

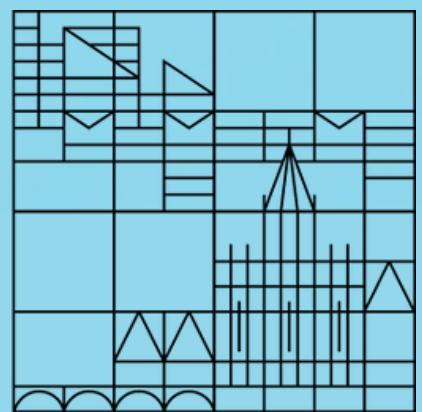
The Basics of Agent-Based Modeling

Computational Modelling of
Social Systems

Giordano De Marzo
Max Pellert



Universität
Konstanz



About Me

- Postdoc at the Political Science department, University of Konstanz
- Junior Research Fellow at Complexity Science Hub Vienna
- Consultant for UN-ILO
- PhD in Physics at Sapienza University (Rome) and Enrico Fermi Research Center
- MSc and BSc in Theoretical Physics at Sapienza University (Rome)



View from my room at Enrico Fermi Research Center

About Me

- Complex Digital Systems
- Social Networks
- Recommendation Algorithms
- Economic Complexity
- Artificial Neural Networks
- Large Language Models

email: giordano.de-marzo@uni-konstanz.de

website: giordano-demarzo.github.io

twitter: @GiordanoMarzo



*View from my room at Enrico
Fermi Research Center*

About Prof. Max Pellert

- Professor for Social and Behavioural Data Science (interim, W2) at the University of Konstanz
- Assistant Professor (Business School of the University of Mannheim)
- Worked in industry at SONY CSL in Rome, Italy
- PhD from the CSHVienna and the Medical University of Vienna in Computational Social Science
- Studies in Psychology and History and Philosophy of Science
- MSc in Cognitive Science and BSc in Economics (both University of Vienna)



About Prof. Max Pellert

Research interests:

- Computational Social Science
- Digital traces
- Affective expression in text
- Natural Language Processing
- Collective emotions
- Belief updating
- Psychometrics of AI

email: max.pellert@uni-konstanz.de

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twitter: @maxp_e



Outline

1. About this Course
2. Complex Social Behavior
3. Agent-Based Modelling (ABM)
4. ABM Example: Date Choice Model



About this Course

Course Objectives

Upon the completion of this course, students will be familiar with the following:

- Various approaches to **model social interactions** to bring the micro-macro gap
- General principles of **agent-based** modelling and **network** modelling
- The analytical approach to formalization, simulation, and analysis of **computational models**
- The role of empirical data in the **calibration** and **validation** of computational models
- The **limitations** and **applications** of computational modelling in the social sciences

Course Format

This course is structures in three different parts:

- 9 Theoretical seminars covering the basics of Agent Based Modeling and of Network Theory
- 5 Coding sessions with prof. Max Pellert
- 4 or 5 Students seminars sessions (depending on number of students)

The coding sessions are optional but strongly recommended!
The first coding session will be tomorrow.

Course Assessment

Students select a published article from a set of readings to present in the second part and to write a review of the article as final report.

The course grade is based on:

- the student **presentation** (50%)
- **participation** in discussions after each presentation (20%)
- and on the **report** (30%)

Coding is not necessary but reimplementing a model from a paper is a great start to present it. This is not a required step: some models might be too complicated or require unavailable data.

Suggested Papers for Exam

- You can check
<https://giordano-demarzo.github.io/teaching/computational-modeling/>
for article suggestions
- Choose by email to me and Prof. Pellert by 15/06.
- You can find your own paper too, but email me and Prof. Pellert for confirmation in advance.
- No paper can be presented by two students: First-come first-served.
- Your presentation date will be chosen at random and announced next week.
- Date swaps are allowed by agreement of both students.

Course Dates

April 9, 2024-The Basics of Agent-Based Modeling

April 16, 2024-Modelling segregation: Schelling's model

April 23, 2024-Modelling cultures: Axelrod's model

April 30, 2024-Basics of spreading: Granovetter's threshold model

May 7, 2024-Opinion dynamics

May 14, 2024-Modelling small worlds

May 21, 2024-Scale-free networks

June 4, 2024-Resilience in social networks

June 11, 2024 (?)-Growth processes and spreading in networks

Students Seminars following

Course Dates

X Wed	May 1, 2024	5:00 PM - 6:30 PM		⚠ Tag der Arbeit
Tue	May 7, 2024	3:15 PM - 4:45 PM	C424	
Wed	May 8, 2024	5:00 PM - 6:30 PM	D433	
Tue	May 14, 2024	3:15 PM - 4:45 PM	C424	
Wed	May 15, 2024	5:00 PM - 6:30 PM	D433	
Tue	May 21, 2024	3:15 PM - 4:45 PM	C424	
Wed	May 22, 2024	5:00 PM - 6:30 PM	D433	
X Tue	May 28, 2024	3:15 PM - 4:45 PM		⚠ Vorlesungsfreie Zeit
X Wed	May 29, 2024	5:00 PM - 6:30 PM		⚠ Vorlesungsfreie Zeit
Tue	Jun 4, 2024	3:15 PM - 4:45 PM	C424	
Wed	Jun 5, 2024	5:00 PM - 6:30 PM	D433	
Tue	Jun 11, 2024	3:15 PM - 4:45 PM	C424	
Wed	Jun 12, 2024	5:00 PM - 6:30 PM	D433	
Tue	Jun 18, 2024	3:15 PM - 4:45 PM	C424	
Wed	Jun 19, 2024	5:00 PM - 6:30 PM	D433	
Tue	Jun 25, 2024	3:15 PM - 4:45 PM	C424	
Wed	Jun 26, 2024	5:00 PM - 6:30 PM	D433	
Tue	Jul 2, 2024	3:15 PM - 4:45 PM	C424	
Wed	Jul 3, 2024	5:00 PM - 6:30 PM	D433	
Tue	Jul 9, 2024	3:15 PM - 4:45 PM	C424	
Wed	Jul 10, 2024	5:00 PM - 6:30 PM	D433	
Tue	Jul 16, 2024	3:15 PM - 4:45 PM	C424	
Wed	Jul 17, 2024	5:00 PM - 6:30 PM	D433	

Possible date
for seminar →

Not sure I'll
make this →

Back to
Konstanz →

Period for
student seminars

Logistic Questions

- You can check
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for article suggestions
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A complex social network graph is displayed against a light blue background. The graph consists of numerous small, semi-transparent grey dots representing individuals or entities, connected by thin white lines representing interactions or relationships. The connections form a dense web of triangles and larger clusters, indicating interconnectedness. The overall structure is organic and sprawling, symbolizing the complexity of social behavior.

Complex Social Behavior

Bank Runs Financial Crisis



Micro-Level

A single person can not cause a bank run or a financial crisis.

Macro-Level

If customers believe that many others withdraw their money the rumor and spreading distrust creates a bank run (tragedy of the commons).

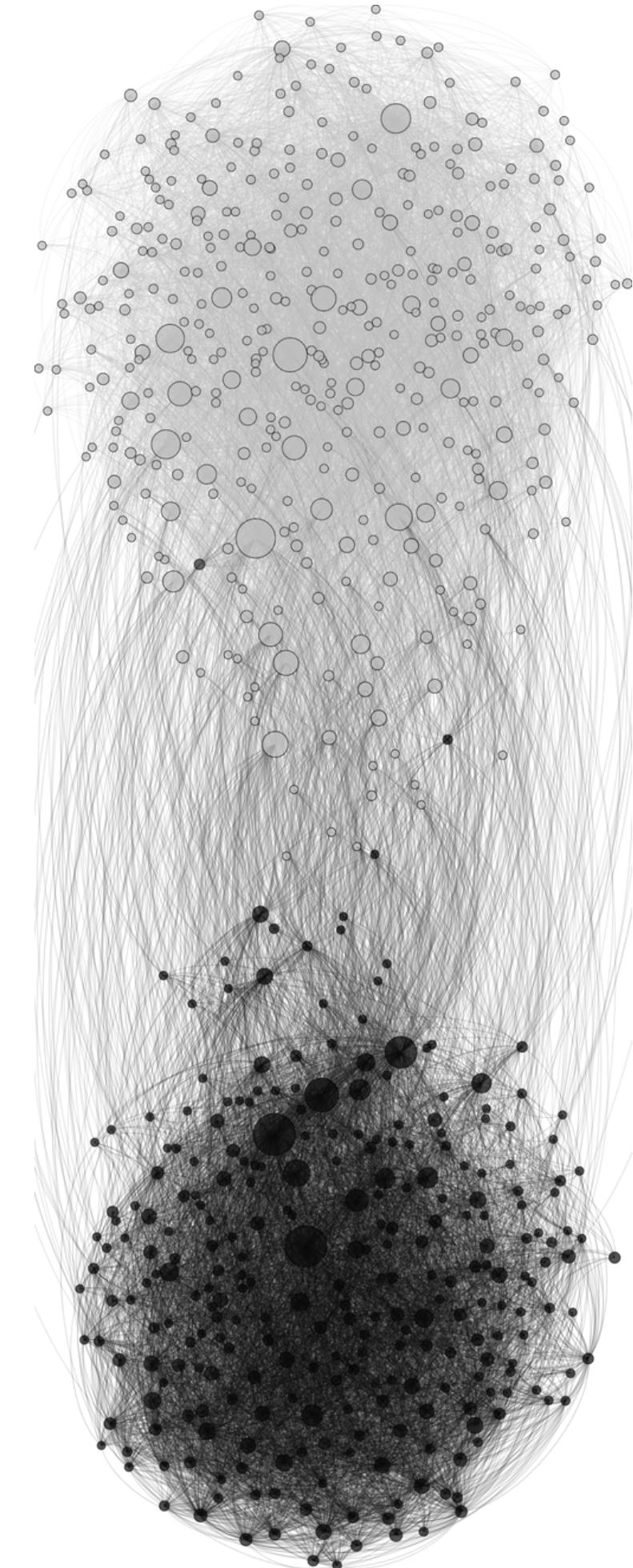
Social Polarization

Micro-Level

Individuals in isolation do not naturally tend to opinion extremes.

Macro-Level

Two opposing groups can become more extreme due to their perception of the behavior and opinions of the other group.



Activation and Inhibition

Micro-Level

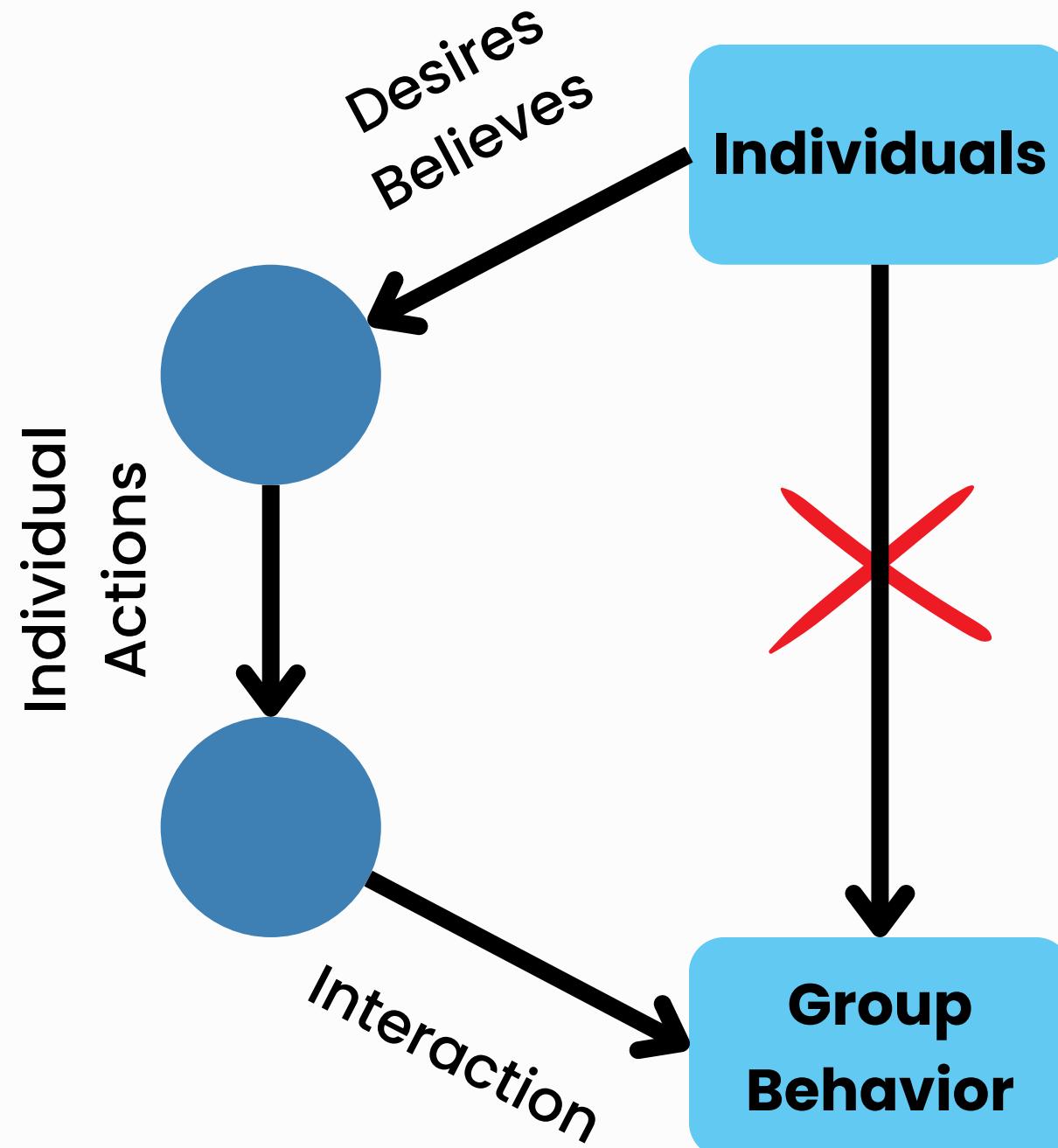
Individuals demonstrating in isolation are peaceful and people alone in the street offer help.

Macro-Level

In a large group a riot can emerge without a clear antecedent. When many people are watching they don't offer help (bystander effect).



The Macro-Micro Gap



Emergent Phenomena

Complex (Social) Systems show spontaneous emergent behaviors that can be hardly directly linked to the microscopic components.

Ex. Cells vs molecules and atoms

Universality

Even if the microscopic components of Complex (Social) Systems may have specific features, these individual features are often barely relevant for the macroscopic behavior.

An Interdisciplinary Field

Individual Level

**Physiology,
Cognitive Sci.**

Group Level

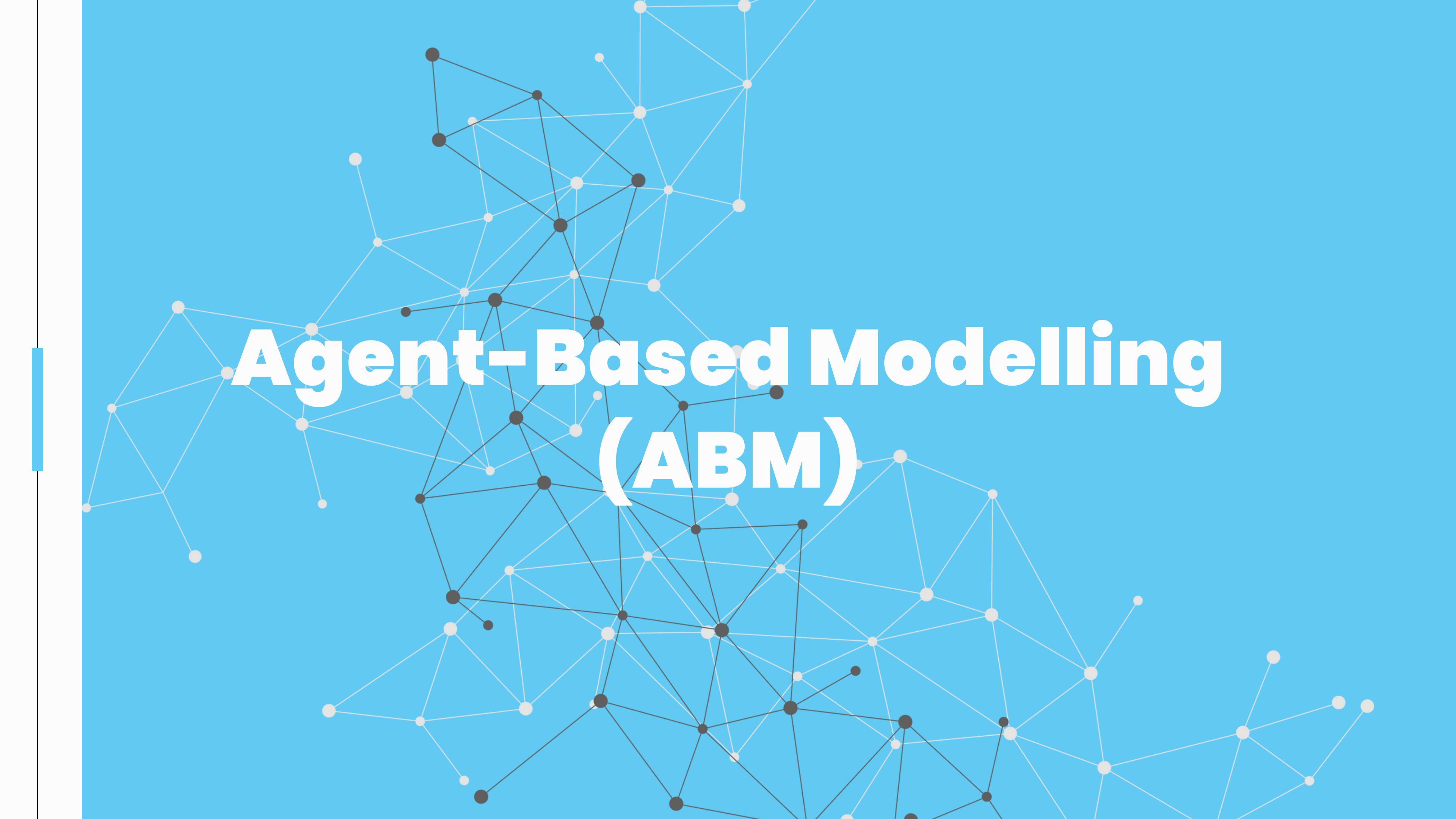
**Computer Sci.,
Math, Physics**

**Sociology, Political
Sci., Economics**

- Opinions
- Emotions
- Believes
- Social Contacts

- Simulations
- Networks
- Dynamics
- Systems

- Norms
- Institutions
- Polarization
- Inequality



Agent-Based Modelling (ABM)

what is an ABM?

Agent-Based Model

A computational analogy of a social system that is composed of a set of agents that represent discrete individuals



Traffic and
mobility



Supply
Chains

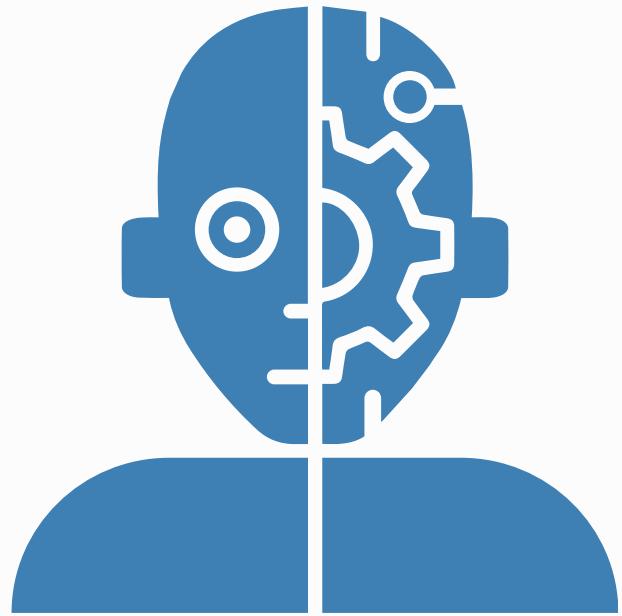


Epidemic
Spreading

What is an Agent?

Agents have **internal states**,
perceive the actions of other agents,
and **interact** with other agents and
their environment (*situated*)

Agents are **active**: they have a
behavioral repertoire, are not just
particles. Often **probabilistic** rather
than deterministic



Agents might have access only
to **limited information** in their
environment or information
can be **manipulated**

Agents might have **internal
goals** that determine their
behavior and can **adapt** to the
behavior of other agents or the
environment

Explaining Emergent Phenomena

Explananda

Observed **collective behavior** or effects are explananda: empirical facts that are missing an explanation.

Ex. Hotter days have higher average crime rates.

ABM

ABM offer explanations by linking the **macroscopic** group behavior to the **microscopical** individual mechanisms.

Ex. Heat makes people be longer in the street, facilitating crime

Analytical Sociology

ABM are part of a larger theoretical approach called **Analytical Sociology**, where everything in a model of social behavior must be explicit.

Ex. coding a simulation of people going out depending on temperature and crimes happening outdoors

ABMs Examples

Explananda

Individual Level

ABM

Spontaneous Traffic Jams

Drivers in cars, trucks etc

A simulation of all vehicles



Traffic and mobility

Global shortage of goods

Companies, warehouses etc.

A simulation of the firm-firm interactions



Supply Chains

Pandemics

Infected and healthy people

A simulations of people spreading a virus



Epidemic Spreading

Limits and Uses of ABMs

ABM do not provide empirical evidence

Simulation results alone are not evidence that humans behave in one way or another. Beware of causal conclusions based on ABM alone!

ABM can generate hypothesis

They can generate hypotheses, for example on the consequences of policies in simulations or formulate predictions. ABM can therefore be tested.

ABM can close the micro-macro gap

They can reconcile empirical observations across individual behavior and collective behavior levels.

ABM help formulating theories

They are a way to analyze theory, showing necessary or sufficient conditions for some collective behavior to emerge

In Silico Social Experiments

ABM are for analysis and testing, not just exploration

Exploring what happens in a simulation is fine, but ABM can do much more!

- **Behavior calibration** of individual agents with experiments or surveys: integrating social and behavioral findings in an ABM
- **Testing outcomes** with large-scale data (e.g. digital traces from computational social systems), across conditions and over time
- **Prediction of observable outcomes** versus parameters of behavior or alternative mechanisms/policies

From factors to actors: Computational Sociology and Agent-Based Modeling. Michael Macy and Robert Willer. Annual Review of Sociology, 2002.

Fundamental properties of ABMs

Causation Modeling

Agent actions and conditions are grounded in observations and dynamics are not ad hoc to get the desired outcome.

Quantifiable Design

Individual dynamics are based on metrics that can be tested with empirical methods (e.g. experiments, surveys).

Measurable Outcomes

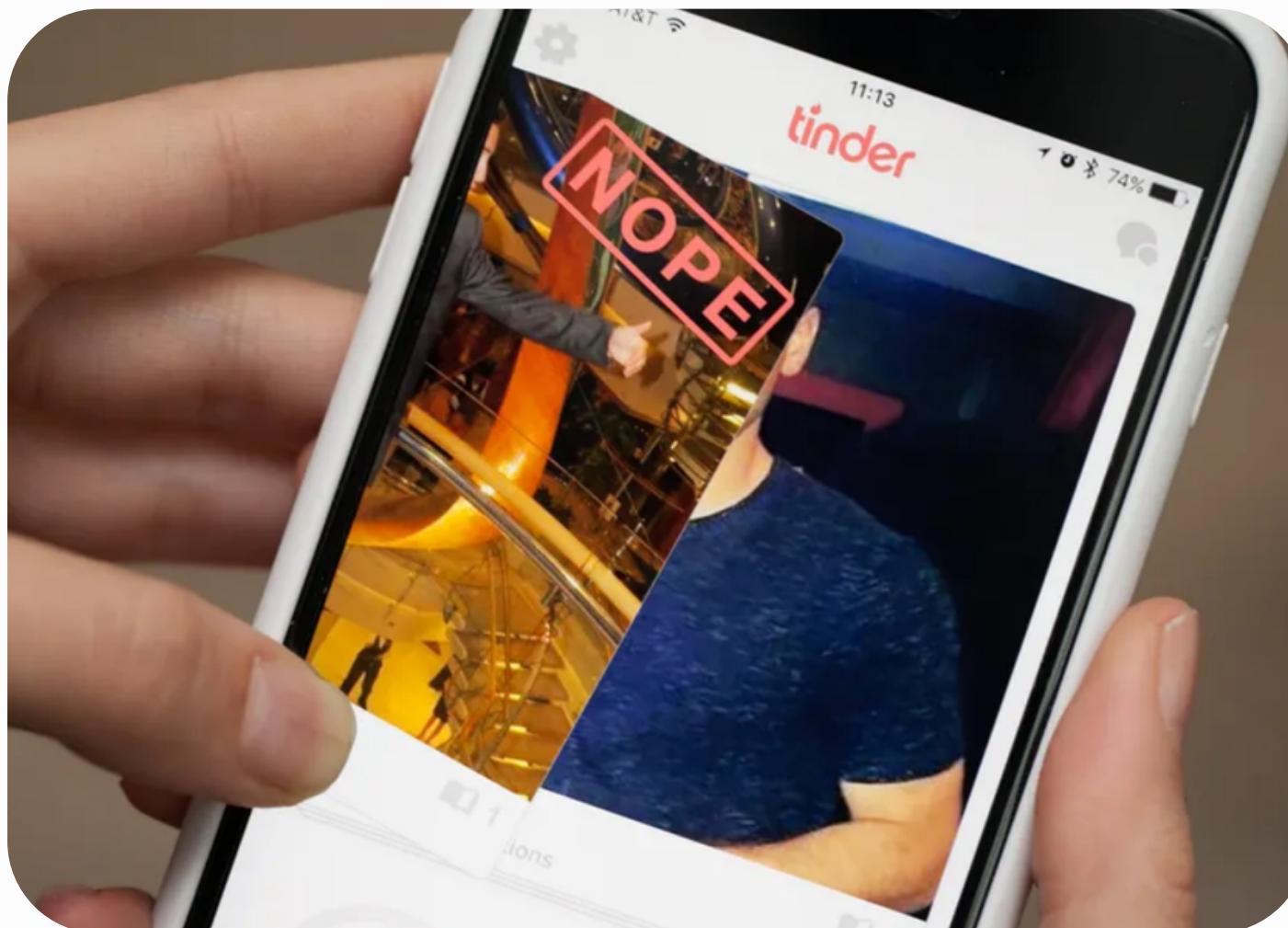
Collective behavior can be aggregated into one or more quantities that can be measured in many simulations and across conditions.

Minimality and Modularity

The ABM can be divided into different blocks describing different properties and interactions among the individuals. Only the minimal, necessary features must be included.

Date Choice Model

Date Choice in Computational Social Systems



Tinder Meat Swipe



Chris Vee
44.000 iscritti

Iscriviti

233



Condividi



The Matching Paradox



Question: *do people seek dating mates that are as attractive as possible or matching their own perceived attractiveness?*

There is conflicting evidence!

- **Individual Level** In experiments participants seek to maximize partner attractiveness, participant attractiveness is barely relevant
- **Group Level** In observational data attractiveness of couples are correlated ($r = 0.6$) and correlation is stronger for more committed couples

Kalick and Hamilton dating model

The model is defined as follows:

- There are N **female** and N **male** agents
- Each agent has a **random attractiveness** between 1 and 10
- Couples are formed by an **iterative process**:
 - a. All single male and female agents are **randomly paired** for a date
 - b. Each individual accept or reject their partner with a **probability** based on a rule taking into account their attractiveness levels (e.g. matching or seeking attractiveness)
 - c. If both agents accept they form a couple and **leave** the dating pool

The matching hypothesis reexamined. Michael Kalick and Thomas Hamilton. Journal of Personality and Social Psychology, 1986.

Model Metrics

Model time t

Percentage of agents that are in a couple. Denoting as N_t the number of couples $t=N_t/N$. Time grows from 0 to 100 with iterations

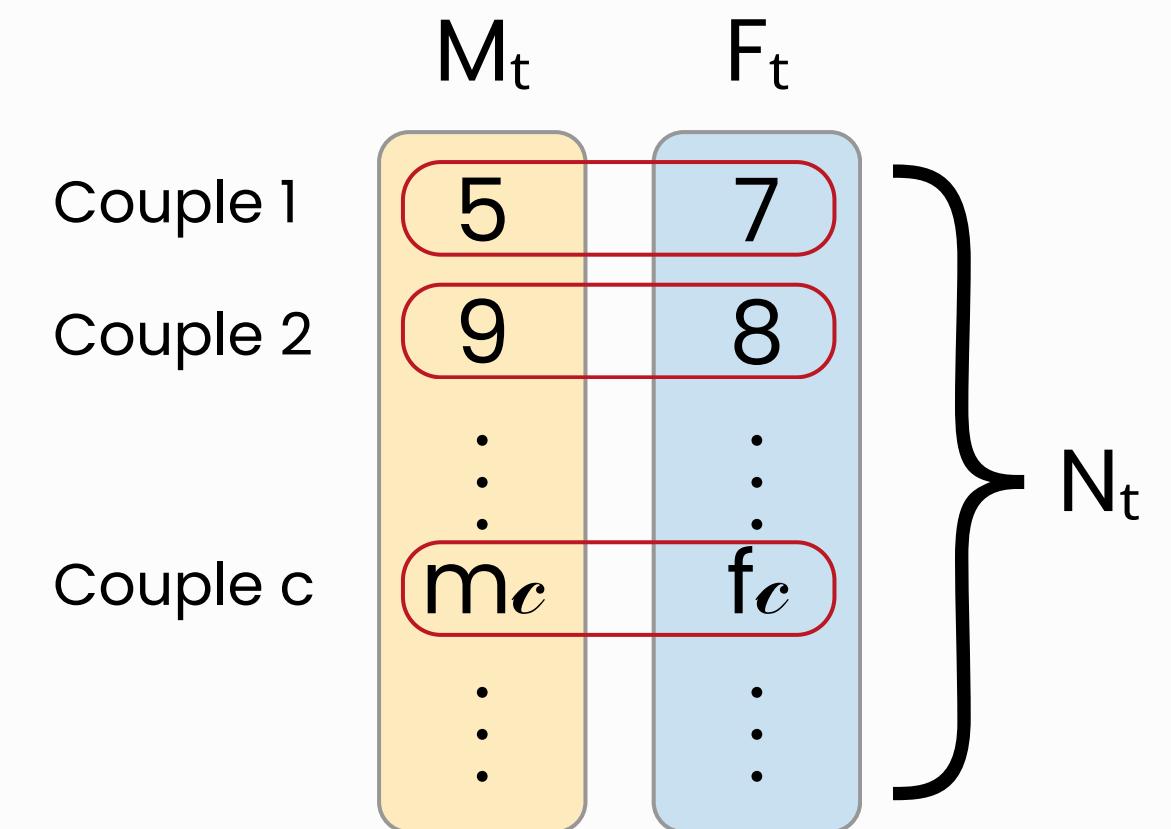
Correlation coefficient r

- M_t and F_t the vectors of male and female attractiveness in couples formed up to time t
- C_t list of all couples
- m_c and f_c male and female attractiveness in couple c

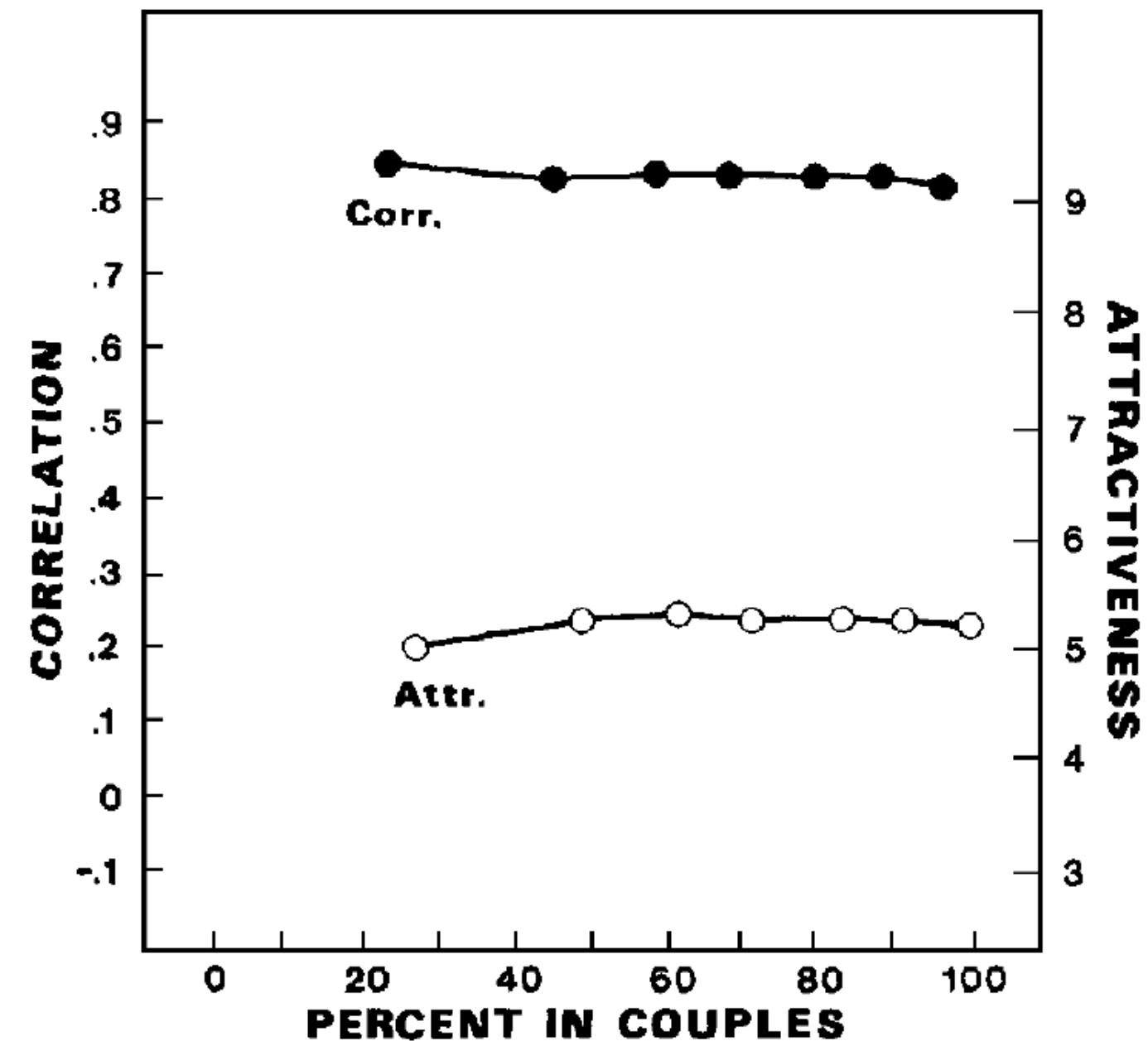
$$r(t) = r(M_t, F_t) = \frac{\sum_{c \in C_t} (m_c - \mu_M^{(t)}) (f_c - \mu_F^{(t)})}{\sqrt{\sum_{c \in C_t} (m_c - \mu_M^{(t)})^2 (f_c - \mu_F^{(t)})^2}}$$

Mean attractiveness μ

$$\mu^{(t)} = \mu_M^{(t)} + \mu_F^{(t)} = \sum_{c \in C_t} \frac{m_c + f_c}{N_t}$$



Seeking Similar Match



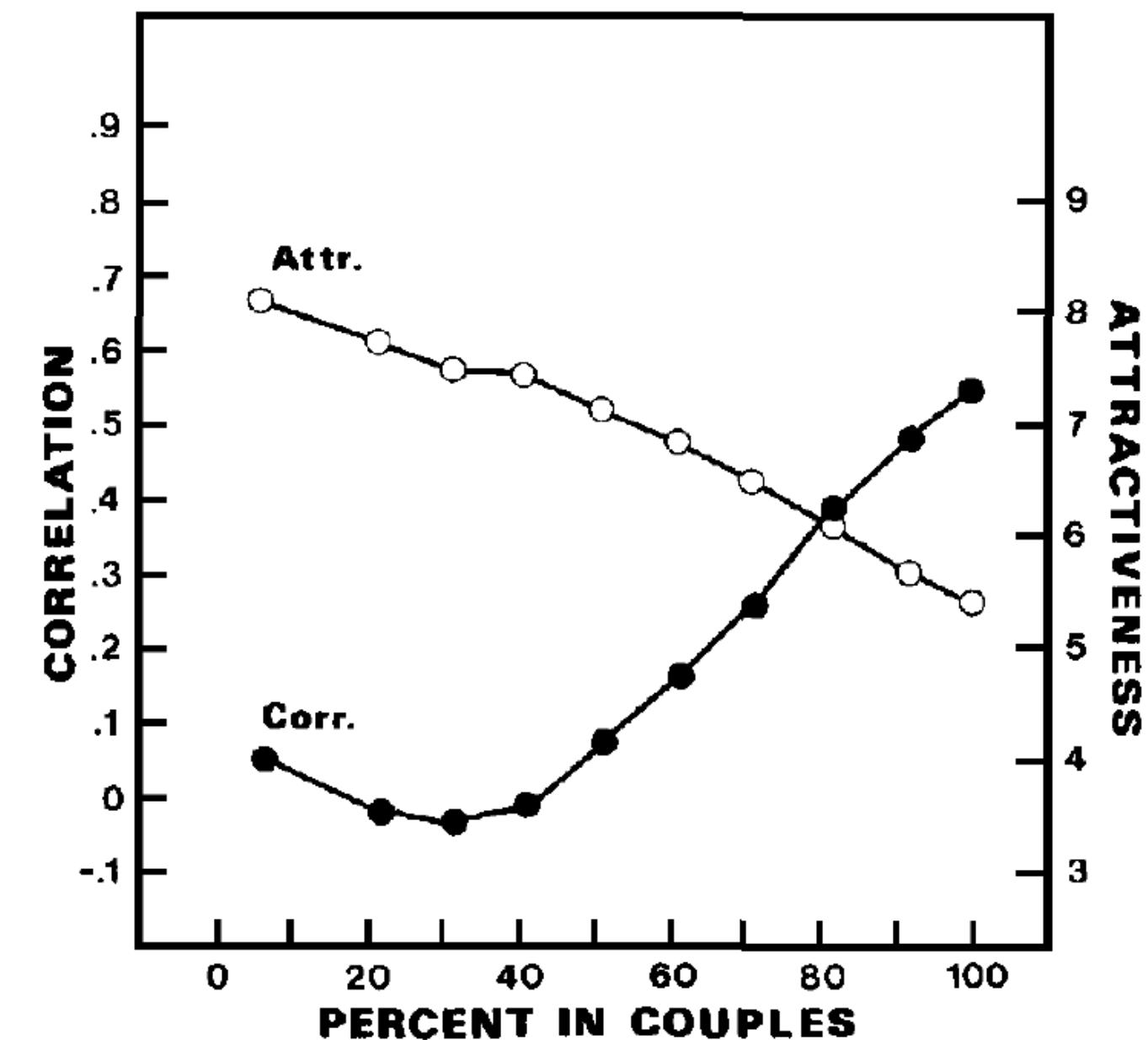
Outcomes over simulation time for the case of **seeking similar partners**:

- Correlation starts and stays very high (0.8)
- There is no real trend in correlation
- Mean couple attractiveness is around the average the whole simulation

Outcomes over simulation time
for the case of **seeking**
attractive partners:

- Correlation starts low but raises pretty up to about 0.55
- Mean couple attractiveness starts much above average and approaches average
- Attractive agents couple earlier

Seeking Attractive Match



What did we learn?

Main Result. Attractiveness matching is not necessary for observed correlations, they can be produced by attractiveness seeking alone.

Micro-Macro Gap. ABM reconciles apparently conflicting empirical results

Comparison with empirical data. Observed empirical correlation is closer to 0.55 than to 0.9. However this is not a strong evidence.

There are many simplifications, don't draw conclusions!

The matching hypothesis reexamined. Michael Kalick and Thomas Hamilton. Journal of Personality and Social Psychology, 1986.

Conclusions

Emergence of Complex Social Behavior

- Humans behave differently in groups as in isolation: collective behavior emerges spontaneously
- Interdisciplinary approach to explain macro dynamics from micro behavior: physics/computer science is the link

Agent-Based Modelling (ABM)

- A computational approach to formalize and analyze social systems
- Agent properties and model objectives and assumptions

ABM Example: Date Choice Model

- Mismatch in empirical results: observations contradict experiments
- A simple model shows that seeking attractiveness in a finite dating pool also generates the observed correlations in couples