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Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Understanding and Solving Societal Problems with Modeling and Simulation

Lecture 1: Why Model?

Prof. Dirk Helbing, Dr. Thomas Chadefaux, Dr. Michael Maes

Why Model?

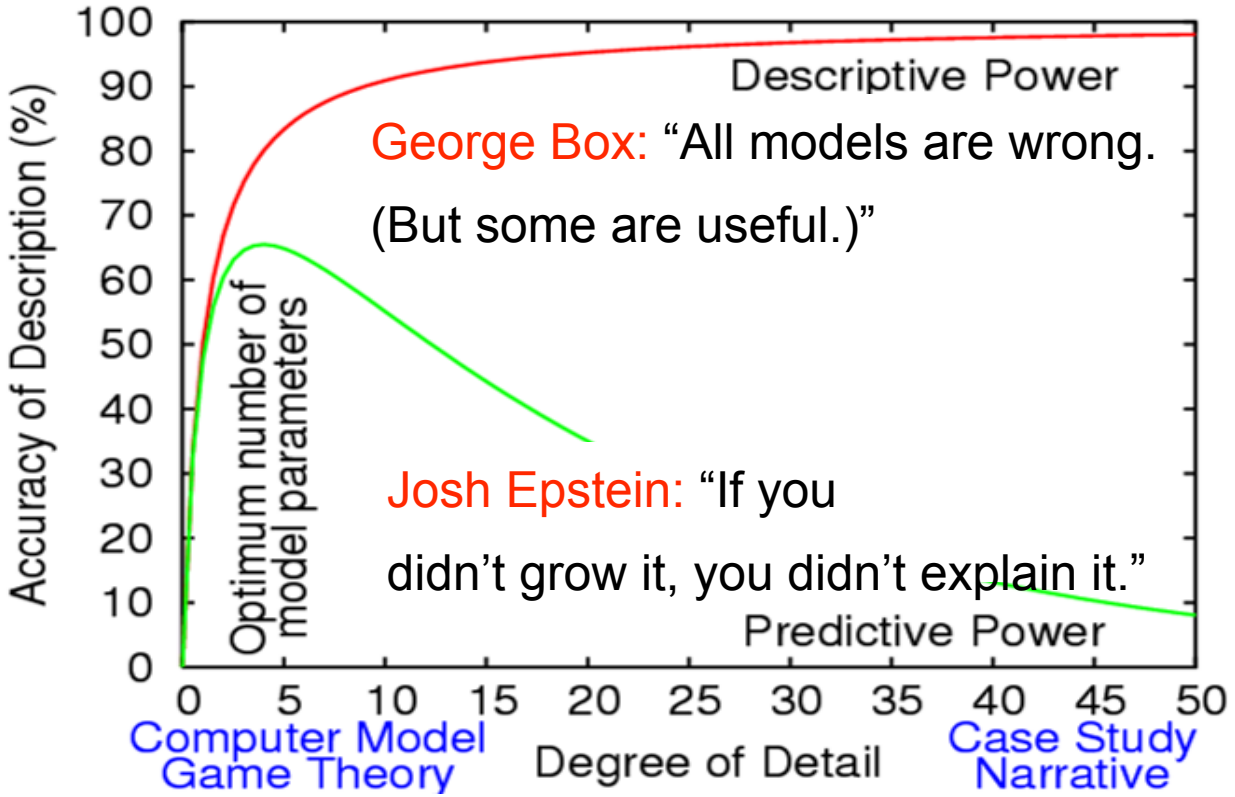
Sociology - The Queen of Sciences?

Auguste Comte (1798-1857)

is often called the “father” of sociology. He proposed a rational (“positivistic”) approach to the study of society, based on observation and experiment. In the beginning, he called his approach “social physics”, but later he used the term “sociology” (meaning knowledge of society).

Auguste Comte considered sociology to be the queen of sciences. Comparing, for example, sociology with biology and physics, the systems it deals with are the most complex ones.

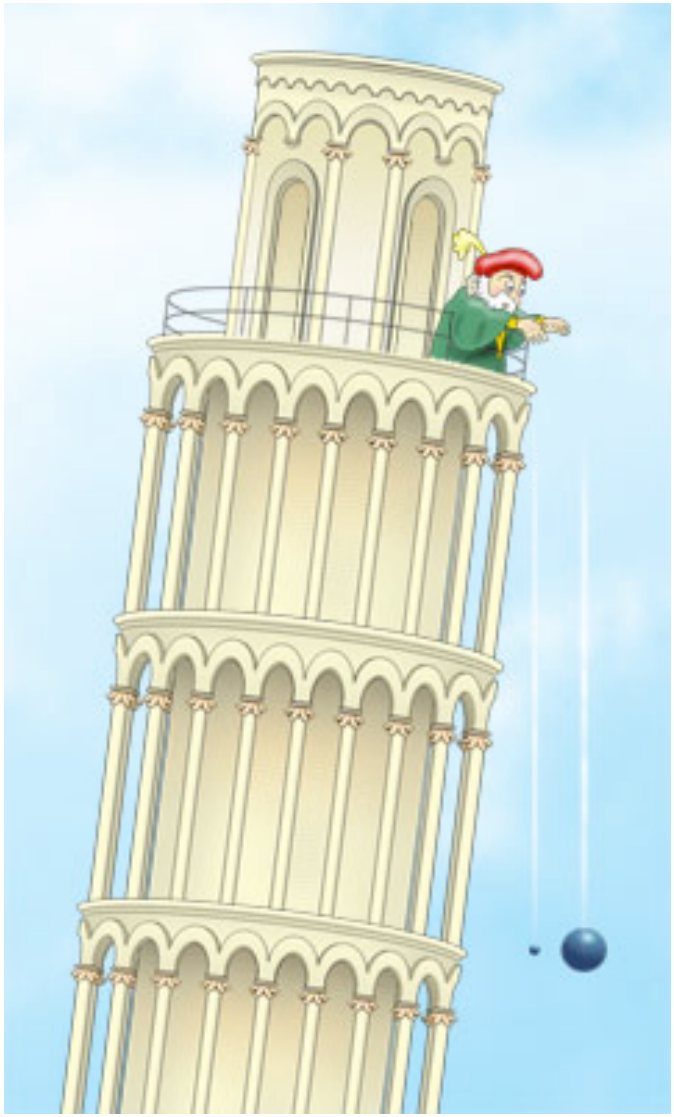
On Simple and Detailed Models



The more parameters a model has, the more difficult it is to fit them all exactly. This may affect the accuracy of predictions.

Many social systems are so complex, that the relevant variables and parameters involved are hard to identify and to measure. I will, therefore, study a few simple, measurable systems (leaving, for the time being, complex issues like meanings, values, historical aspects, and other behavioral dimensions aside), hoping that one can learn something more general from the principles observed in these examples.

The Need of Simplification and Abstraction



"Y'know, Henry, I had no idea it would be so fun to go skydiving with a physicist."

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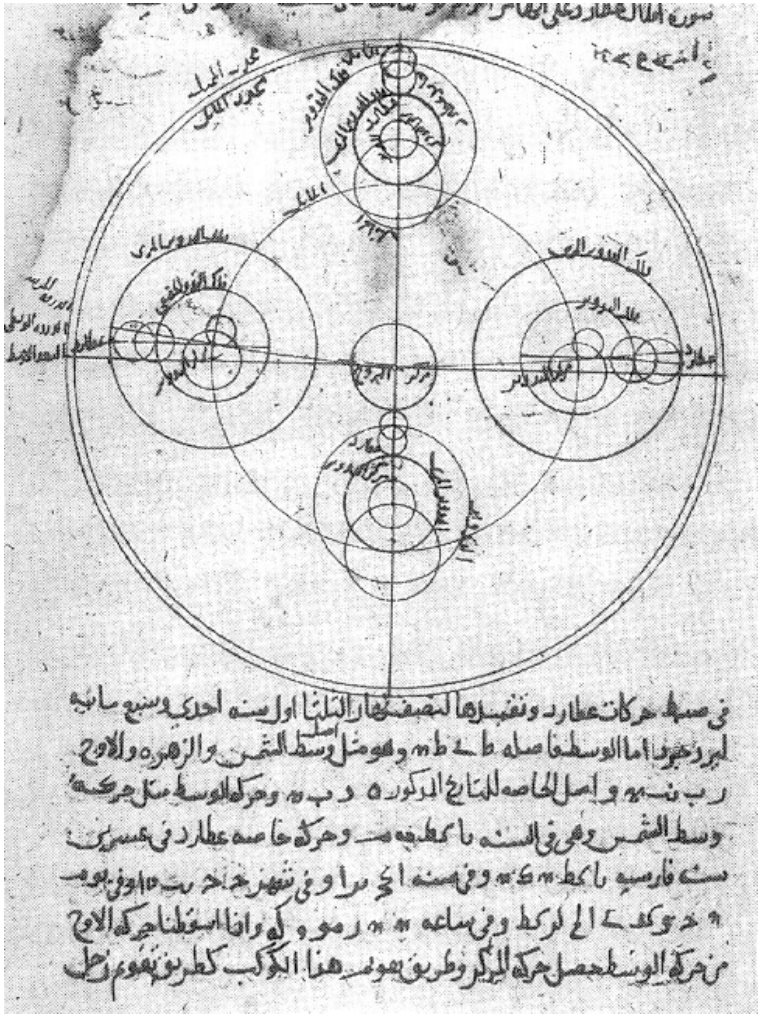
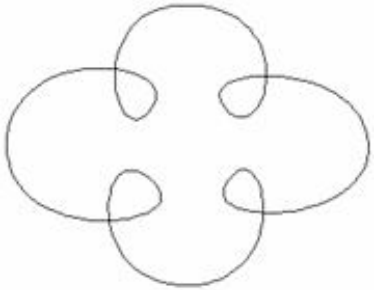
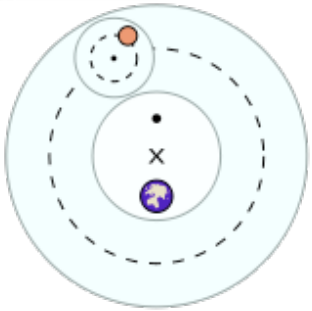
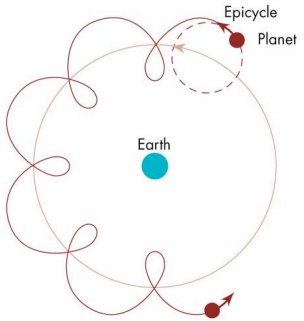
A Note on Simple Models

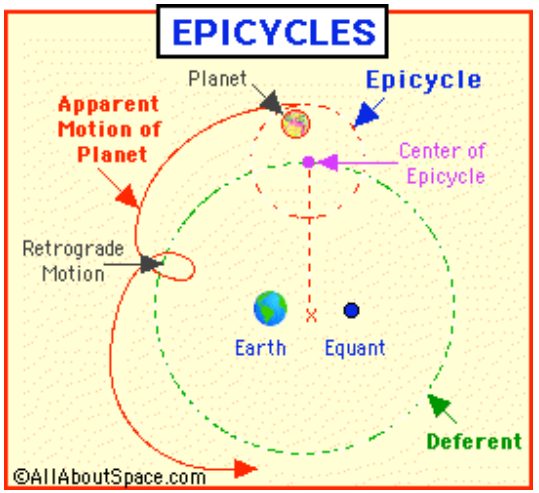
Geocentric Picture: Epicycles around the Earth







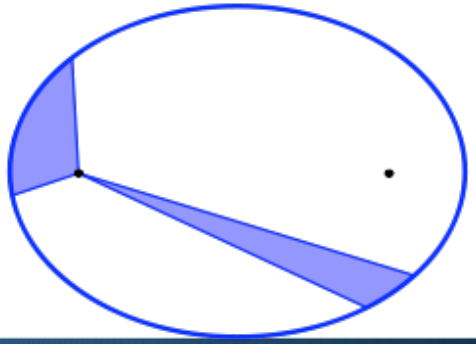




Heliocentric Picture:

Elliptical paths

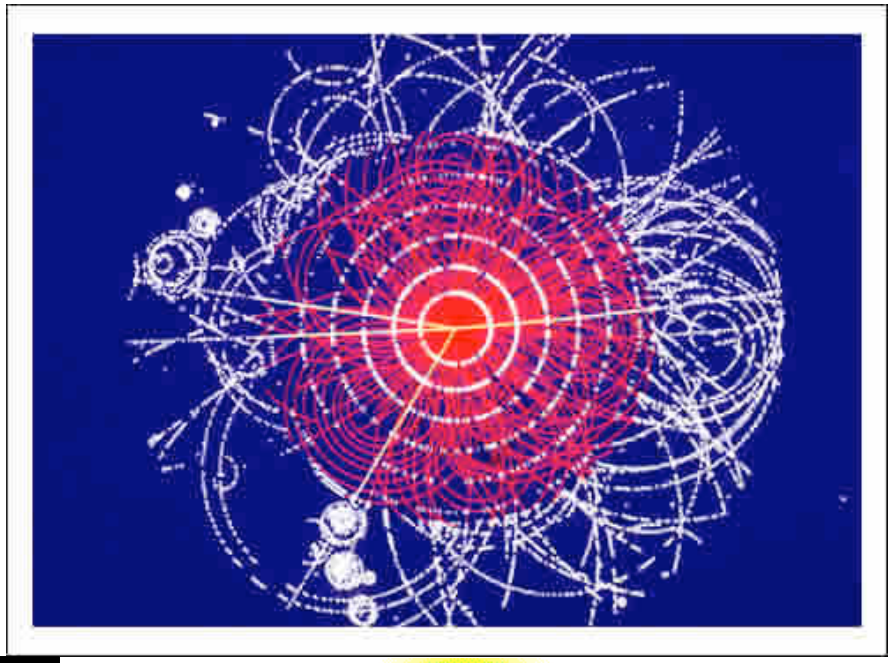
around the sun

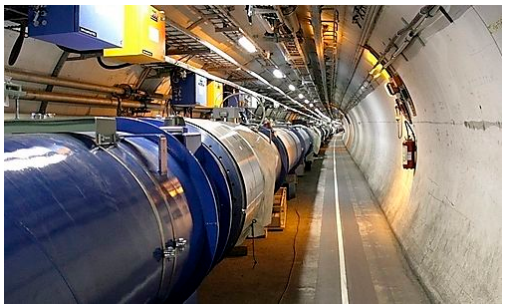


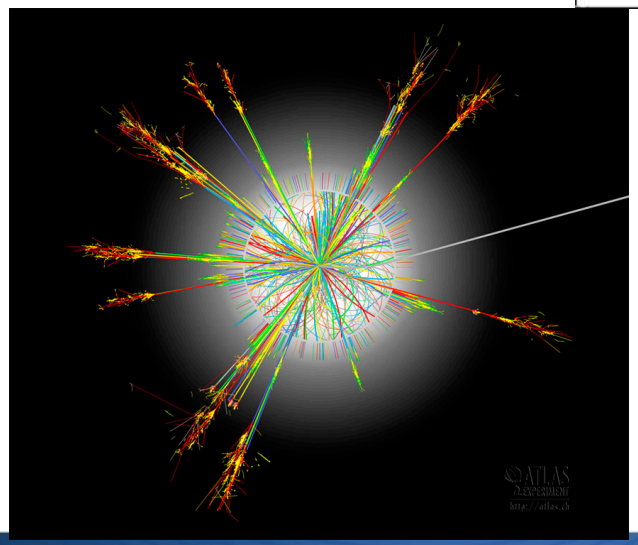
Stylized Facts of Collective Opinion Formation

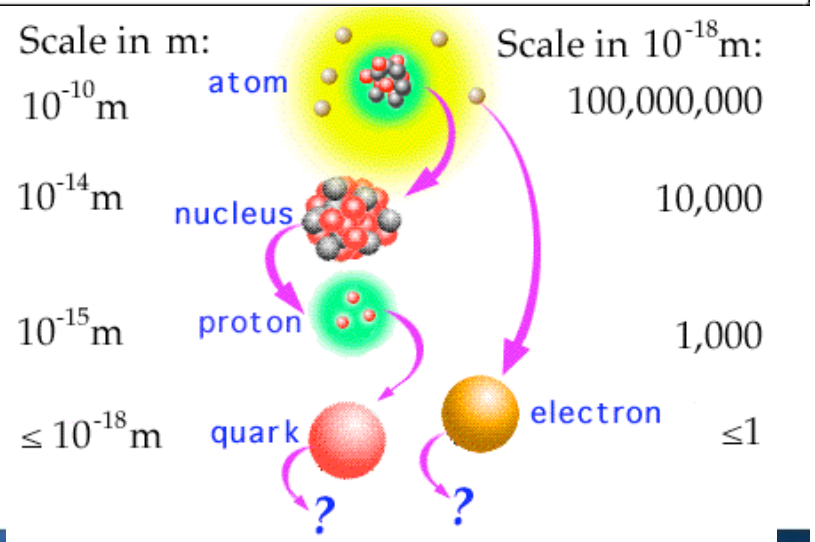
- Individuals are influenced by other people's stated opinions
- Collective opinion formation creates a tendency of convergence
- However, consensus does not always happen
- If consensus occurs, this creates confidence in the correctness of the opinion
- People tend to form groups, but groups may also split up
- As a result, the typical observation is a "pluralistic society"
- Emergent groups are characterized by similar opinions and/or behaviors ("homophily")

Can We Understand a System from Elementary Processes?









Social Systems as Physical Systems?

The differences from physical systems are as important as the similarities. They are the most interesting aspects for a new science of society.

Not Everything in Socio-Economic Systems May be Understood By Simple Models

- Some of the reasons are
  - the huge number of variables involved,
  - the relevant variables and parameters are often unknown,
  - empirical studies are limited by technical, financial, and ethical issues,
  - factors such as memory, anticipation, decision-making, communication, interpretation of intentions and meanings complicate the situation a lot.
- The non-linear dependence of many variables leads to complex dynamics and structures, and often paradoxical effects. Linear statistical methods do not reveal mechanisms of self-organization!
- Furthermore, heterogeneity (due to individuality, social difference and specialization), and the fact that the observer participates and modifies social reality, imply additional difficulties.
- Conclusion: It seems worth trying to start with simple, well measurable systems such as crowds or traffic, and only then proceed with more complex phenomena.

Some Fundamental Phenomena/Problems in Social Systems

- "Homophily" (interaction with similar people) and social agglomeration
- Social influence: Collective decision making and behavior, voting behavior
- Cooperation in social dilemma situations
- Group identity: Group formation, group and crowd dynamics, coalition formation, social movements, organizations
- Social norms and conventions, conformity, integration, social roles and socialization, social institutions, evolution of language
- Social differentiation, inequality, and segregation
- Social structure, hierarchical organization, etc.
- Deviance
- Social exchange, trading, market dynamics
- Conflicts, revolutions, violence, and wars

Model Ingredients: Elementary Properties of Individuals

- Birth, death, and reproduction
- Individuals need resources (e.g. eat and drink)
- Competition, fighting ability
- Tool-making ability, possibility to grow food, hunt etc.
- Perception
- Curiosity, exploration behavior, ability for innovation
- Emotions
- (Memory)
- Mobility and carrying capacity
- Communication
- Learning and teaching ability
- Possibility of trading and exchange

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Some Grand Challenges (‚Hilbert Problems‘)

1. Socio-Economic and Real-World Challenges
2. Measurement and Methodological Issues
3. Understanding Underlying Principles
4. Modeling of Complex Adaptive Agents
5. Interactions, Networks, and Systemic Interdependencies
6. Dynamics and Change
7. Self-Organization, Collective Behavior, Co-Evolution and Emergence
8. Risks, Systemic Instability, and Resilience
9. Markets, Transaction and Exchange Systems
10. Institutions and Integrative Systems Design
11. Management of Complexity and Sustainability
12. Information, Innovation, and Knowledge
13. Social and Economic Capital
14. Values, Responsibility, and Ethics

DH (2012) Accelerating scientific discovery by formulating grand scientific challenges

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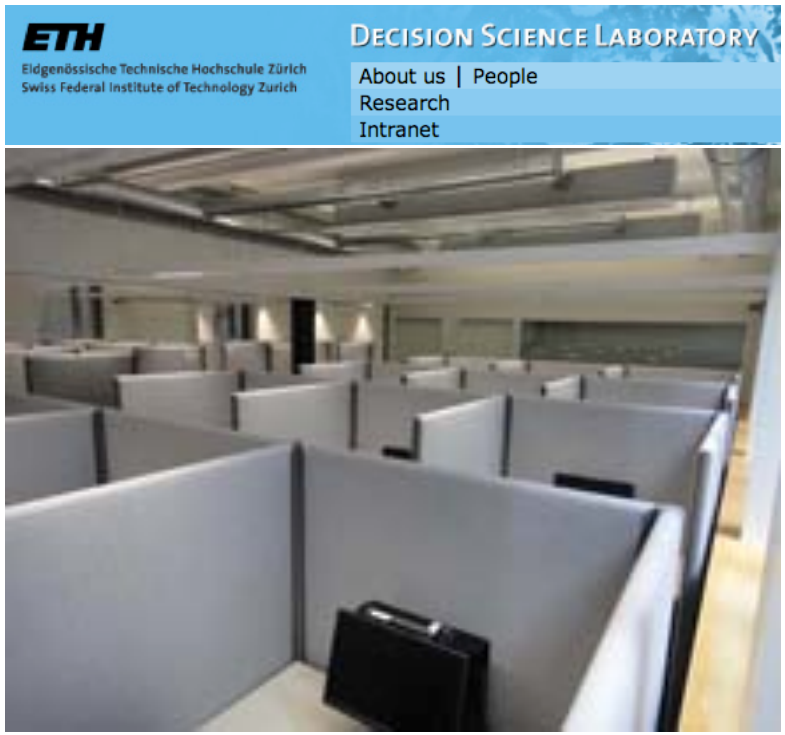
New Instruments to Explore the World

Hubble, Nasa

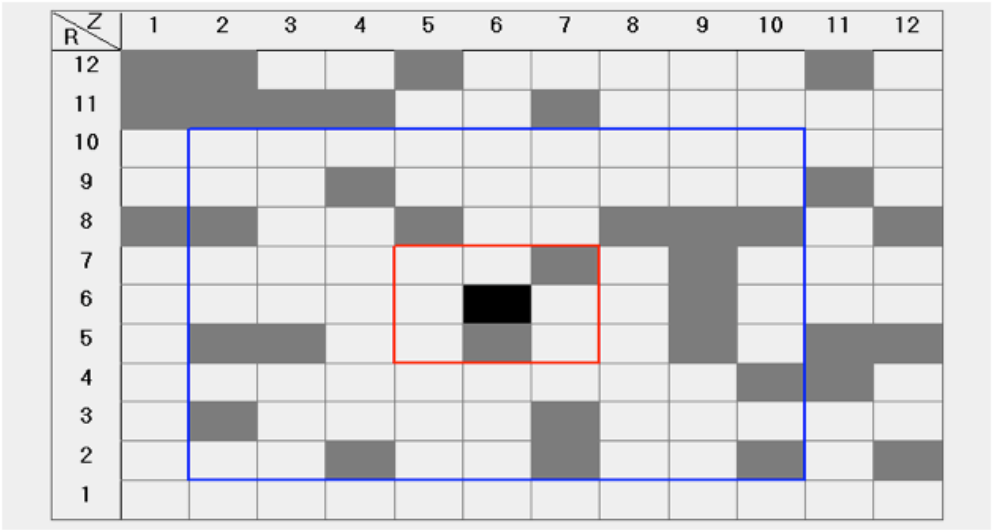
Connect web experiments with data mining and modelling tools to reach an acceleration of knowledge generation as in the Human Genome Project

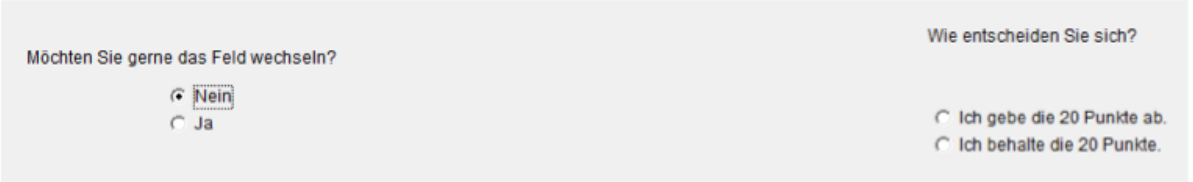
Laboratory Experiments



Joint work with Carlos Roca,

Charles Efferson and Sonja Vogt





Measuring the Social World

1. Goal: Measure the world's state, 'social footprint' and social capital (e.g. trust) in real time, detect possible threats and opportunities

2. Privacy-respecting data mining

'CERN-like' vision: Create a measurement instrument for techno-socio-economic-environmental systems

Painting by Maurits Cornelis Escher

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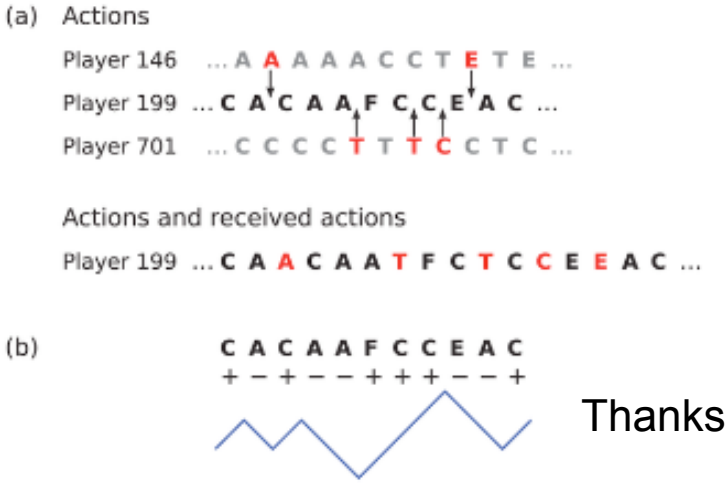
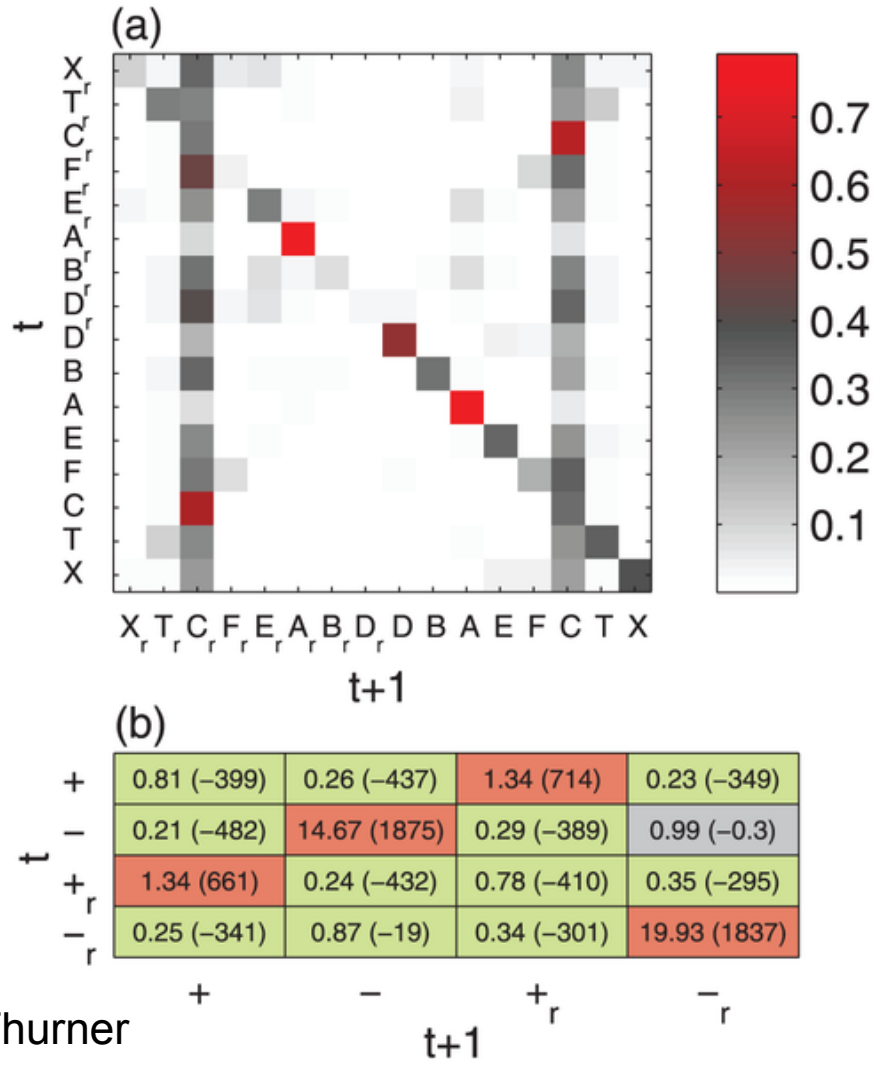
Interactive Games as Experimental Platform





Thanks to Stefan Thurner

‘Human-Genome-Project-like’ vision: Develop interactive platforms for rapid experimenting, to better understand human behaviour

Outline

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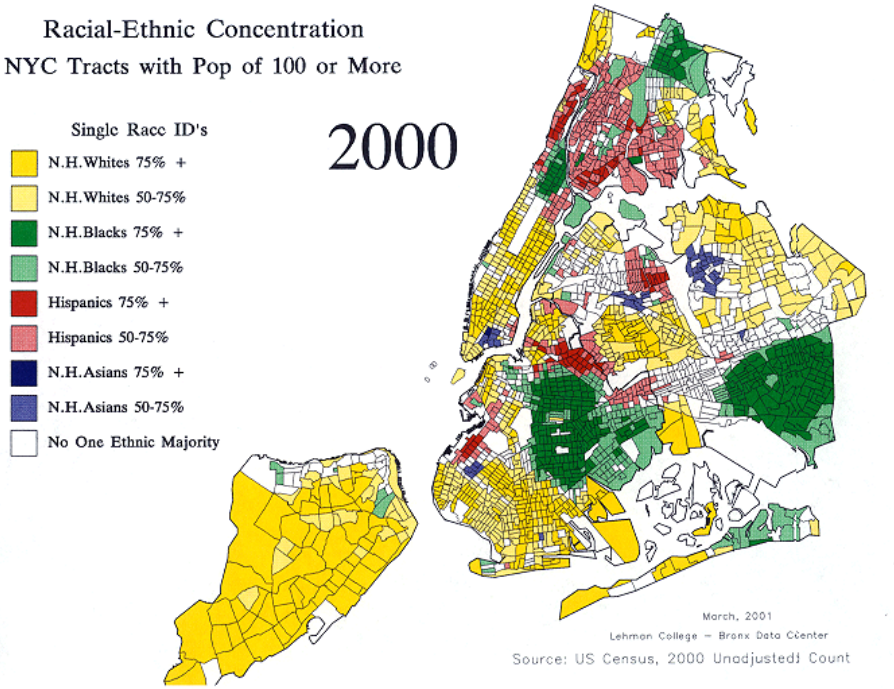
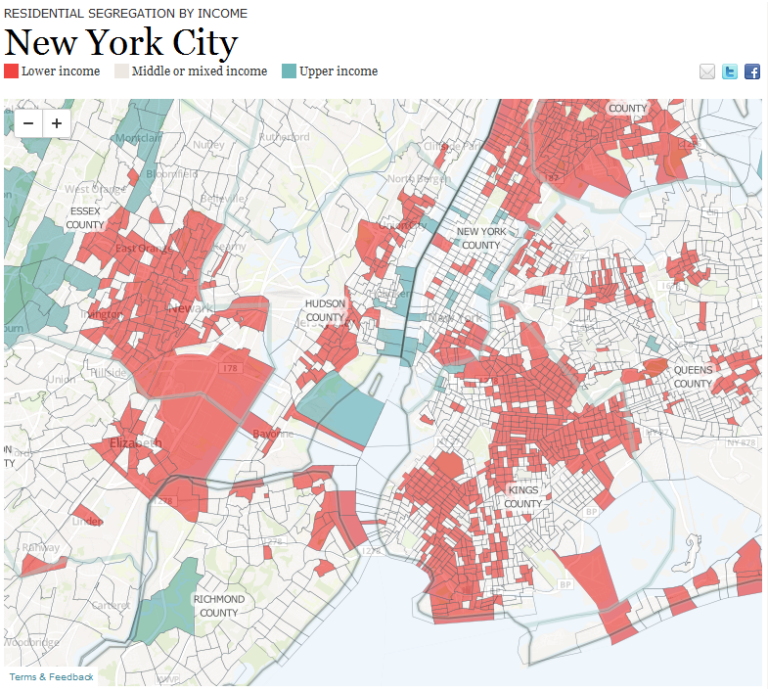
Week 2: Residential Segregation





NetLogo

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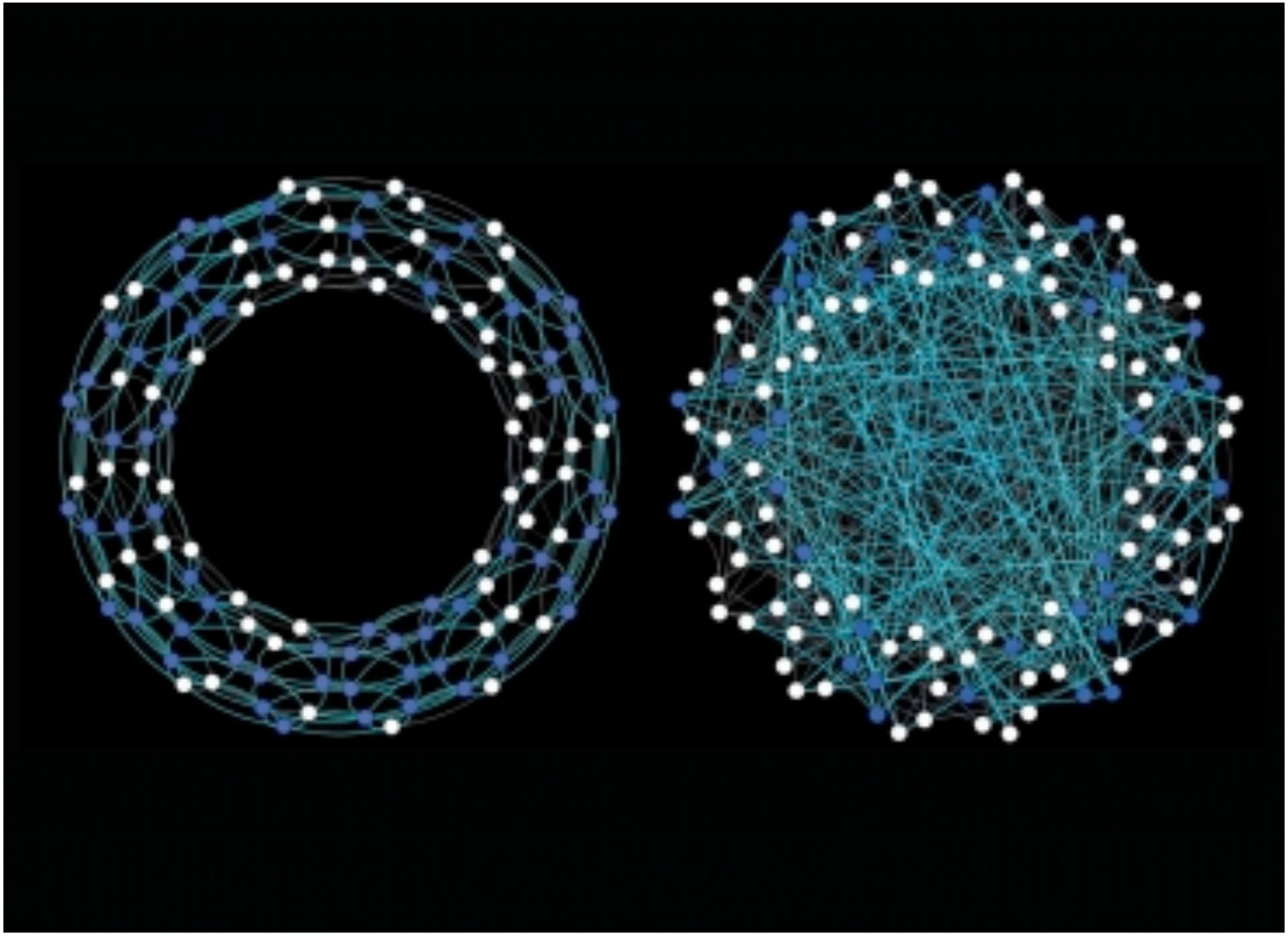
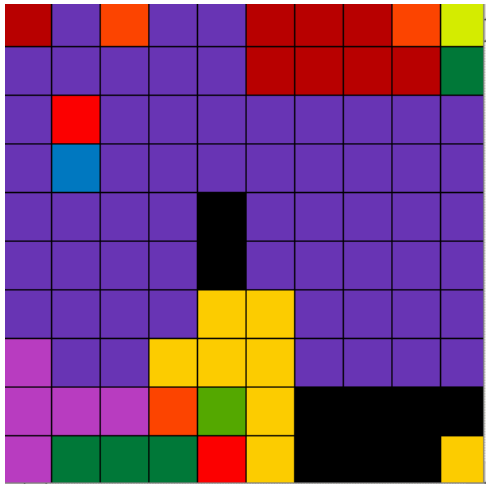
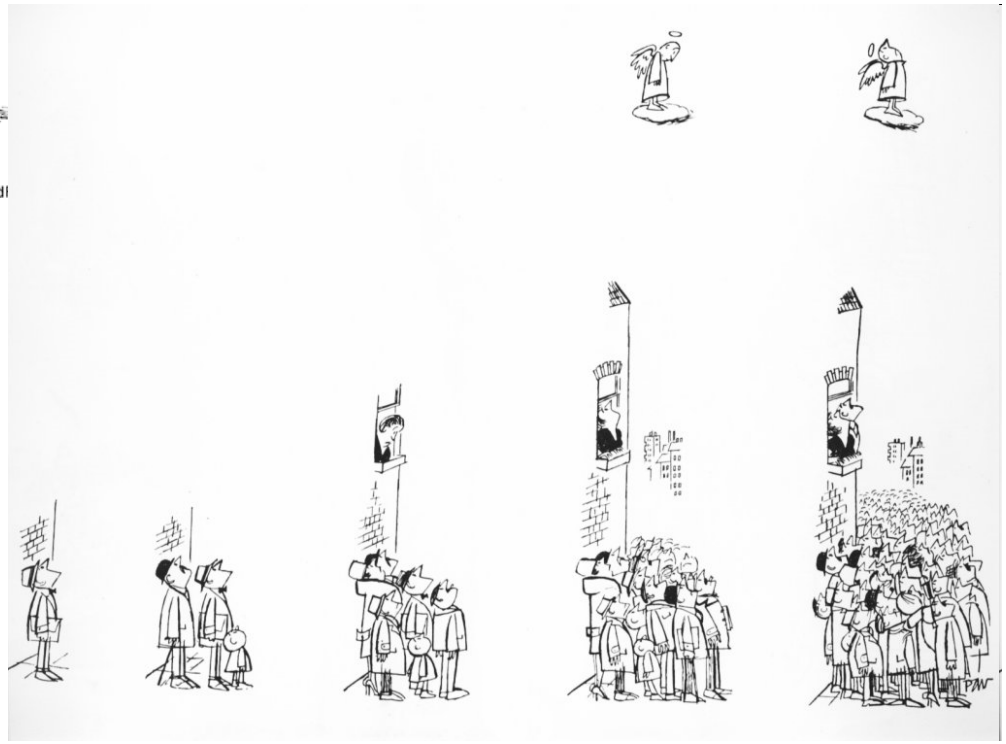
Week 3: Diffusion of Diseases and Gossip in Social Networks

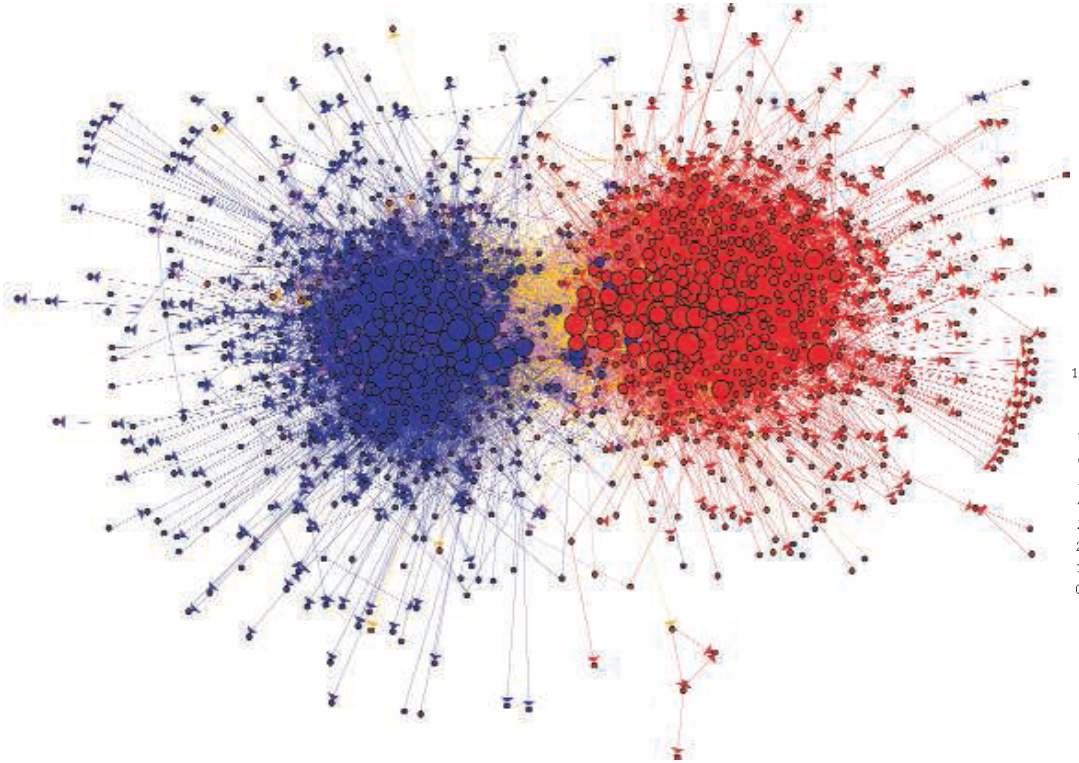


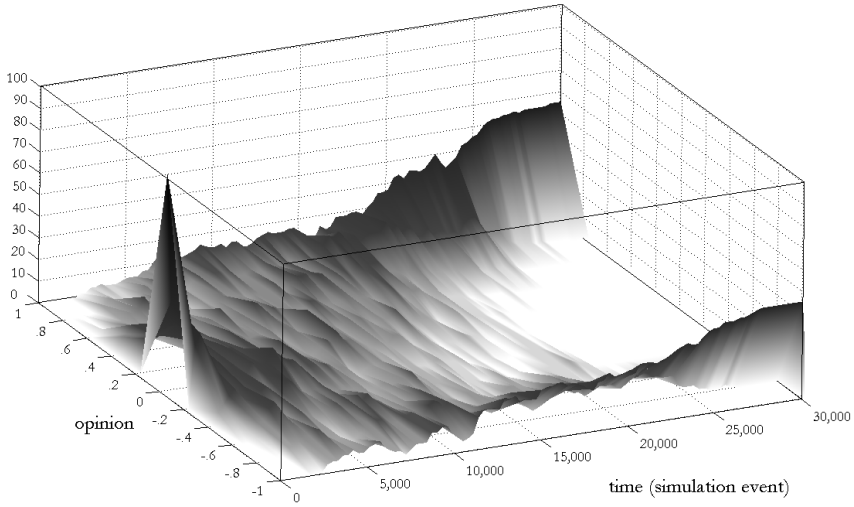
Week 4: Globalization of Culture





Week 5: Opinion Polarization





Week 6: Stampedes, Crowds and Mecca

Love Parade Disaster in Duisburg, 2010

At low densities:

self-organized lane formation,

like Adam Smith's invisible hand

At large densities: coordination breaks down

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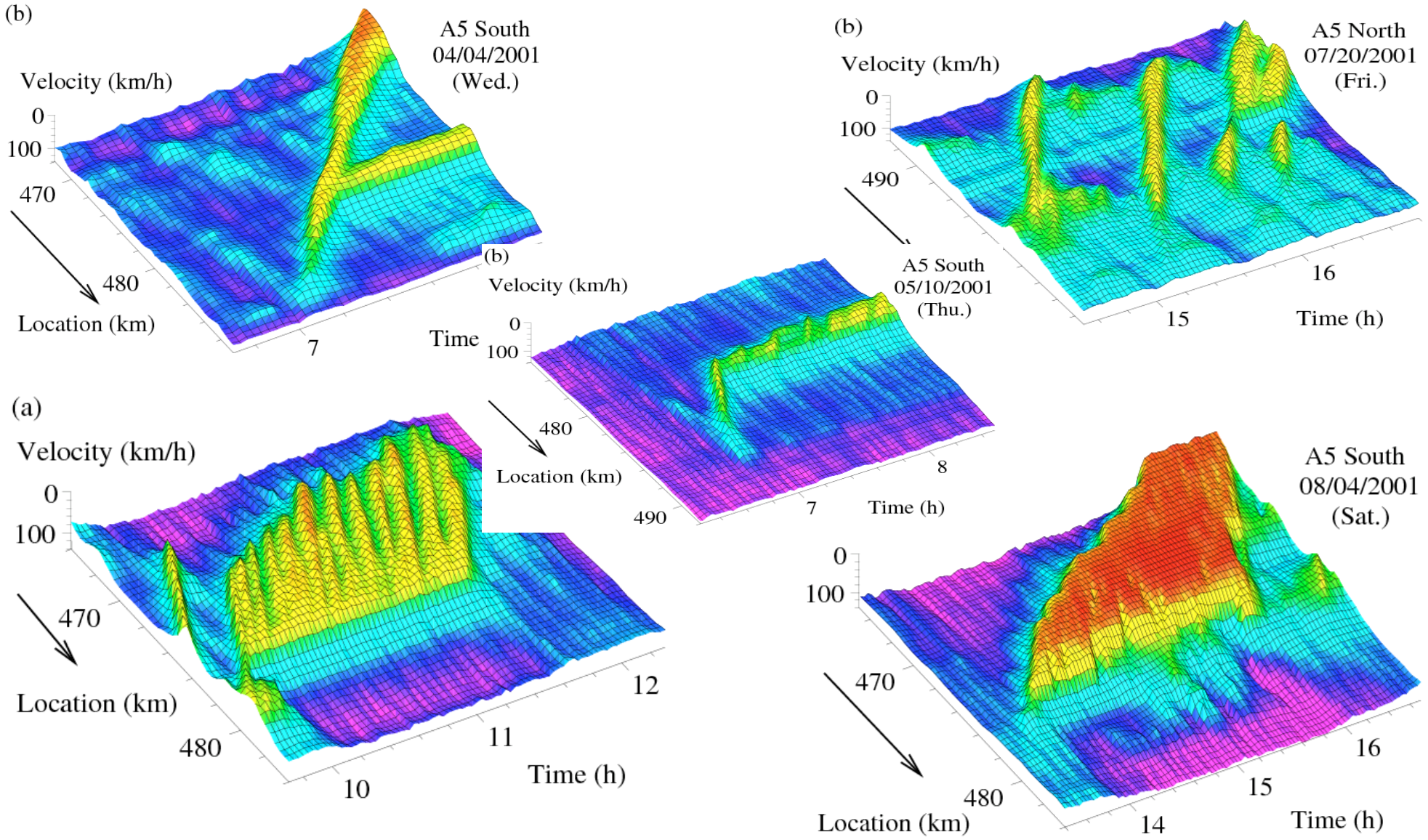
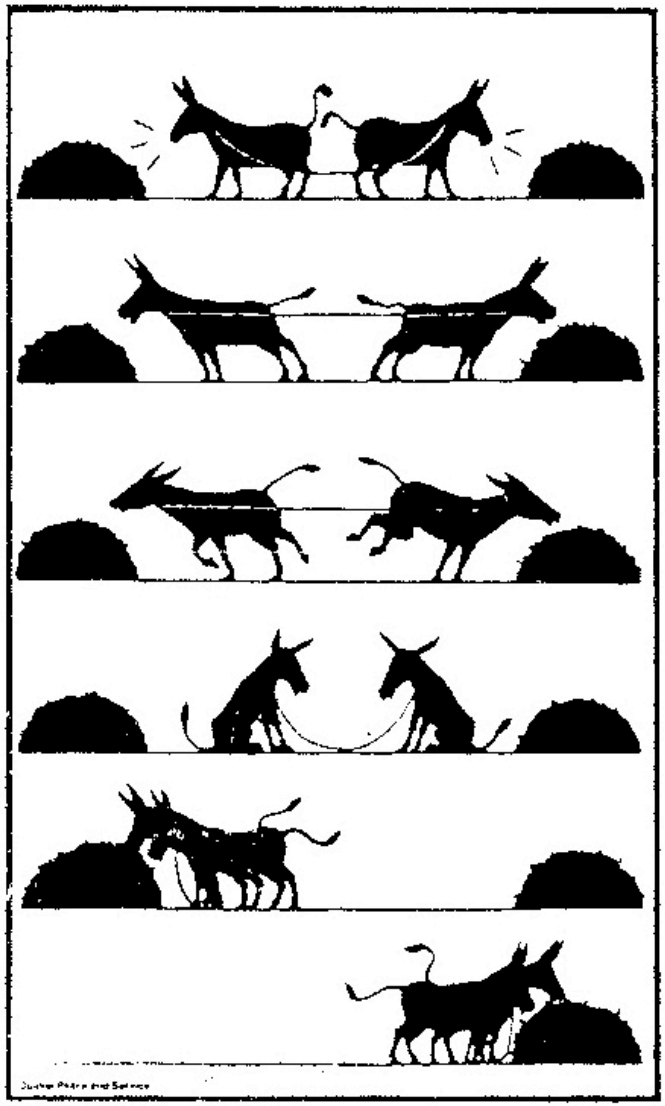
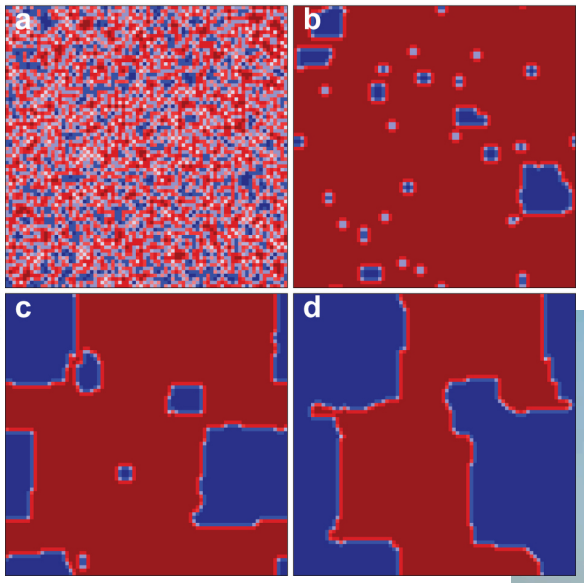
Week 7: Traffic Jams

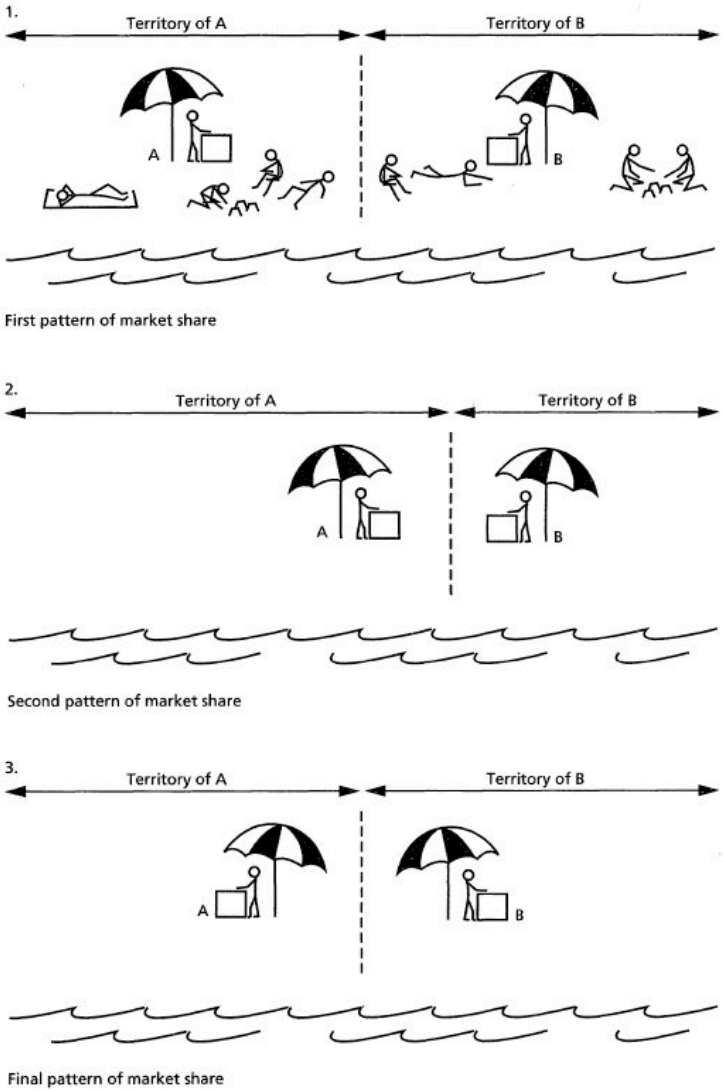


Week 8: The Breakdown of Cooperation

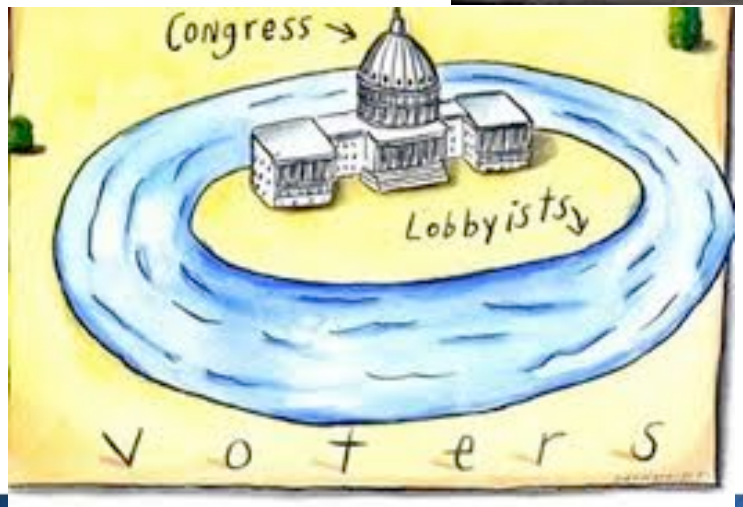




Week 9: Voting and the Impossibility of Democracy

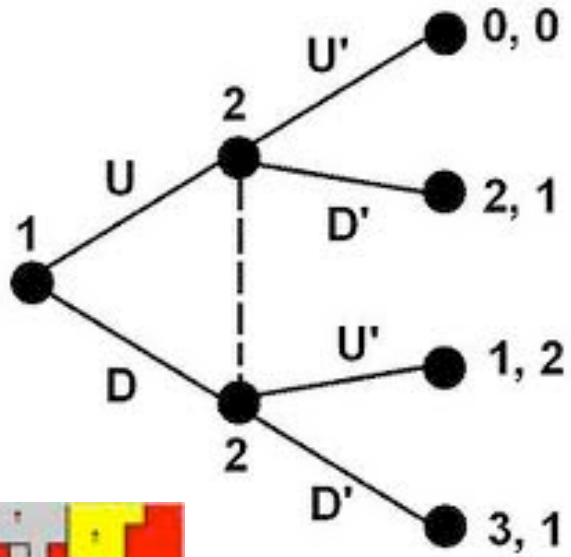


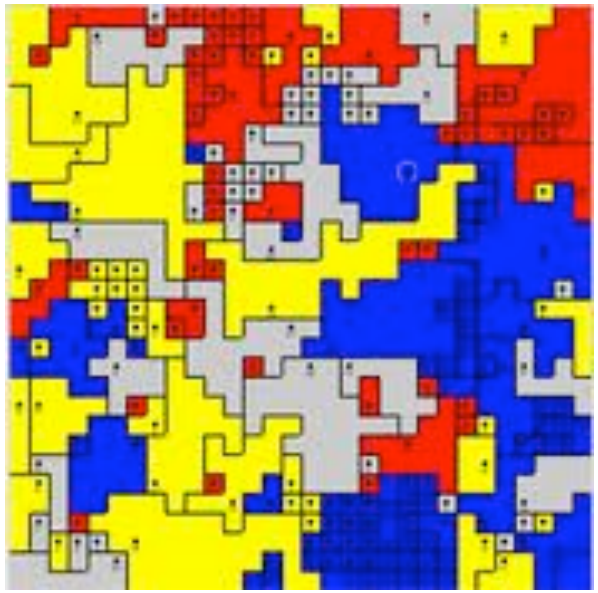
Week 10: Collective Action, Unions and Protests



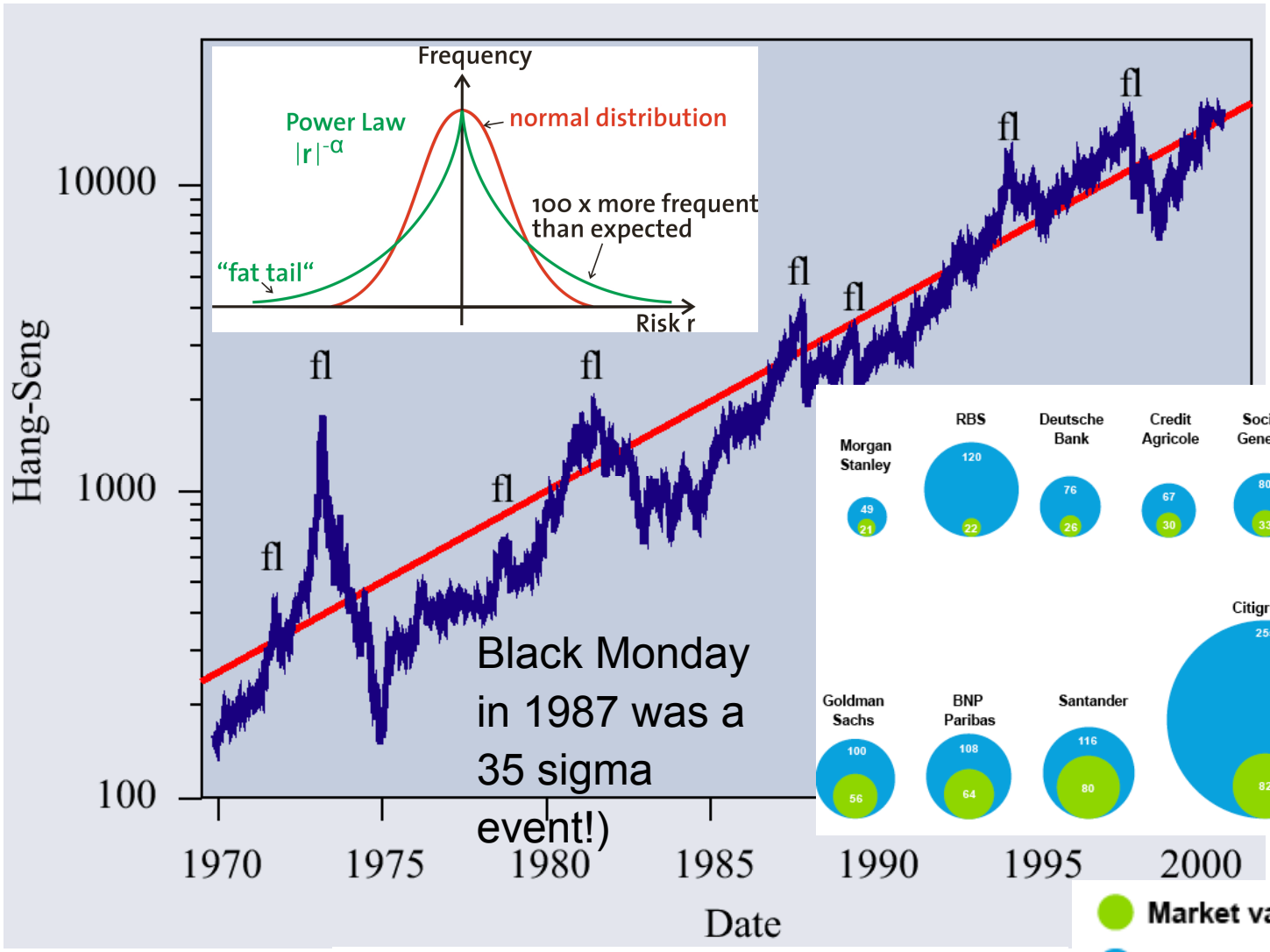
(Illustration: James T. Pendergrast)

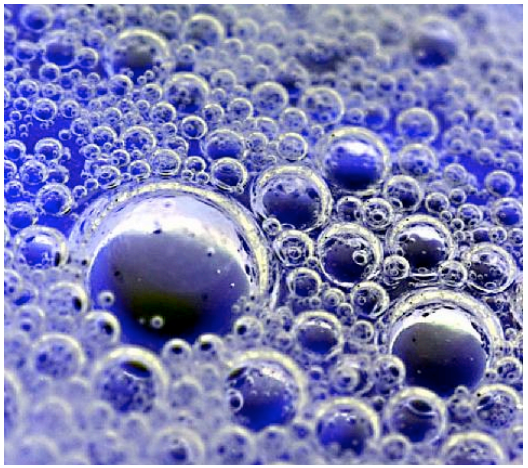
Week 11: Conflict and War

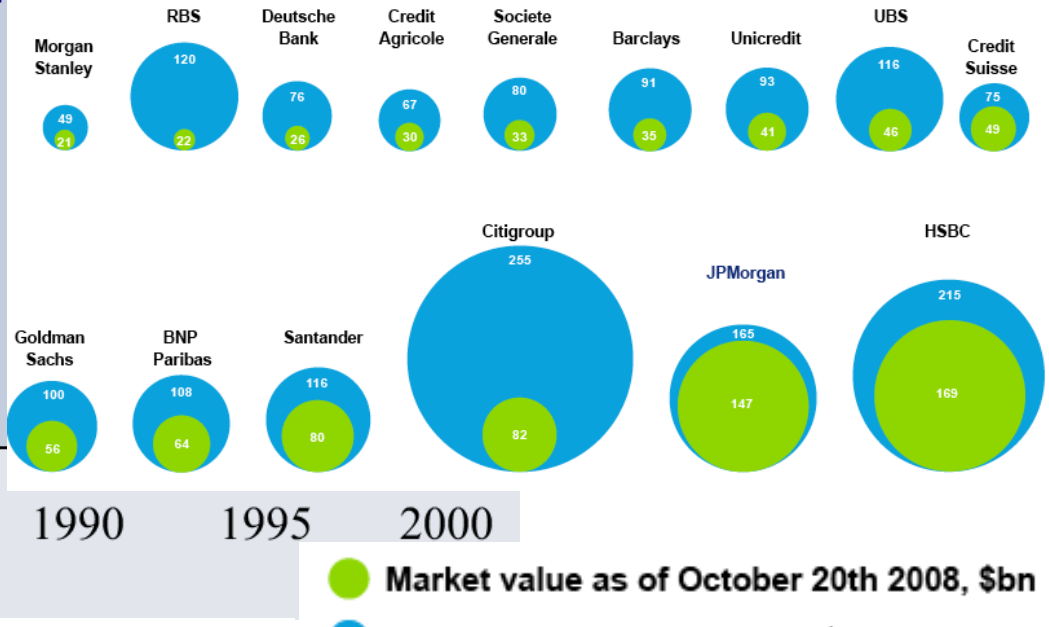




Week 12: Financial Crises and Bubbles







Source: J.P. Morgan, Bloomberg, Oct 20 2008

Grading for this course

Grading

- Your grade will be based on two things
  1. A written exam at the end of the course
  2. A modeling exercise
- Both parts will have equal impact (50 percent) on your grade
- The exam will cover all sessions of the course

The modeling exercise

- Identify an interesting research problem
- Develop a new model, or build on an existing one
- Analyze the model with the methods that we introduce here.
- Write your results up (max 3 pages)
- Discuss potential policy implications of your results.

- The exercise must be handed in two weeks after the exam.
- Group work is not allowed.