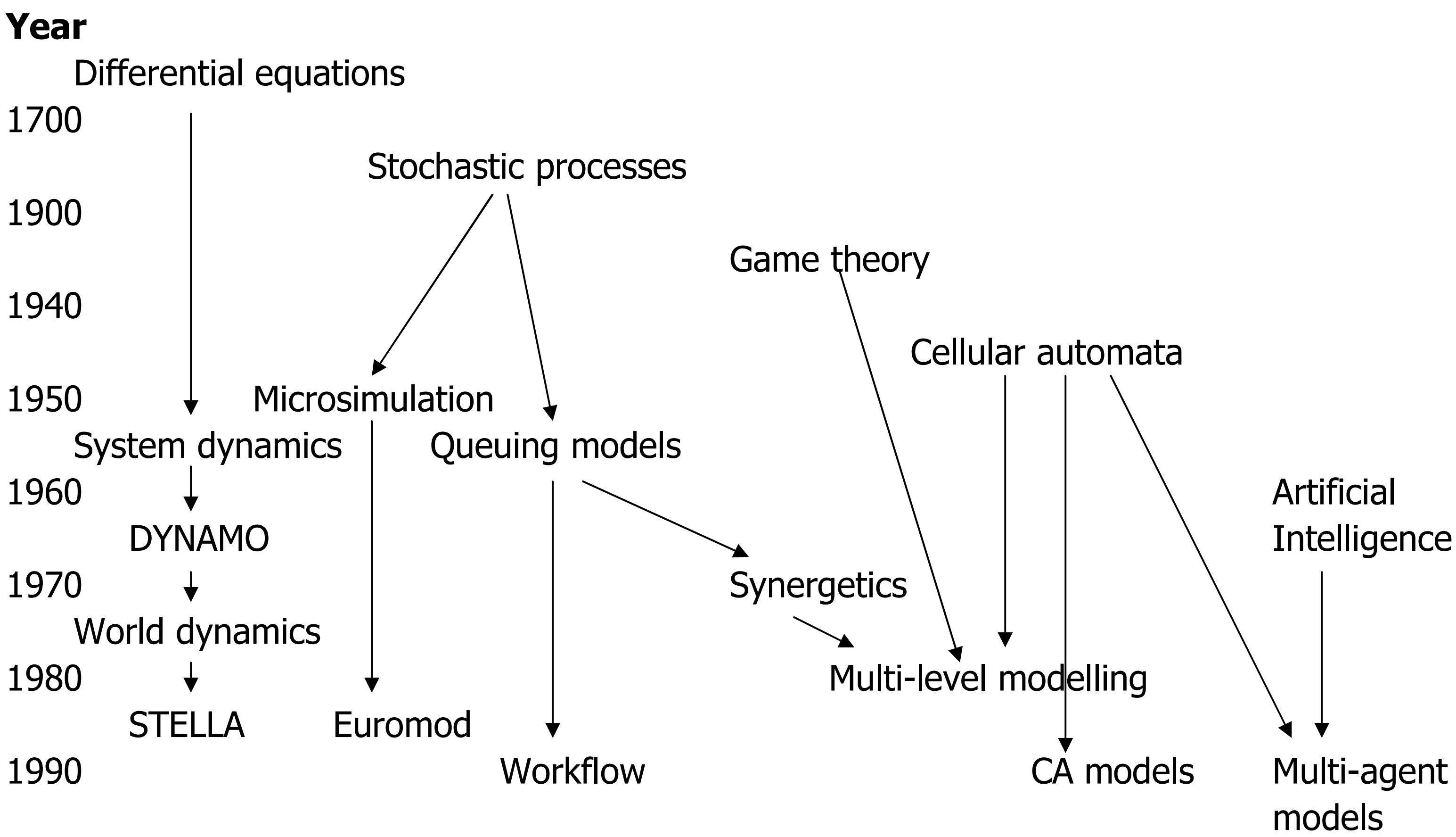
The uses of simulation

- Understanding
  - MOSES, the Model of the Swedish Economic System
- Prediction
  - DYNAMOD (National Center for Social and Economic Modelling)
- Tool
  - Expert systems to simulate the expertise of professionals

The uses of simulation

- Training
  - Flight simulator
- Entertainment
  - SimCity
- Formalisation
  - MANTA, formalization of theories on self-organization
- Discovery
  - Discover the consequences of theories in the “artificial society”, study the effectiveness of policies

History



Year
Differential equations
1700
Stochastic processes
1900
Game theory
1940
Cellular automata
1950
Microsimulation
System dynamics
Queuing models
1960
Artificial Intelligence
DYNAMO
1970
Synergetics
World dynamics
1980
Multi-level modelling
STELLA
Euromod
1990
Workflow
CA models
Multi-agent models

Social simulation: Special features

- Non-linearity
- Path-dependence
- Complexity
- Emergence
- Self-organization
- Bounded rationality

Non-linearity

- Linear models
  - Effect on a dependent variable is proportional to the sum of of a set of independent variables
- Non-linear
  - Chaotic, sensitive to initial conditions
  - The only generally effective way of exploring non-linear behavior is to simulate it by building a model and then running the simulation.

Path dependence

- Where the system evolves depends on its history: trajectories are important

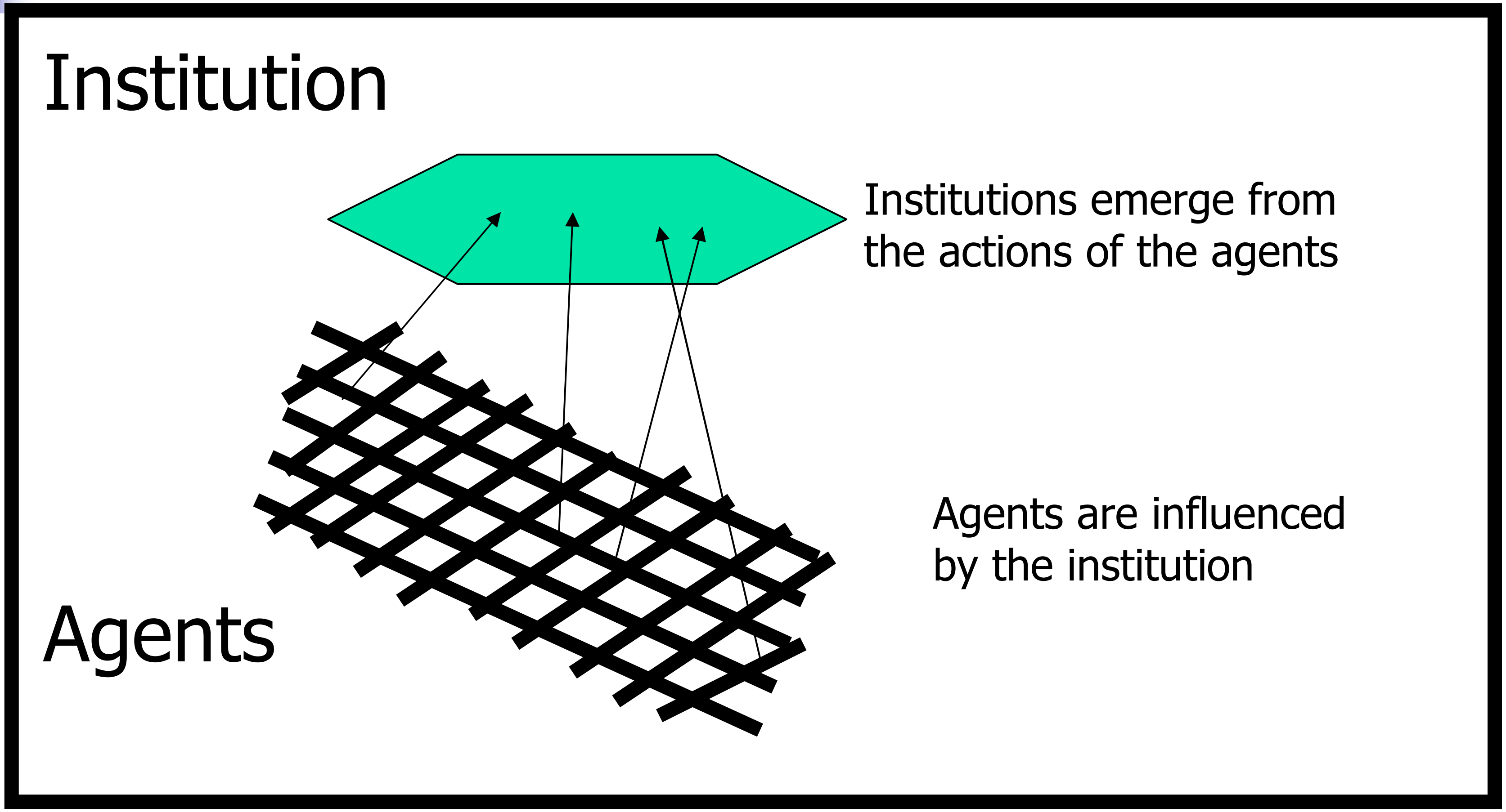
Complexity

- Simple behavior and simple rules can yield very complex organizations
  - Ants
  - Human organizations

Emergence

- A phenomenon is emergent if it requires new categories to describe it that are not required to describe the behavior of the underlying components
- Example: Temperature is an emergent property of the motion of atoms. An individual atom has no temperature, but a collection of them does.

Second-order emergence



Self-organization

- General organization that appears without central planning from the actions of individual agents
- An emergent property

Bounded rationality

- Herbert Simon (1954): Bounded rationality implies
  - Local information
  - Limited capacity to process information

Classification of simulation models

	Number of levels	Interaction between agents	Complexity of agents	Number of agents
System dynamics	1	No	Low	1
Microsimulation	2	No	High	Many
Multi-level simulation	2	No	Low	Many
Cellular automata	2	Yes	Low	Many
Distributed AI	2+	Yes	High	Few
Evolutionary models	2+	Yes	High	Many

Limits to simulation

- Repeatability and comparability
- Generalisability
- Prediction
  - Qualitative
  - Quantitative
- Data availability
- Validation

Stages of simulation-based research

- Pre-modelling
  - The “puzzle”
  - The objectives
- Modelling
  - Designing
  - Building
  - Verification
  - Calibration
  - Validation
  - Sensitivity analysis
- Reporting

The “puzzle”

- Identify a “puzzle”: A question whose answer is not known and which will be the aim of the research to resolve.

The objective

- What is the objective of using a simulation model?
  - Prediction or understanding?
  - Qualitative or quantitative prediction?
  - Etc.

Design

Every model is a simplification: Decide what needs to be left out and what needs to be included.

Abstract	The greater the conceptual leap Interpretation? General Extreme case: explain nothing
Detailed	Data requirements Many parameters: validity? Specific Extreme case: the reality itself

Building

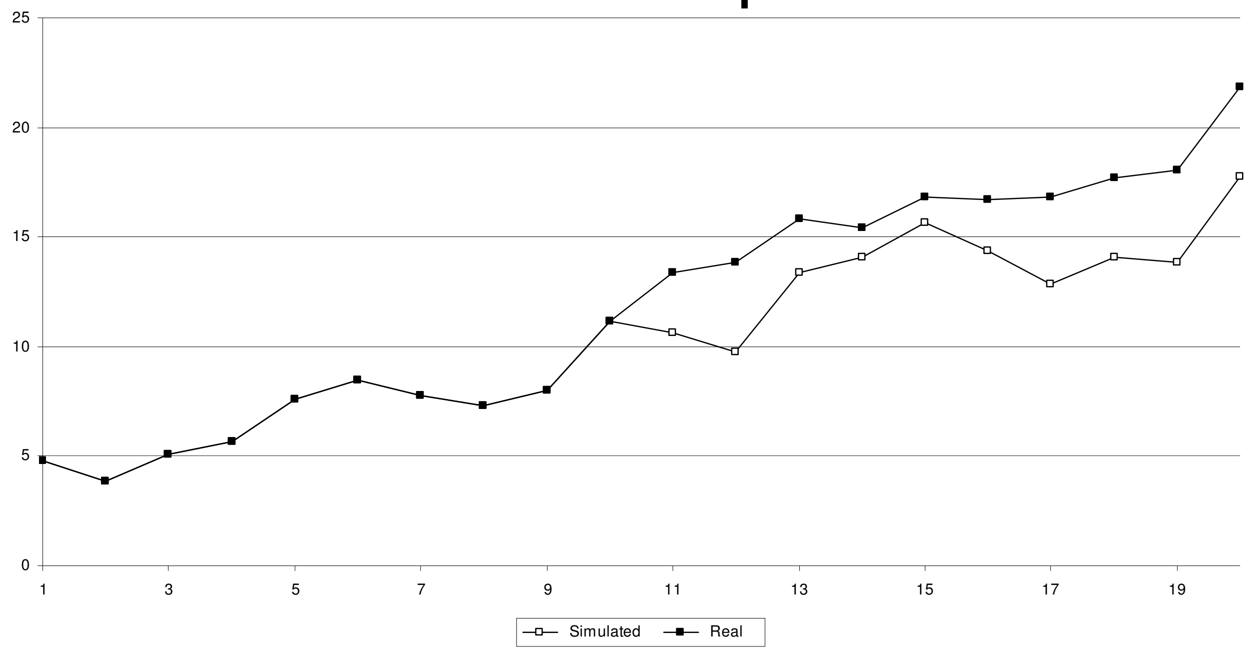
- Select a computer language/platform
  - Interpreted languages (Java, Lisp, APL, etc.) vs. compiled languages (C, C++, Pascal, etc.)
  - Package programs
- Structure
  - Agents, interactions, initial conditions, etc.

Verification

- Check that the the program does what it was planned to do.
- A difficult and time consuming, but very important task
- Use a modular structure
- Plan “test cases”

Calibration

- Select parameter values such that the simulation data will be as close as possible to the real data.



Validation

- Check if the simulation is a good model of the target.
- Compare the output of the simulation with the data collected from the target
  - Initial conditions
  - Parameter values
  - Stochastic processes
  - Data problems
- Are long run simulations "reasonable"?
- Are "emergent" behaviors/structures are "reasonable"?

Sensitivity analysis

Check if the simulation results are **sensitive** to

- Random effects
- Changes in initial conditions
- Changes in parameter values
- Changes in behavioral specifications

Reporting

- The reader should be ables understand the social science aspects of the research
- The reader should be able to replicate the simulation