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School of Business Informatics
and Mathematics

Agent-Based Modeling for Social Simulations

CS 704: Social Simulation Seminar

Session I

April 2, 2020

Kilian Theil

Prof. Heiner Stuckenschmidt

UNIVERSITY OF MANNHEIM
School of Business Informatics and Mathematics

Intro

Organization

- Course website:
  - University of Mannheim → Data and Web Science Group → Teaching → Course Details → Courses for Master Candidates
  - https://www.uni-mannheim.de/dws/teaching/course-details/courses-for-master-candidates/cs-704-social-simulation-seminar/

Heiner

- Prof. Heiner Stuckenschmidt
- Chair of Artificial Intelligence
- Co-head of the Data and Web Science Group
- Focus:
  - Standard & non-standard reasoning
  - Applications of AI in various domains (web data integration & management, semantic web, ontology management, …)

Kilian

- M.Sc. Kilian Theil
- 3rd-year PhD student w/ Heiner
- Focus
  - Ethical implications of smart cities
  - Textual analysis for behavioral economics

Outline

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Date	Time	Title	Room
02/04/20	12:00–13:30	Agent-Based Modelling (ABM) for Social Simulations	online
09/04/20	12:00–13:30	ABM in NetLogo	online
tba	tba	Paper Presentations by Students	online
tba	tba	Project Presentations by Students	online

Grading

- **50%** for an individual **presentation** of a recent research paper
  - Deliverables: presentation (15min + 5min Q&A)
- **50%** for a **practical group project** presenting an own simulation model implemented in NetLogo
  - Groups of ca. 3–5 people (given the seminar size: one or two groups in total)
  - Deliverables: presentation (25min + 10min Q&A), 10-page report, code
  - Grade will be given based on the report

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Papers for Presentations (1/3)

- Baeza, A., & Janssen, M. A. (2018). **Modeling the Decline of Labor-Sharing in the Semi-Desert Region of Chile.** Regional Environmental Change, 18(4), 1161-1172. [PDF]
- Birks, D., & Davies, T. (2017). **Street Network Structure and Crime Risk: An Agent-Based Investigation of the Encounter and Enclosure Hypotheses.** Criminology, 55(4), 900-937. [PDF]
- El Hachami, K., & Tkiouat, M. (2018, April). **An Approach for Modeling the Economy as a Complex System Using Agent-Based Theory.** In Intelligent Systems and Computer Vision (ISCV), 2018 International Conference on (pp. 1-6). IEEE. [PDF]
- García-Magariño, I., Lombas, A. S., Plaza, I., & Medrano, C. (2017). **ABS-SOCI: An Agent-Based Simulator of Student Sociograms.** Applied Sciences, 7(11), 1126. [PDF]
- Hébert, G. A., Perez, L., & Harati, S. (2018). **An Agent-Based Model to Identify Migration Pathways of Refugees: The Case of Syria.** In Agent-Based Models and Complexity Science in the Age of Geospatial Big Data (pp. 45-58). Springer, Cham. [PDF]

Papers for Presentations (2/3)

- Kowalska-Pyzalska, A. (2017). **Willingess to Pay for Green Energy: An Agent-Based Model in NetLogo Platform.** 2017 14th International Conference on the European Energy Market (EEM). [HTML]
- Lemos, C. M. (2018). **ABM of Civil Violence: ODD Description.** In Agent-Based Modeling of Social Conflict (pp. 51-63). Springer, Cham. [HTML]
- Malik, A., & Abdalla, R. (2017). **Agent-Based Modelling for Urban Sprawl in the Region of Waterloo, Ontario, Canada.** Modeling Earth Systems and Environment, 3(1), 7. [PDF]
- Muhammad, A., Kashif, Z., & Saini, D. (2018). **Agent-Based Simulation of Socially-Inspired Model of Resistance Against Unpopular Norms** Proceedings of the 10th International Conference on Agents and Artificial Intelligence (ICAART 2018) - Volume 1, pages 133-139. [PDF]
- Ponziani, F., Tinaburri, A., & Ricci, V. (2018). **A Multi Agent Approach to Analyse Shift in People Behaviour Under Critical Conditions.** International Journal of Safety and Security Engineering, 8(1), 1-9. [PDF]

Papers for Presentations (3/3)

- Putra, H. C., Andrews, C. J., & Senick, J. A. (2017) **An Agent-Based Model of Building Occupant Behavior During Load Shedding.** In Building Simulation (pp. 1-15). Tsinghua University Press. [PDF]
- Rai, S., Carter, T., & Sharma, B. (2019). **Using NetLogo to Simulate Building Occupancy of a University Building.** ASEE 2019 Annual Conference. [PDF]
- Scott, N., Livingston, M., Hart, A., Wilson, J., Moore, D., & Dietze, P. (2016). **SimDrink: An Agent-Based NetLogo Model of Young, Heavy Drinkers for Conducting Alcohol Policy Experiments.** Journal of Artificial Societies and Social Simulation, 19(1). [HTML]
- Sturley, C., Newing, A., & Heppenstall, A. (2018). **Evaluating the Potential of Agent-Based Modelling to Capture Consumer Grocery Retail Store Choice Behaviours.** The Ionternatinal Review of Retail, Distribution and Consumer Research, 28(1), 27-46. [HTML]
- Thuy An Vo, T., van der Waerden, P. J. H. J., & Wets, G. (2016). **Micro-Simulation of Car Drivers’ Movements at Parking Lots.** Procedia Engineering, 142, 100-107. [HTML]

Preliminary Topics for Practical Projects

- Influence of scarce parking space on illegal parking
- Tickets and their effect on long-term parking behavior
- Parking behavior under dynamic pricing

→ The final scenario will be discussed in the second session.

Social Simulation

Computational Scientific Methods

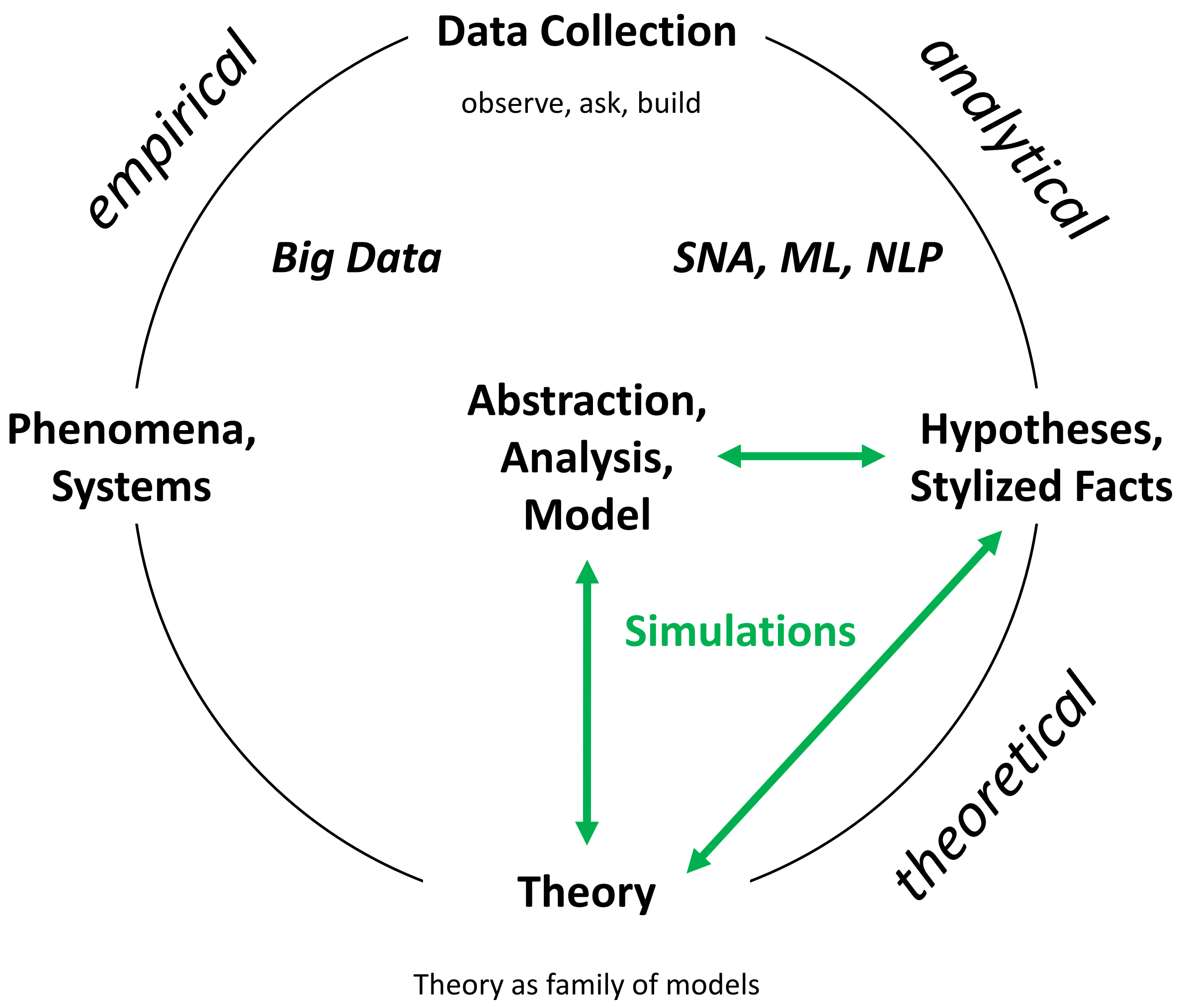


Figure taken from: Martin Hilbert (2018) "UCCSS ABM1 Agent-Based Modeling Introduction"

Modeling as Mapping

"What do you consider the largest map that would be really useful?"

"About six inches to the mile."

"Only six inches!," exclaimed Mein Herr. "We very soon got to six yards to the mile. Then we tried a hundred yards to the mile. And then came the grandest idea of all! We actually made a map of the country, on the scale of a mile to the mile!"

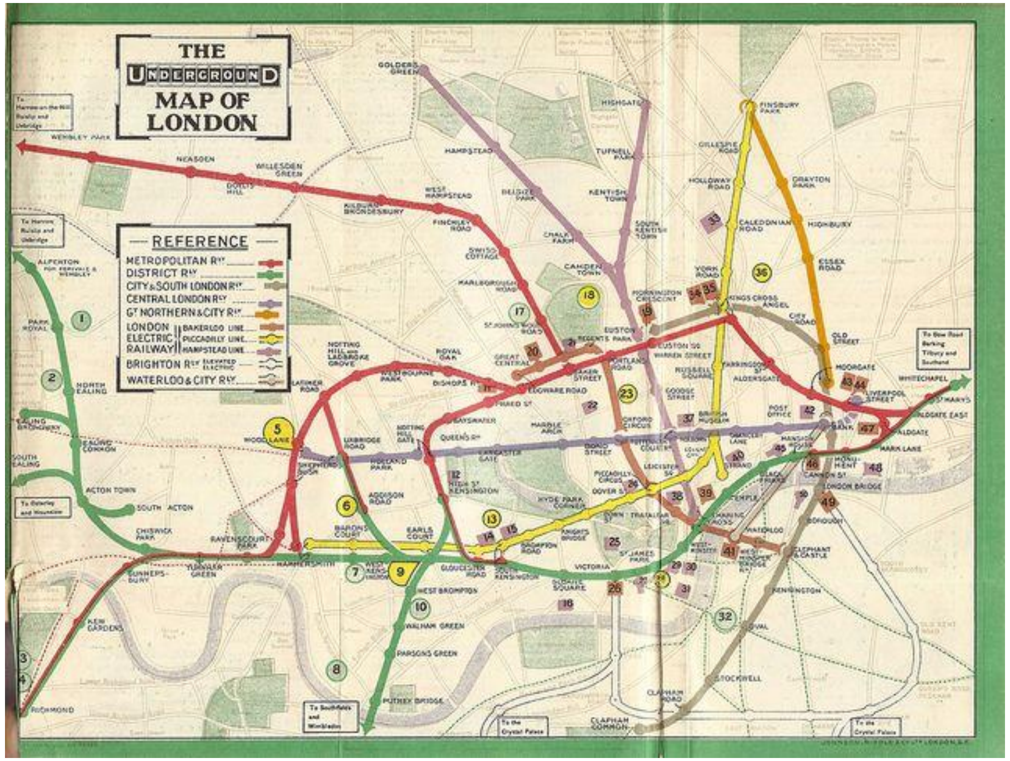
"Have you used it much?," I enquired.

"It has never been spread, out, yet," said Main Herr. "The farmers objected: They said it would cover the whole country, and shut out the sunlight! So we now use the country itself, as its own map, and I assure you it does nearly as well."

Source: Lewis Carroll (1833) "Sylvie and Bruno Concluded"

Example taken from: Martin Hilbert (2018) "UCCSS ABM1 Agent-Based Modeling Introduction"

The London Underground



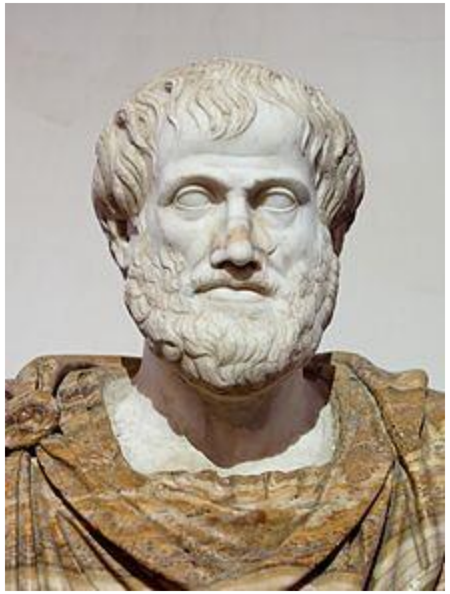
1911

1933

Systems

- Greek σύστημα *(systēma)*
  - "whole concept composed of several parts"
  - i.e. a group of interacting/interrelated entities forming a whole
- Types
  - Natural systems
    - Solar systems, living systems, …
  - Artificial systems
    - Cultural systems, social systems, …

Emergence



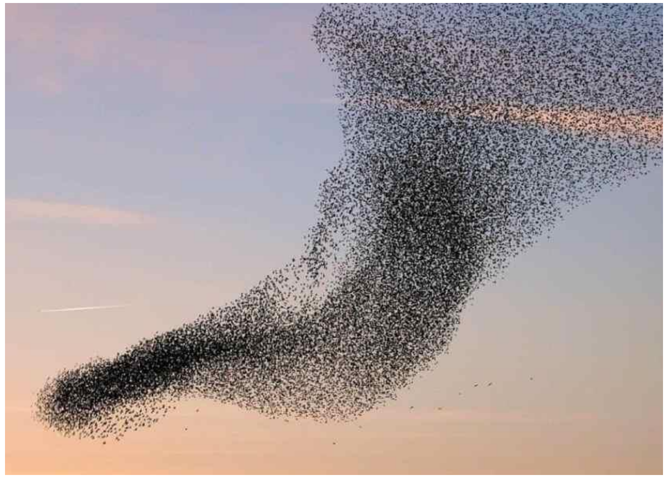
Aristotle
(384–322 BC)

“The whole is greater than the sum of its parts.”

≈ systems have properties that their parts do not have

Examples of Emergence

Termite “cathedral”



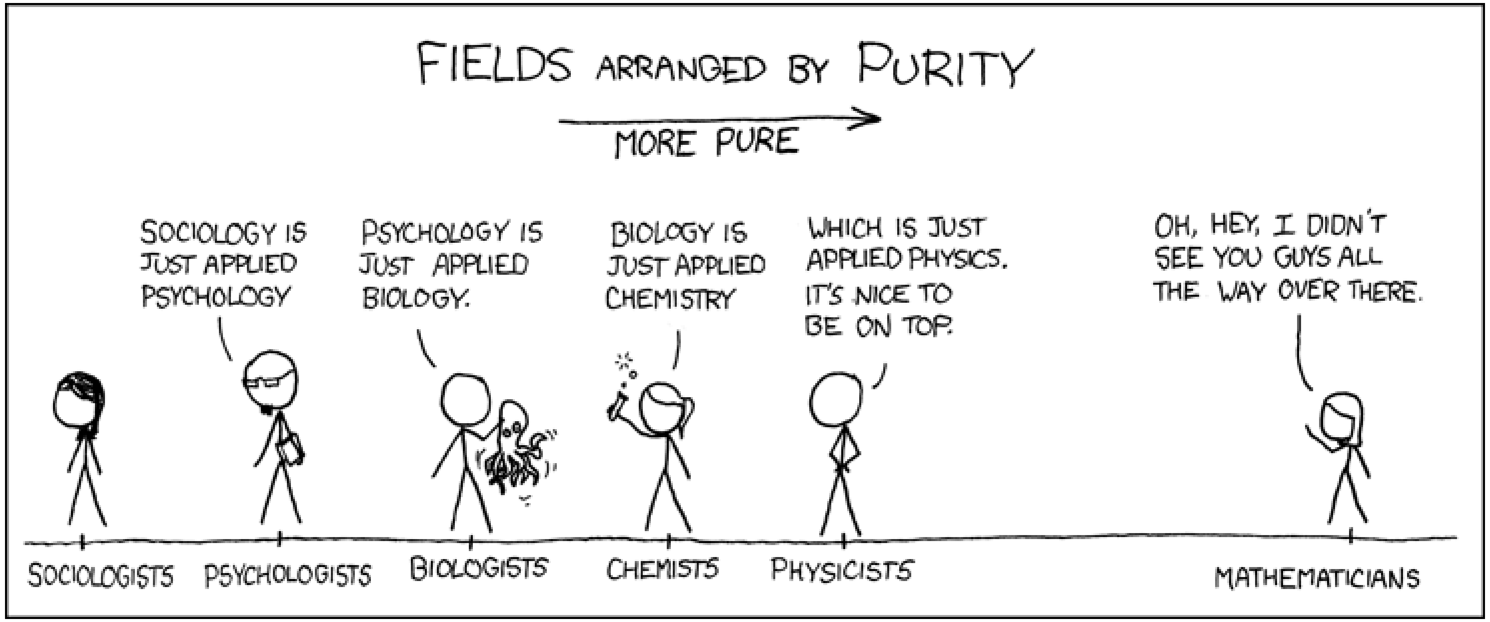
Bird flock

Football match

Romanesco

Urban traffic

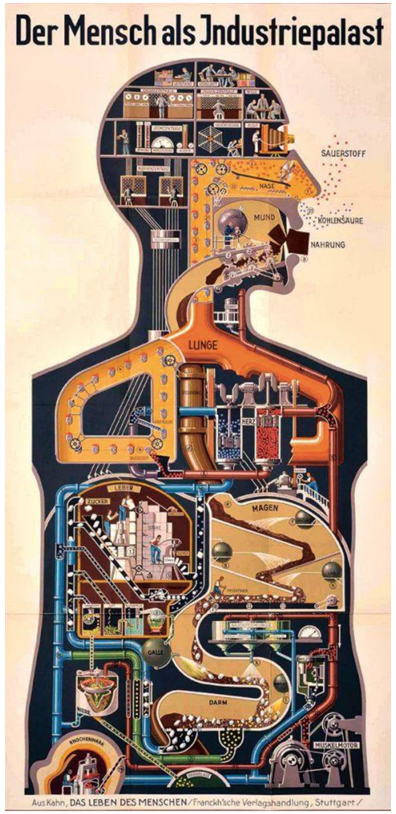
Emergence in the Sciences



Source: https://xkcd.com/435/

What might be the problem with this (satirical) view?

Reductionism



Fritz Kahn (1926)

- **Systems** are **determined by** their **components**
- Lawlike relationships can be reduced to causal-deterministic events
  - One cause has exactly one effect (***monocausalism***)
- All worldly phenomena can – in theory – be explained by microphyscis

Holism

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- Greek ὅλος (*holos*) = “all, whole, entire”
- **Systems** should be viewed **as wholes**, not collections of their parts
- **Component parts** are best understood in context and **in relation to one another**
- Example
  - Detailed understanding of individual behavior does not help to predict group behavior (emerges at collective-level)

Complexity Theory

- Complexity Theory serves as conceptual **basis for** the **analysis of** configurations and **complex causal conditions** (Brenes et al. 2017)
- **Tipping point** is a useful principle to think in complexity theory terms (Gladwell 2000, Urry 2005)
  - When a system passes a particular threshold, a switch can occur
  - E.g. quick spread of an epidemic (Corona virus)

Tenets of Complex Systems

- Non-linearity
- Path-dependence
  - Sensitivity to initial conditions
- System history
  - Importance of small historical events
- Emergence
  - Macroscopic phenomena not perceivable on a microscopic scale
- Irreducibility
  - Higher-level entities are not merely aggregated but holistic
- Adaptivity
- Self-organization
- Order ↔ Chaos

— Turner & Baker (2019)

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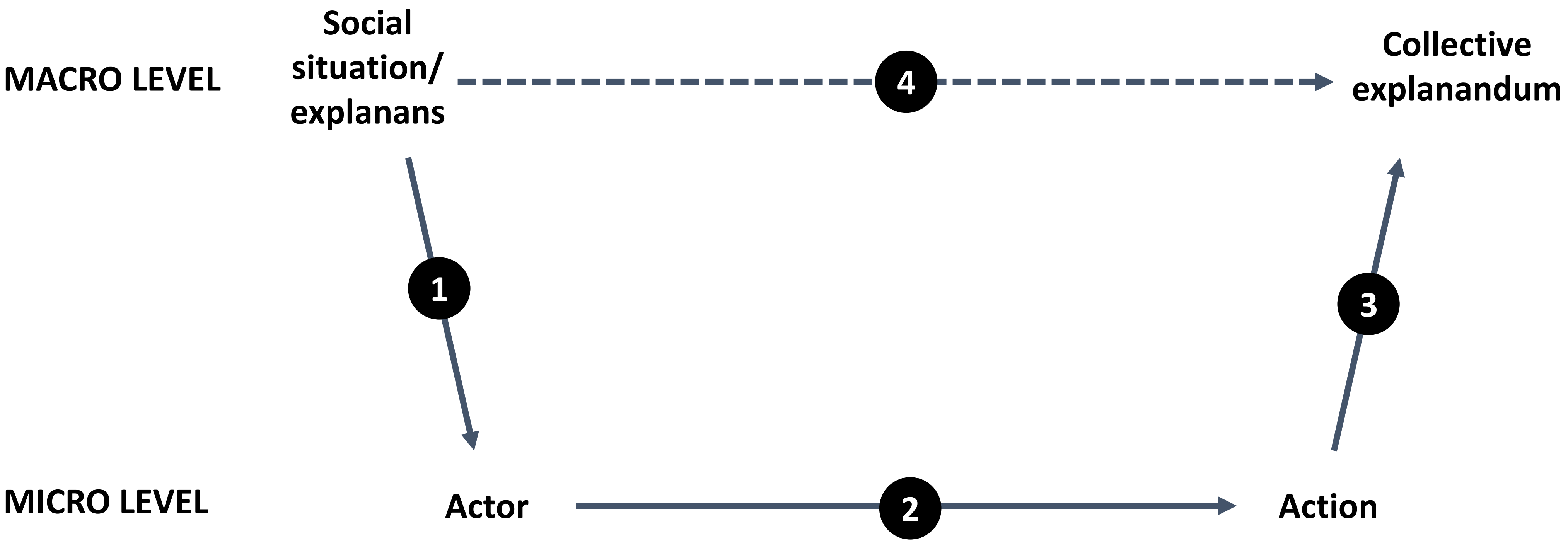
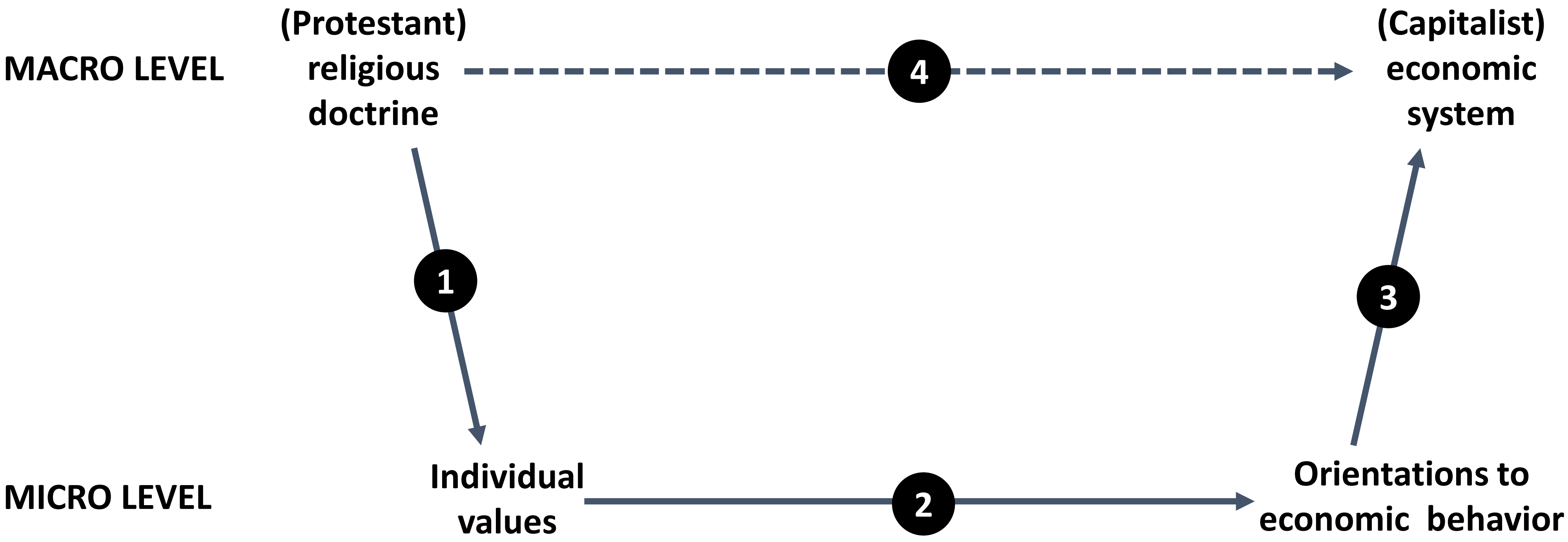
Coleman's Boat



Source: James Coleman (1990): "Foundations of Social Theory", p. 702

Figure adapted from: Hartmut Esser (1999): "Soziologie: Allgemeine Grundlagen", p. 98

Coleman’s Boat Applied



Coleman’s interpretation of the micro-level linkages of Max Weber’s thesis in “The Protestant Ethic and the Spirit of Capitalism”

Social Simulation

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- **Model social processes/mechanisms/behaviors computationally** (Davidsson 2002, Gilbert & Conte 2006)
- Targets problems in sociology, psychology, political science, economics, anthropology, linguistics, … (Takahashi et al. 2007, p. 354)
- Aims to **cross** the gap between **descriptivism** used in social sciences **& formalism** used in natural sciences by focusing on the processes/mechanisms/behaviors constructing social reality
- Simulates societies as complex non-linear systems which are difficult to study with mathematical equation-based models

Agent-Based Modeling (ABM)

- **Agent-based modelling**: autonomous decision-makers (“**agents**”) recursively **compete via** predefined behavioral patterns (“**rules**”)
  - Model complex social systems such as traffic behavior (Helbing 2013)
- Bottom-up design
- Individual behavior may affect the entire collective & vice versa
  - **Emergence**: systems may have properties which their parts don’t have on their own

ABM as Complement for (Social) Science?

- ABM is a “third way of doing science” in addition to induction & deduction (Axelrod, 2003)
- ABM’s ability to grow artificial societies holds the prospect of a new “generative” kind of social science (Epstein, 2006)
- “[U]nsuitability of competing modeling formalisms to address the problem of social science, agents as a **natural ontology for** many social problems, and emergence” (Bankes, 2002)
- ABM not only helps to determine the implications of theory (strengths, inconsistencies, deficiencies) but also to provide a basis for obtaining **causal explanations of** modelled **phenomena** (Macal, 2016)

To build an ABM, one has to define …

- A **macro-social outcome** of interest to explain
  - e.g. population level of inequality (e.g. as measured by the Gini coefficient), employment rates, or the ratio of number of street bumps between neighborhoods of different types
- Types and number of **agents**
  - e.g. deciders and affected individuals (such as employment service employees and job seekers) including their relevant characteristics (e.g. socio-economic status, gender)
- **Condition-action rules** defining the actions an agent will perform given specific conditions
  - e.g. that an individual presented with a low employability skill will or will not intensify independent job search depending on their educational attainment), showing how the environment can affect the agent and vice versa
- Properties of the **environment**
  - e.g. topographical characteristics (streets, income levels in different locations, or social network structures)
- **Time**, i.e. the (non)simultaneity in the sequence of different agents' actions

Source: Gilbert, N. (2008) "Agent-Based Models."

Analyzing an ABM

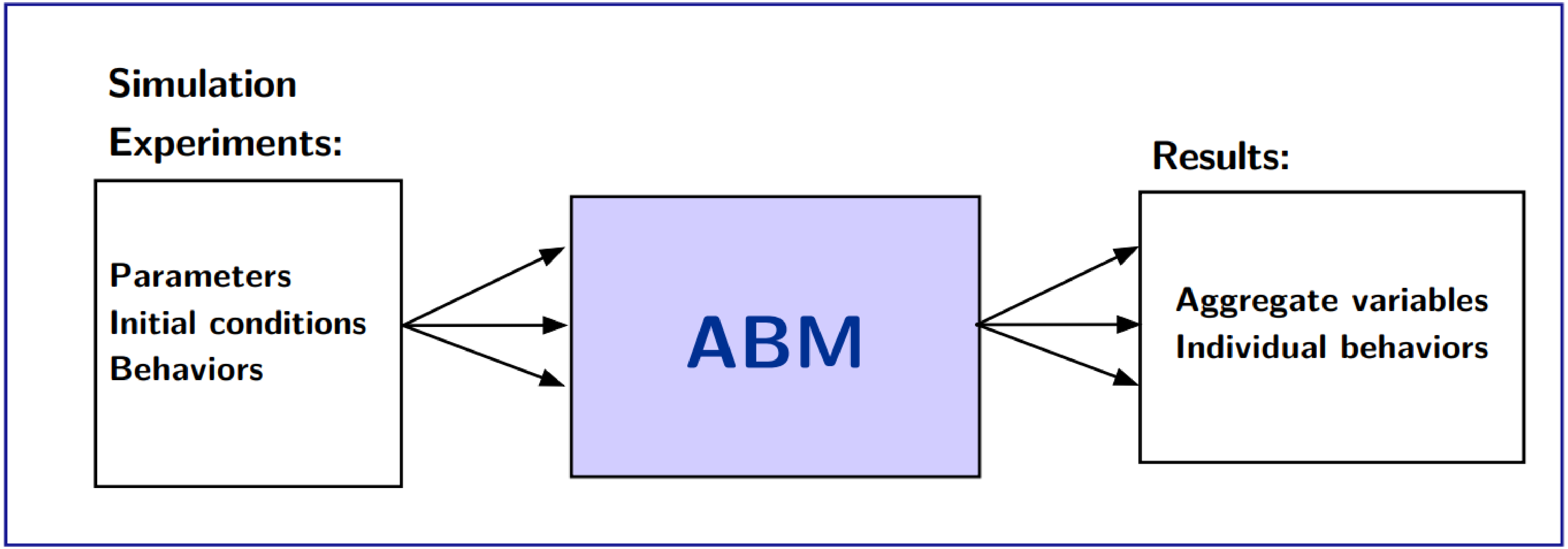


Figure taken from: Murat Yıldızoğlu (2015). "Pre-conference workshop on Agent-based Models in Economics and Finance. Chapter 1 – Introduction: Economy as a complex adaptive system (CAS)", p. 4.

Examples of ABM

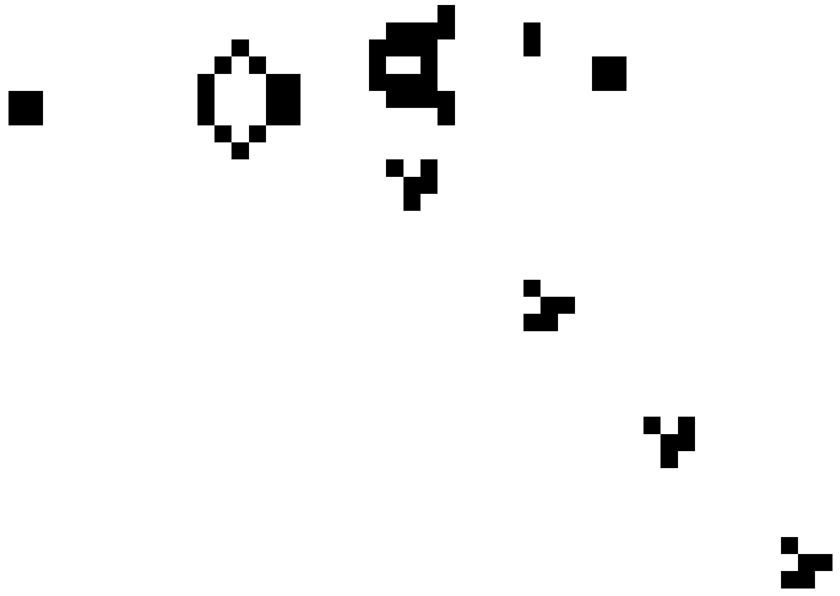
Conway‘s Game of Life

- **Cellular automaton** devised by John H. Conway in 1970
- World = 2-dimensional grid of cells (i.e. the agents)
- Cells can be either **alive** (on) **or dead** (off)
- 4 simple rules determine if a cell will live/die in the next generation

4 Rules of Life

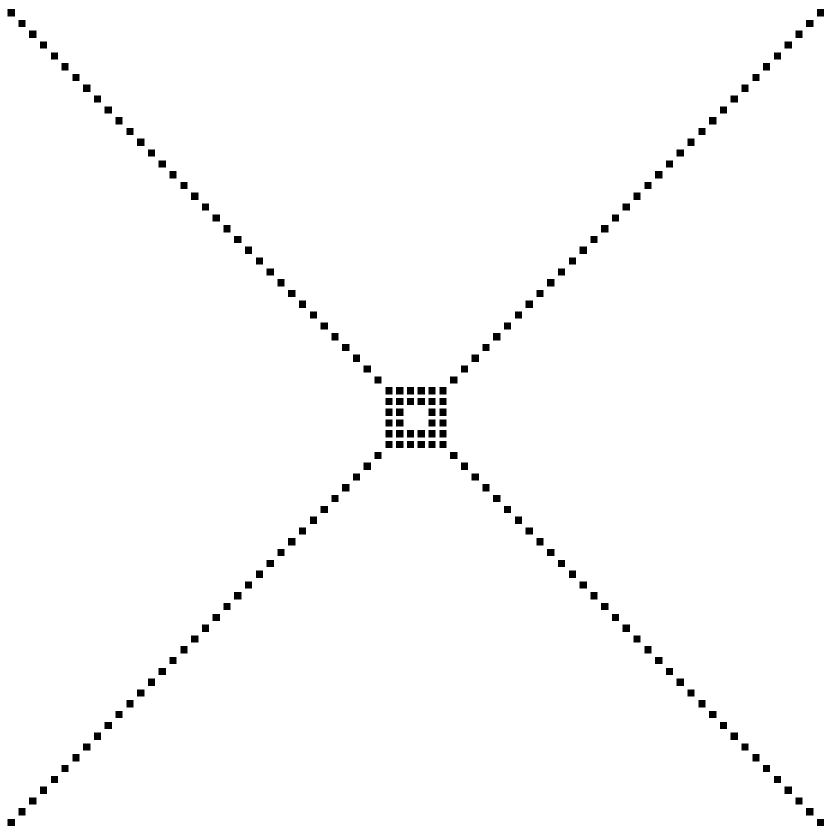
1. **Birth**: Dead cells with three alive neighbors live
2. **Isolation**: Alive cells with ≤ 1 living neighbor die
3. **Overcrowding**: Alive cells with ≥ 4 living neighbors die
4. **Survival**: Alive cells with 2 or 3 alive neighbors will live

Sample Pattern # 1

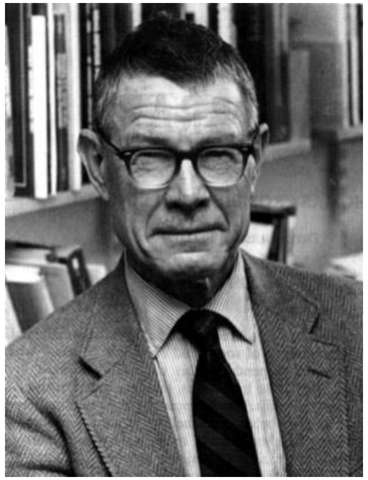


"Gosper's Glider Gun"

Sample Pattern # 2



Schelling's Segregation Model (1971)



Thomas C. Schelling
(1921–2016)

- ABM of social **segregation dynamics**
- Originally non-computational
- Macal (2016): How can individuals acting according to micro-level rules of social behavior/interaction produce emergent patterns at a macro-level that are:
  - unexpected
  - not easily predictable
  - not solvable by analytical means

The Agents

- Two types of agents: red and blue
  - Randomly located on a grid of cells (chessboard)
  - Cells can also be empty, depending on a density parameter *d*
- Agents can be **happy or unhappy**, depending on a **%-similar-wanted** parameter *s* and their adjacent neighbors

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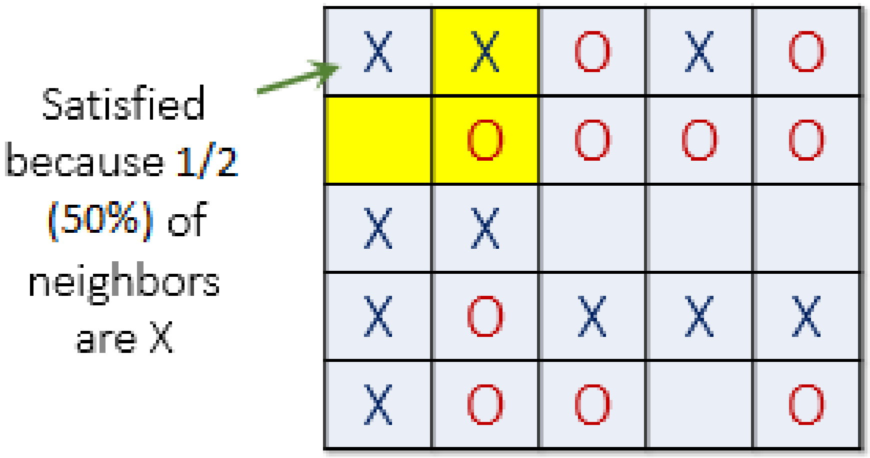
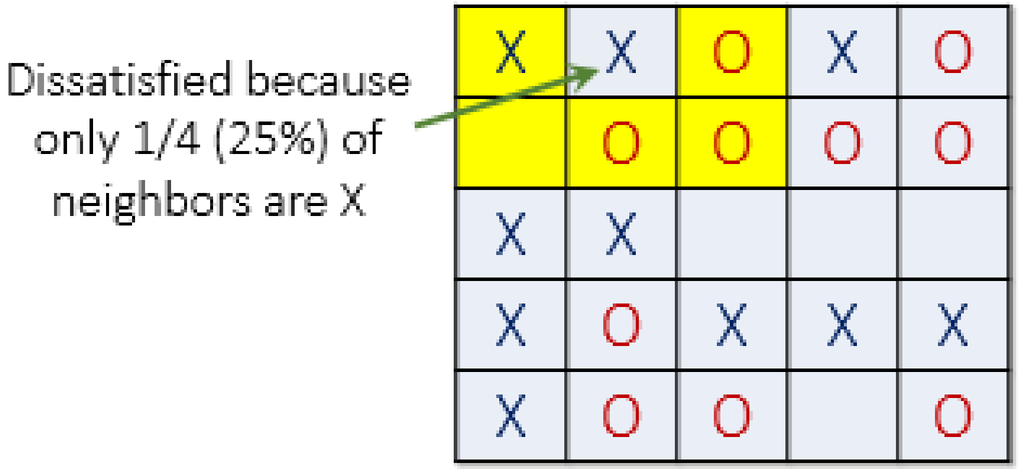
Rules of Satisfaction

- Lets assume *s* = 30%





Figures taken from: Frank McCown "Schelling's Model of Simulation"
[*http://nifty.stanford.edu/2014/mccown-schelling-model-segregation/*](http://nifty.stanford.edu/2014/mccown-schelling-model-segregation/)

Rules of Movement

- When an agent is not satisfied, it can be moved to any vacant location in the grid
- Any algorithm can be used to choose this new location
  - For example, a randomly selected cell may be chosen, or the agent could move to the nearest available location.
- In the NetLogo implementation, unsatisfied agents turn around by a random number of degrees (1 to 360) & move 1 to 10 steps forward, until they find an empty spot
  - i.e. they move locally

NetLogo Implementation

- Wilensky, U. (1997): “NetLogo Segregation model.” http://ccl.northwestern.edu/netlogo/models/Segregation. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Try Out the Model in NetLogo

- Install the NetLogo version suitable for your system: https://ccl.northwestern.edu/netlogo/download.shtml
- Load the model under “File” -> “Models Library” -> “Social Science” -> “Segregation”
- Click “Setup” to initialize the model with the current parameters
- Click “Go” to run the model until it converges / “Go once” to run it for one step
- Try moving the “%-similar-wanted” slider and see how it affects the results
  - Tipping points seem to occur when moving the slider from 26% to 25% and from 75% to 76%

Summary

- The whole is more than the sum of it parts
  - e.g. “intolerance can lead to diversity“ (please don‘t take this literally!)
  - @holism, @emergence
- Dependence on initial conditions
  - Single runs depend highly on parameters (*d*, *s*) and randomness
- Invariant distribution of equilibria
  - Repeated runs lead to converging distributions of outcomes
- Phase transitions
  - Be aware of modelling assumptions
  - @tipping point

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Further Reading

- Davidsson, Paul (2002). Agent Based Social Simulation: A Computer Science View, *Journal of Artificial Societies and Social Simulation* 5(1).
- Macal, C. M. (2016). “Everything you need to know about agent-based modelling and simulation.” In: *Journal of Simulation* 10.
- Resch, Michael M.; Kaminski, Andreas; Gehring, Petra (eds.) (2017). “The Science and Art of Simulation I. Exploring – Understanding – Knowing.” Cham: Springer.
- Turner, J. R., & Baker, R. M. (2019). “Complexity Theory: An Overview with Potential Applications for the Social Sciences.” *Systems* 7(1).

Sources (1/2)

- Axelrod, R (2003). “Advancing the Art of Simulation in the Social Sciences.” *Japanese Journal for Management Information Systems* 12(3).
- Bankes, S. C. (2002). “Agent-Based Modeling: A Revolution?” *Proceedings of the National Academy of Sciences* 99 (3).
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- Gilbert, Nigel (2008): “Agent-Based Models.” Los Angeles: Sage.

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Sources (2/2)

- Gladwell, Malcolm (2000): “The Tipping Point. How Little Things Can Make a Big Difference.” Little, Brown and Company.
- Helbing, Dirk (2013). “Verkehrsdynamik: Neue physikalische Modellierungskonzepte.” Berlin: Springer.
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- Urry, John (2005): “The Complexity Turn.” In: *Theory, Culture & Society* 22(5).
- Weber, Max (1905): “Die Protestantische Ethik und der ‘Geist’ des Kapitalismus.” In: *Archiv für Sozialwissenschaft und Sozialpolitik* 21.