Global Participatory Computing for Our Complex World

Dirk Helbing (ETH Zurich)

FuturICT

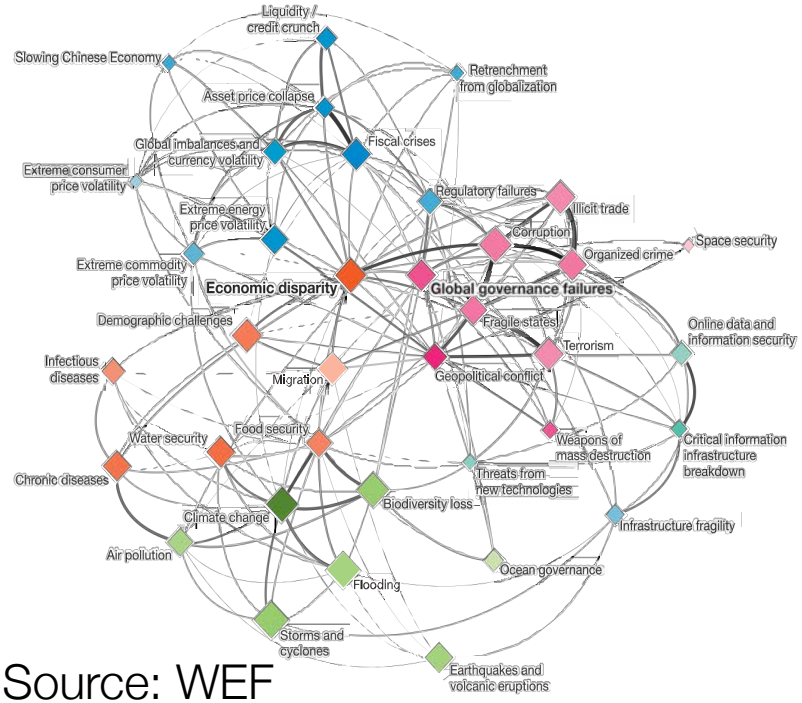
www.futurict.eu

New science and technology to understand and manage our complex world in a more sustainable and resilient way

What It Means to Live in an Information Age

Hyper-connected systems

These have created great opportunities, but also systemic risks and too much complexity



Source: WEF

Big Data

Will produce more data in next 10 years than in previous 1000 years

ICT is part of the problem, but also key to the solution! Need to understand socially interacting systems!

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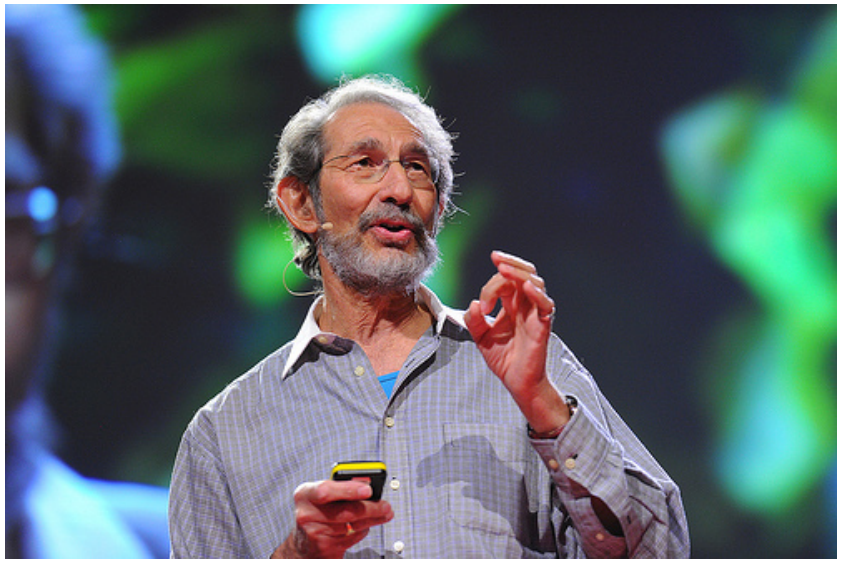
We Can‘t Anymore Do Business As Usual

“Our financial, transportation, health system are broken.”

Sandy Pentland, MIT Media Lab



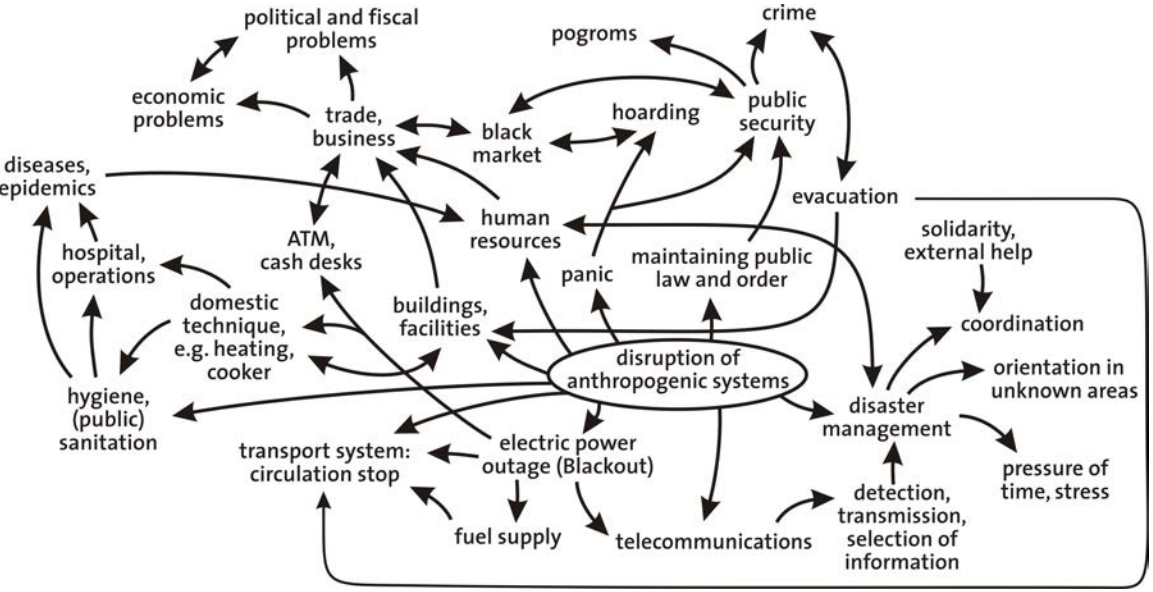
“We are seeing an extraordinary failure of our current political and economic system.”

Geoffrey West, former president of the Santa Fe Institute

Networking is Good … But Promotes Cascading Effects

- We now have a global exchange of people, money, goods, information, ideas…

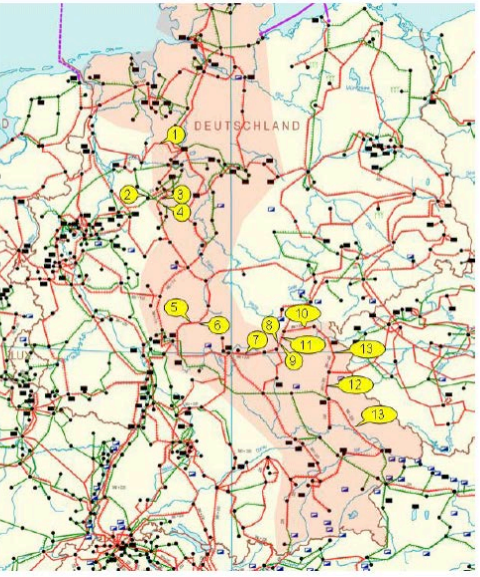
- Globalization and technological change have created a strongly coupled and interdependent world

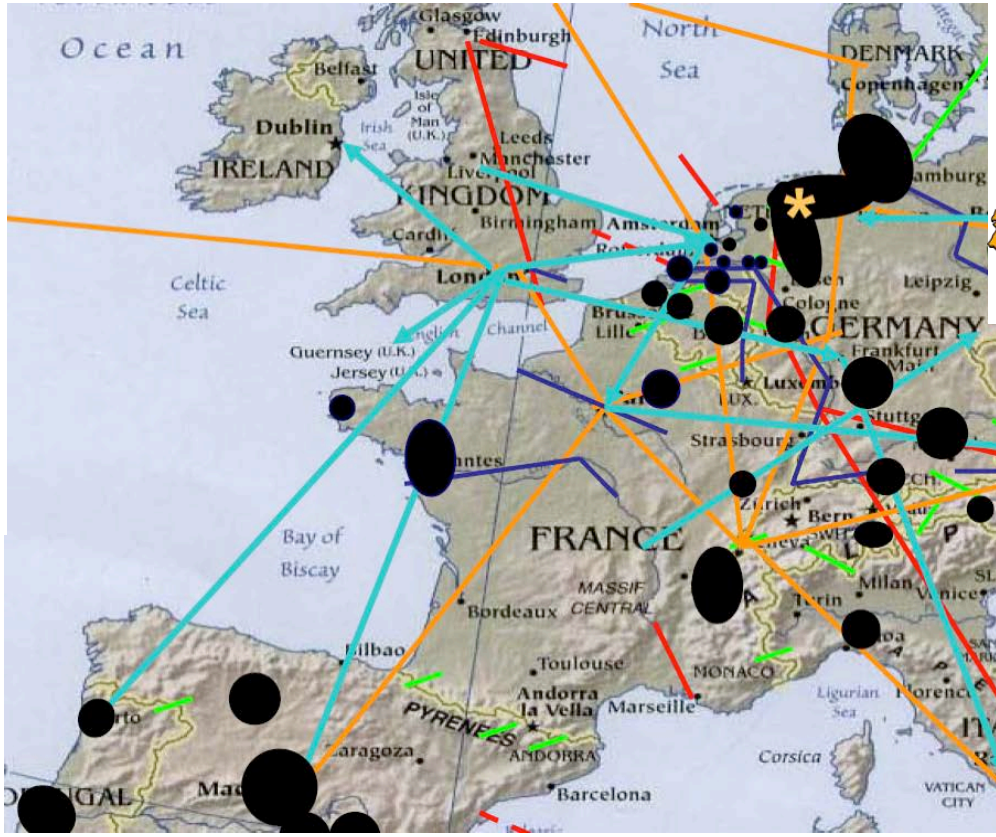


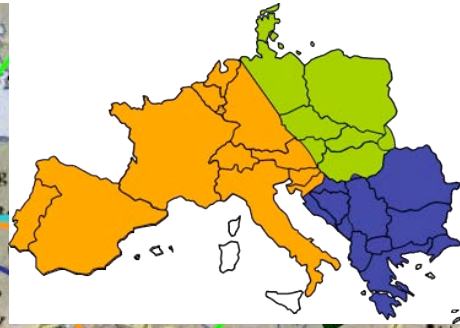
Network infrastructures create pathways for disaster spreading!
Need adaptive decoupling strategies.

Cascading Effect and Blackout in the European Power Grid

Failure in the continental European electricity grid on November 4, 2006







EU project IRRIIS: E. Liuf (2007) Critical Infrastructure protection, R&D view

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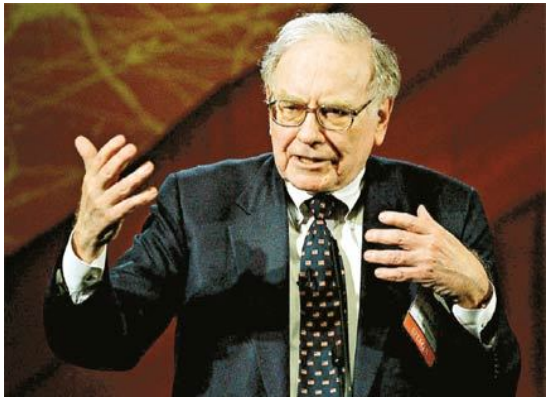
Are Derivatives Financial Weapons of Mass Destruction?



Buffett warns on investment 'time bomb'

Derivatives are financial weapons of mass destruction

Warren Buffett

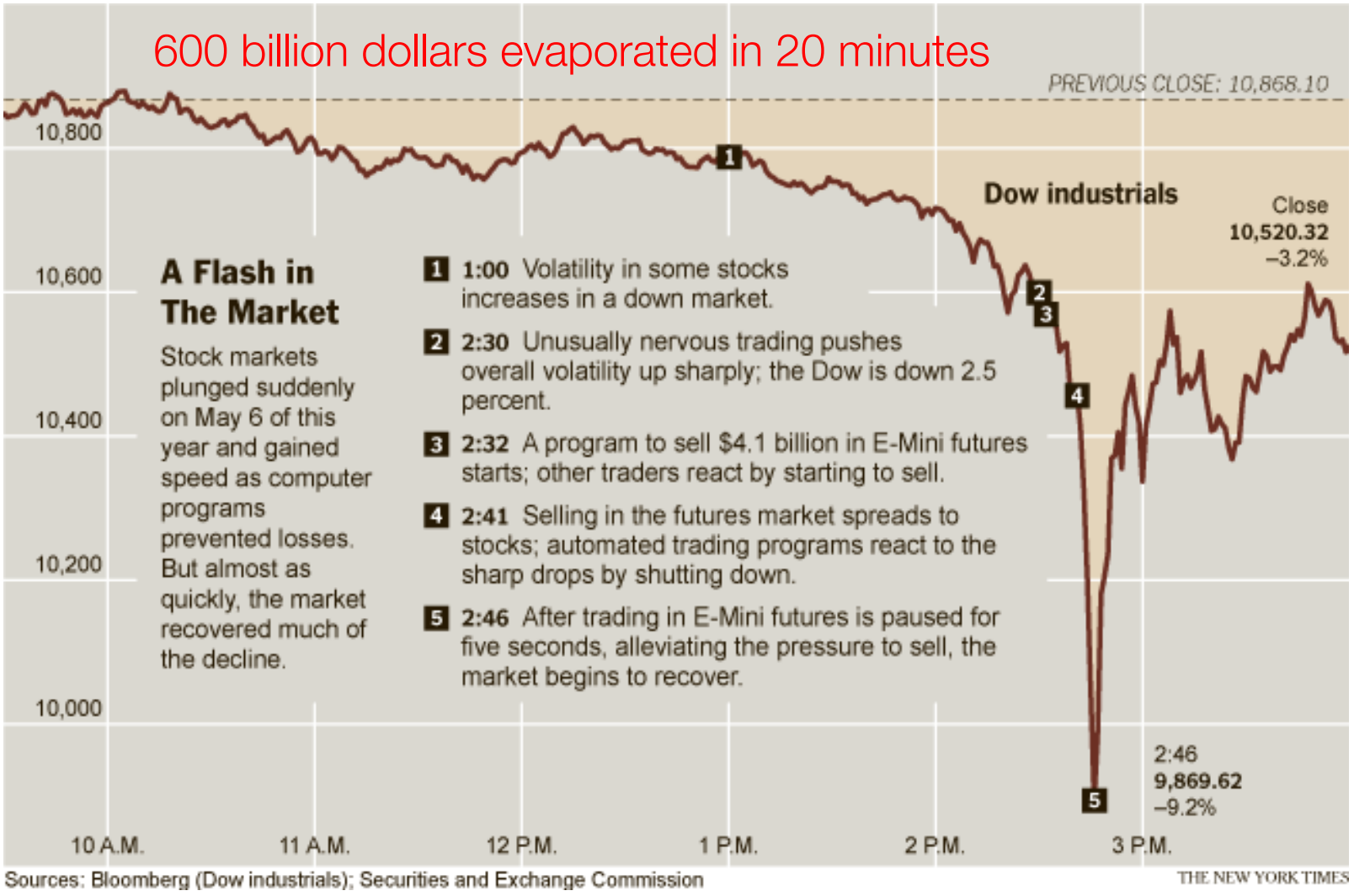
The rapidly growing trade in derivatives poses a "mega-catastrophic risk" for the economy ..., legendary investor Warren Buffett has warned.

The world's second-richest man made the comments in his famous and plain-spoken "annual letter to shareholders", excerpts of which have been published by Fortune magazine.

The derivatives market has exploded in recent years, with investment banks selling billions of dollars worth of these investments to clients as a way to off-load or manage market risk.

But Mr Buffett argues that such highly complex financial instruments are time bombs and "financial weapons of mass destruction" that could harm not only their buyers and sellers, but the whole economic system. **(BBC, 4 March, 2003)**

The Flash Crash on May 6, 2010



The flash crash turned solid assets into penny stocks within minutes.
Was an interaction effect, no criminal act, 'fat finger', or error.

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Cascading Effects During Financial Crises

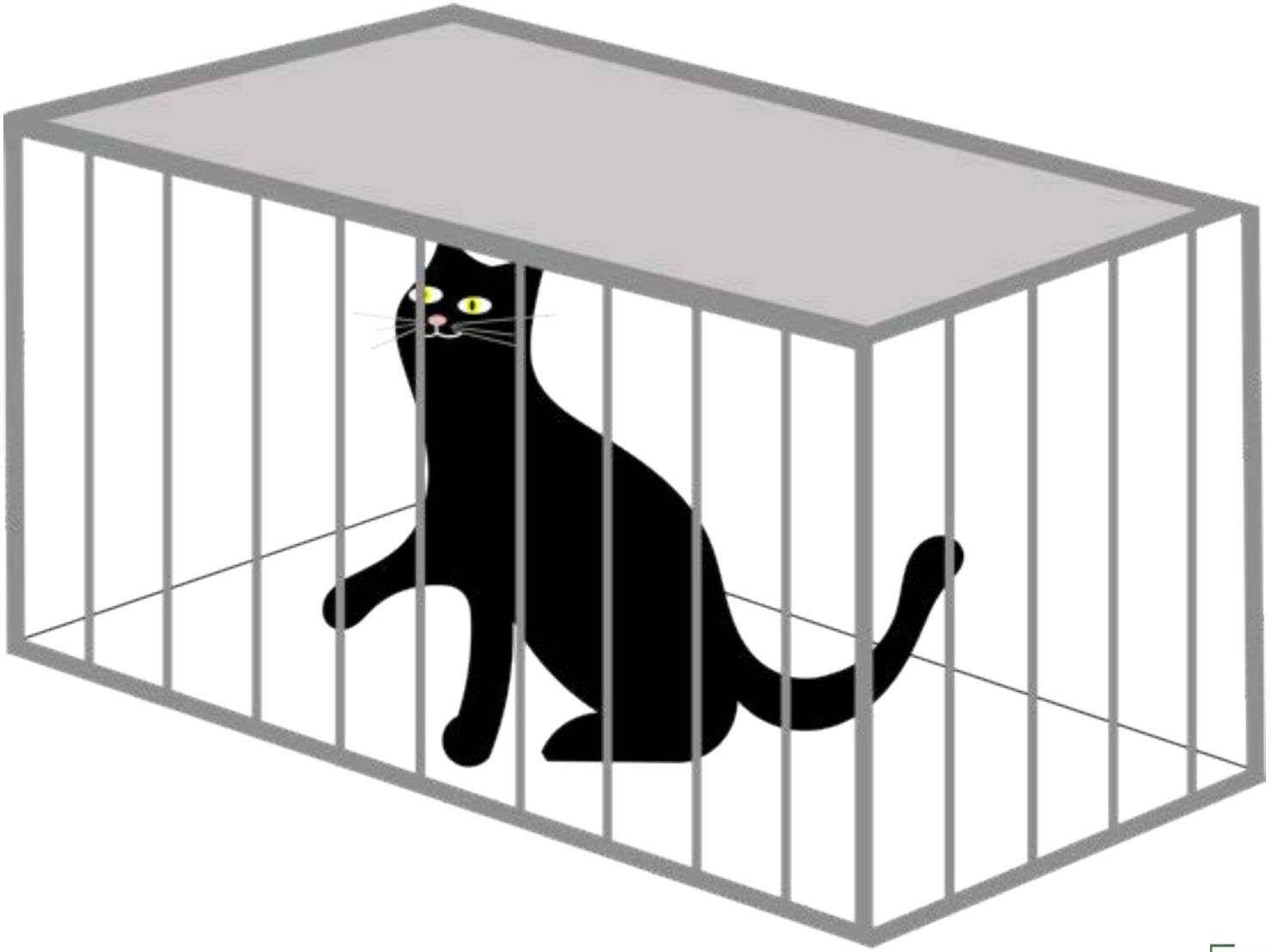
Video by Frank Schweitzer et al.

Need New Science to Fill Knowledge Gaps

For 30 years or so have we globalized our world and pushed for technological revolutions, but the global systems science to understand the resulting complex systems is lacking.

1. Science of systemic risks
2. Practically relevant theory of complex systems
3. New data science
4. Integrated systems design to manage complexity
5. Coevolution of ICT with society

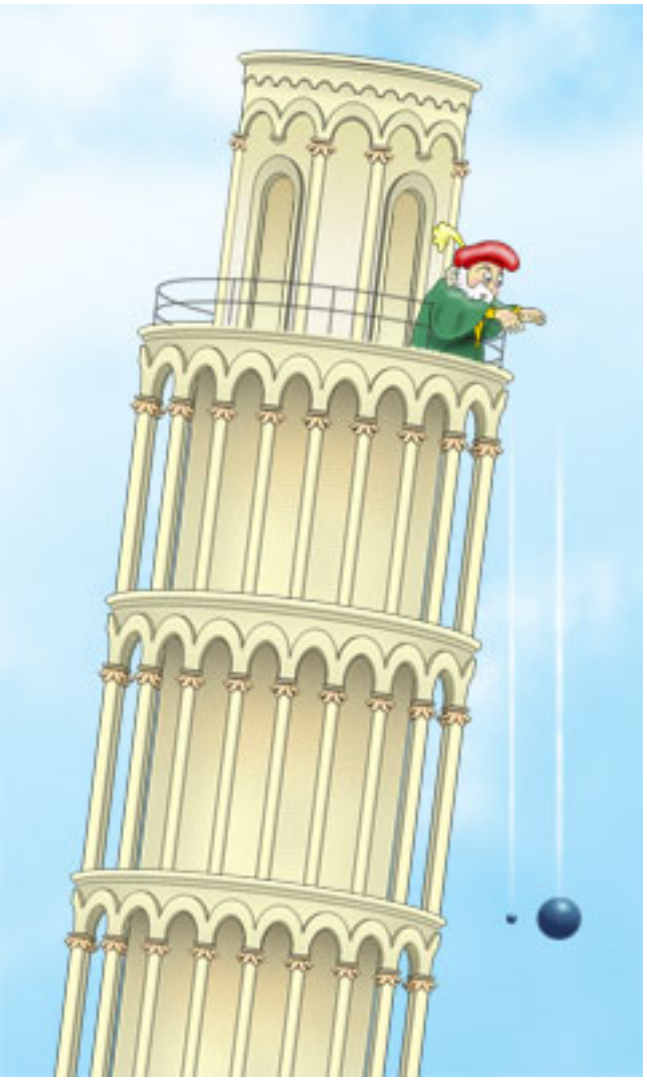
Our Thinking Determines What We See …



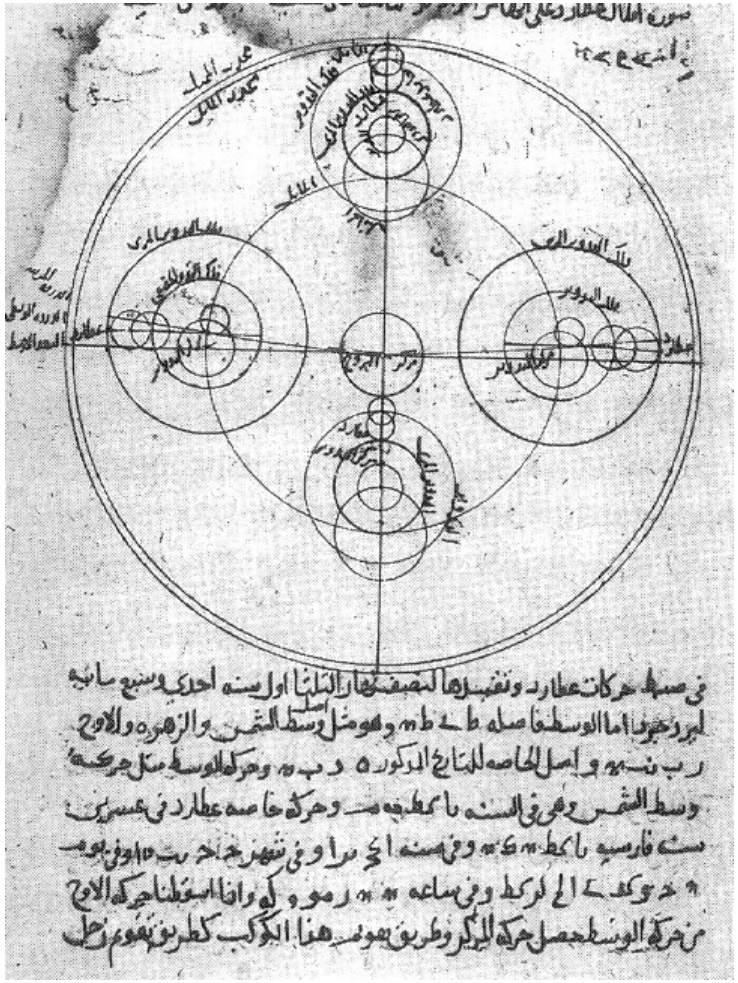
…And What We Can't See…!

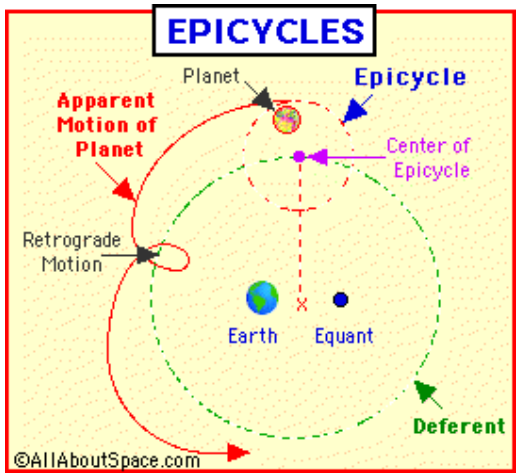
We need to overcome the limitations of our conventional thinking!

We Should Not Trust Our Intuition

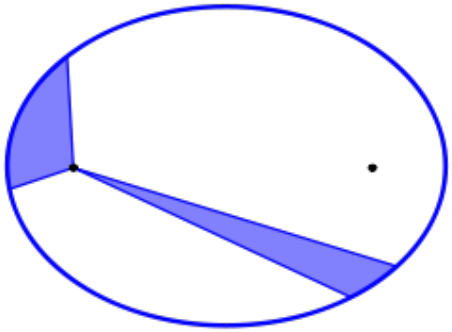


Geocentric Picture:
Epicycles around the Earth





Heliocentric Picture:
Elliptical paths
around the sun



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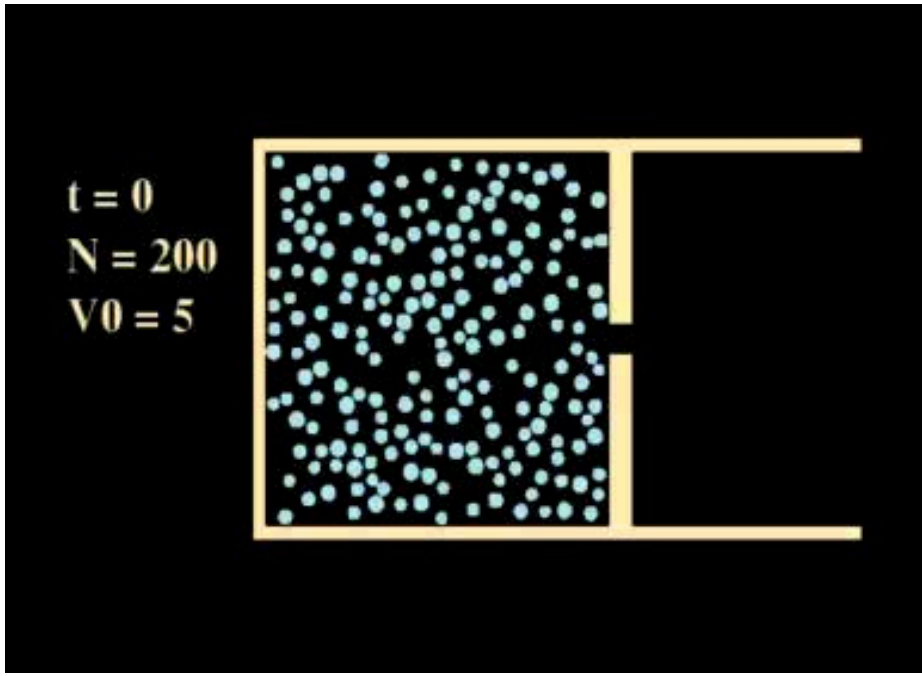
Emergent Phenomena in Pedestrian Crowds

At high densities, several people may compete for the same gap and block each other. This constitutes a conflict and causes intermittent outflows and a faster-is-slower effect.

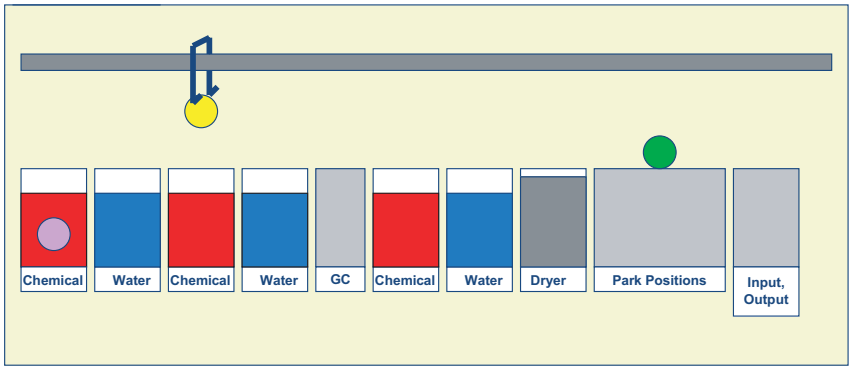


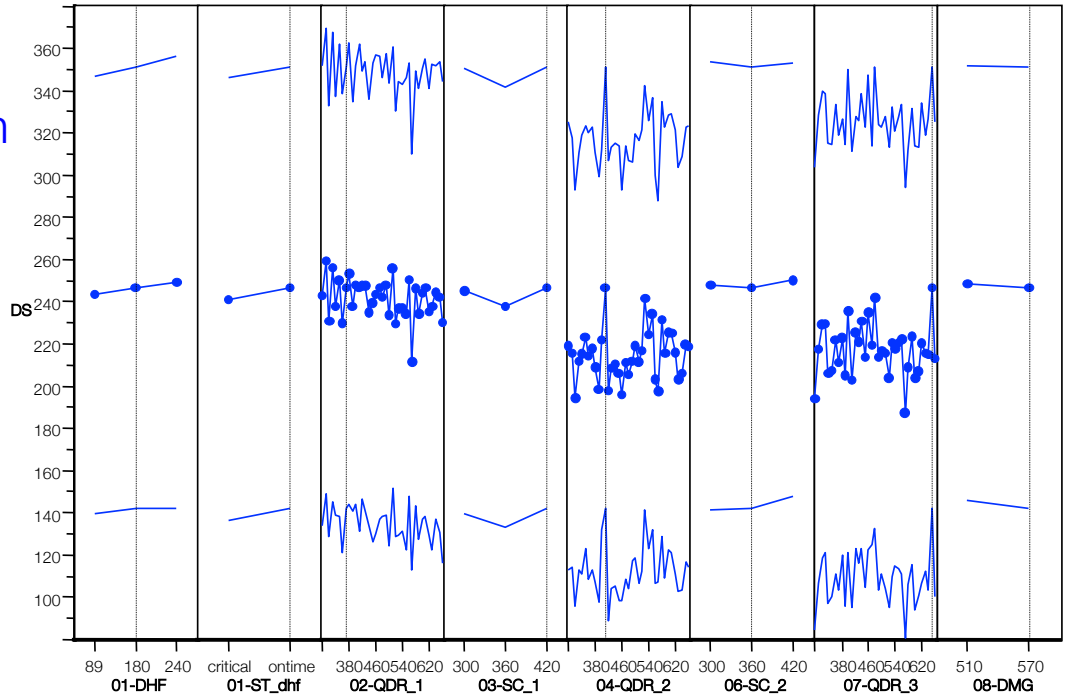
At low densities:
self-organized lane formation,
like Adam Smith's invisible hand

At large densities:
coordination breaks down

Low Predictability Due to the Sensitivity to Varying Model Parameters

Wet Bench in Semiconductor Production





Throughput	TEST_1	TEST_2	TEST_3
Analyse software	266,8	255,9	246,1
Production machine	150,9	155,5	178,4
Difference in w/h	115,9	100,4	67,7

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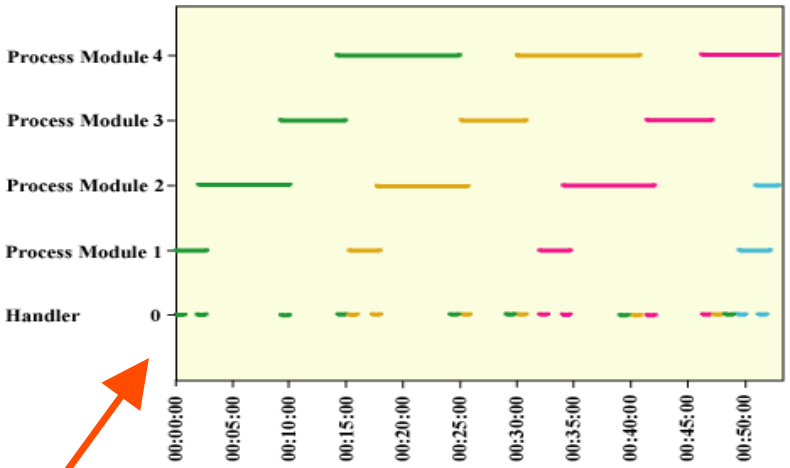
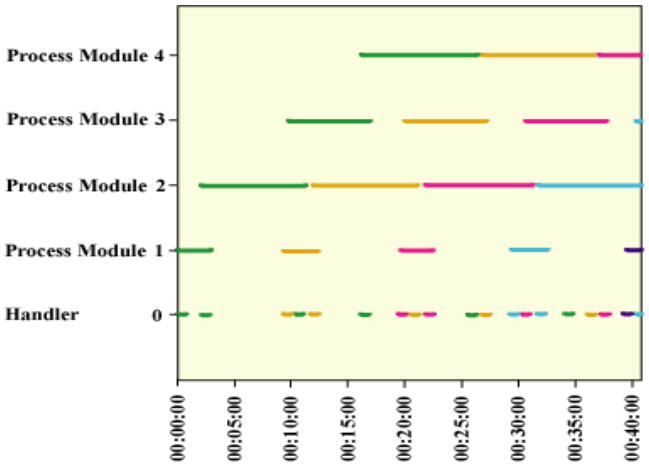
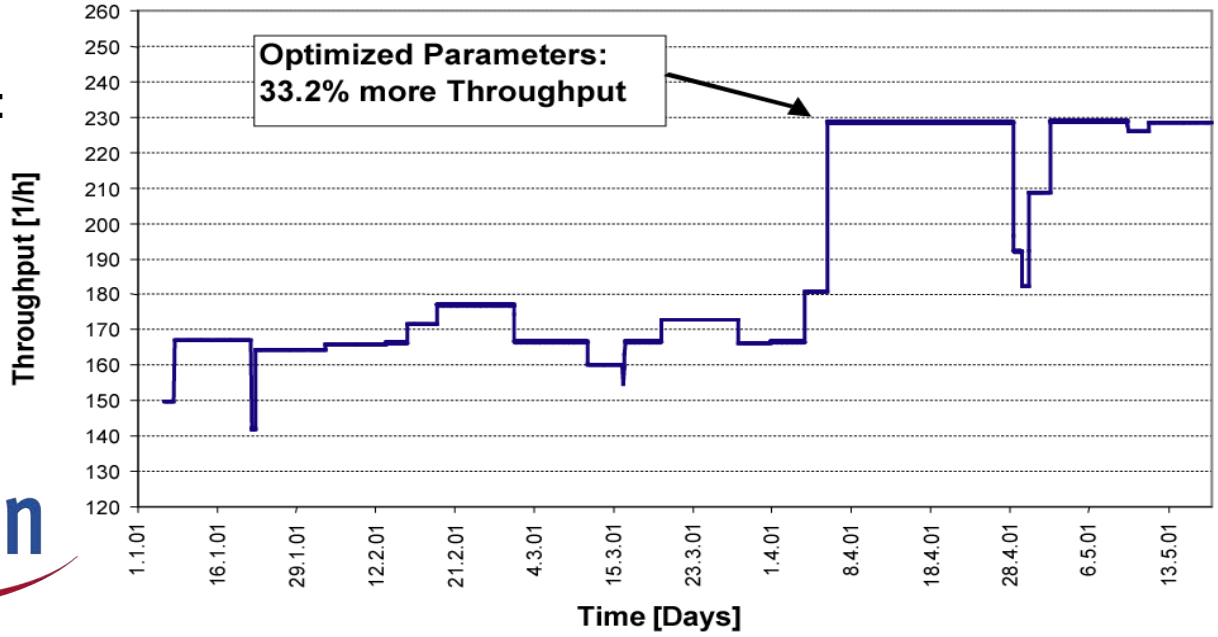
Paradoxical Slower-Is-Faster Effect in Chip Production





Slower-is-faster effect

Old recipe: ca. 170/h



New recipe: ca. 230/h

Infineon

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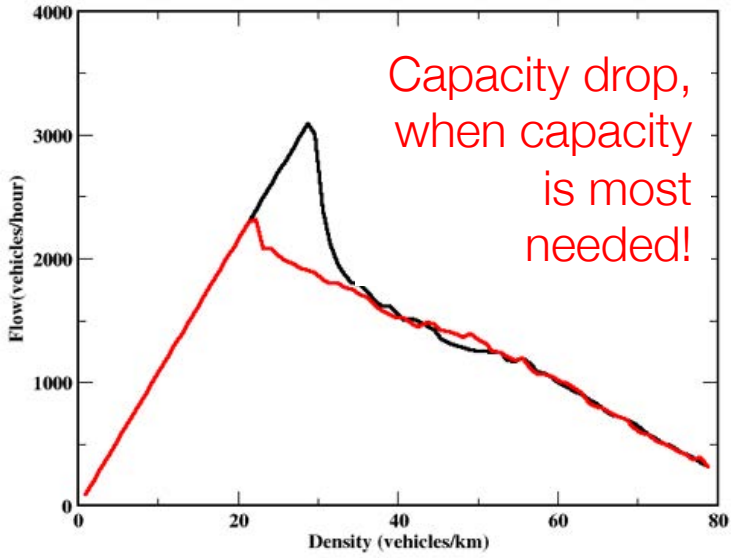
As Coupling Gets Stronger, System Behavior Can Change Completely: Traffic Breakdowns



Thanks to Yuki Sugiyama

At high densities, free traffic flow is unstable:
Despite best efforts, drivers fail to maintain speed

As Coupling Gets Stronger, System Behavior Can Change Completely: Crowd Disasters

At low densities:
self-organized lane formation,
like Adam Smith's invisible hand

Love Parade Disaster in Duisburg, 2010

At large densities: coordination breaks down

Too Much Networking Can Cause Self-Destabilization: Breakdown of Cooperation

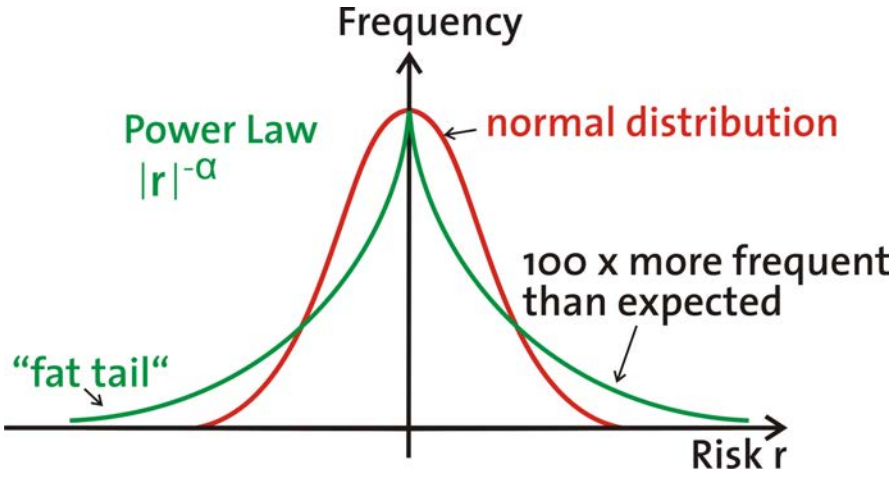
Imitation of best neighbor

- All defectors
- Small probability for strategy mutation

Different recipes, new solutions, and a paradigm shift in our understanding of the world are needed.

Strongly Coupled and Complex System Behave Fundamentally Different

1. Faster dynamics
2. Increased frequency of extreme events – can have any size
3. Self-organization dominates system dynamics
4. Emergent and counterintuitive system behavior, unwanted feedback, cascade and side effects
5. Predictability goes down
6. External control is difficult
7. Larger vulnerability



Change of perspective (from a component- to an interaction-oriented view) will reveal new solutions!

Need a science of multi-level complex systems!

Instruments to Explore the World

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

Hubble, Nasa

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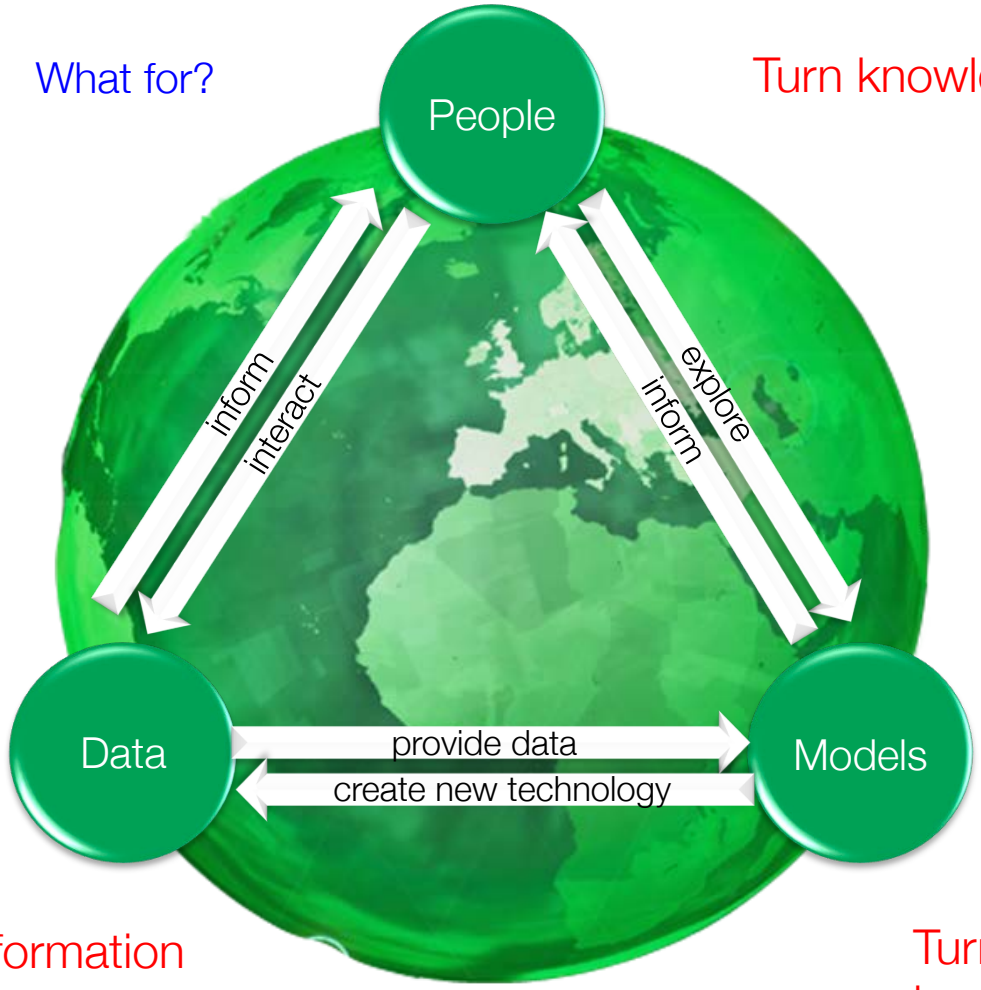
Build platforms
to explore & interact

What for?

Turn knowledge into wisdom



What is?

Create systems
to sense &
understand

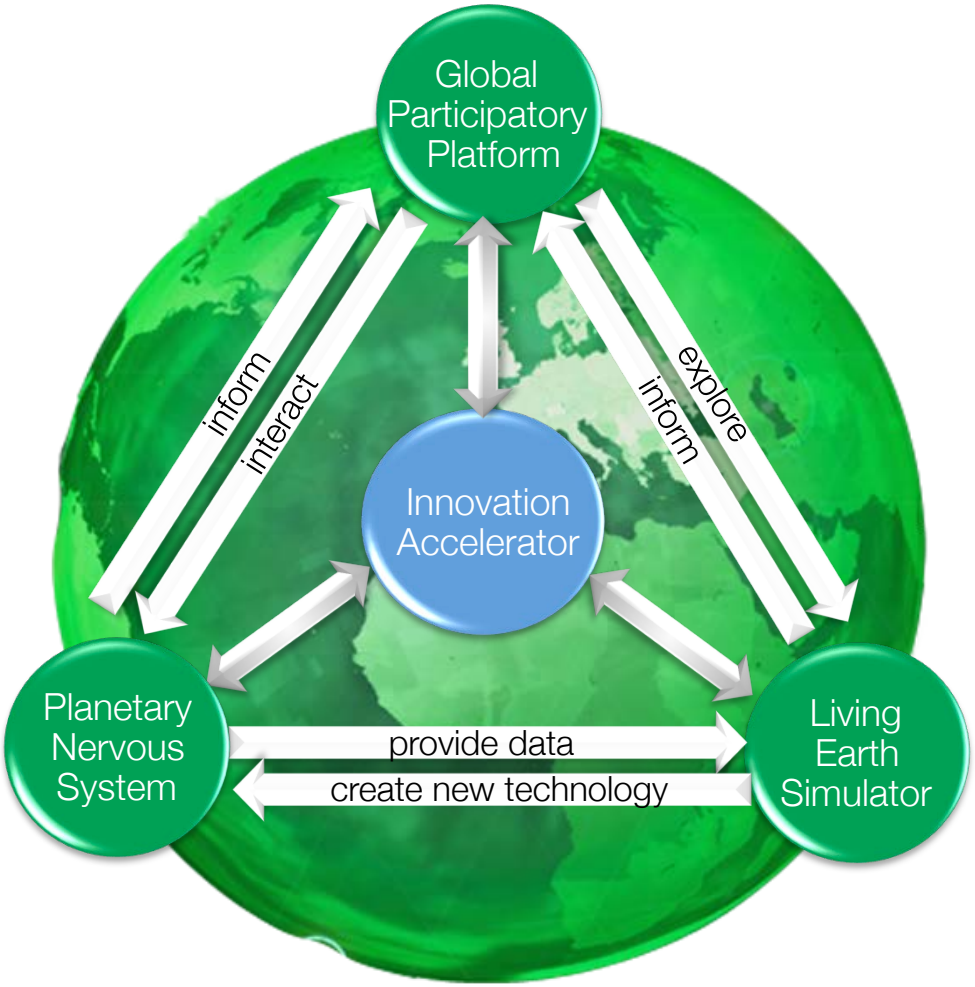
Turn data into information

What if?

Develop models
to simulate &
predict

Turn information into
knowledge

Platforms
to explore & interact



Systems
to sense &
understand

Models
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Platforms
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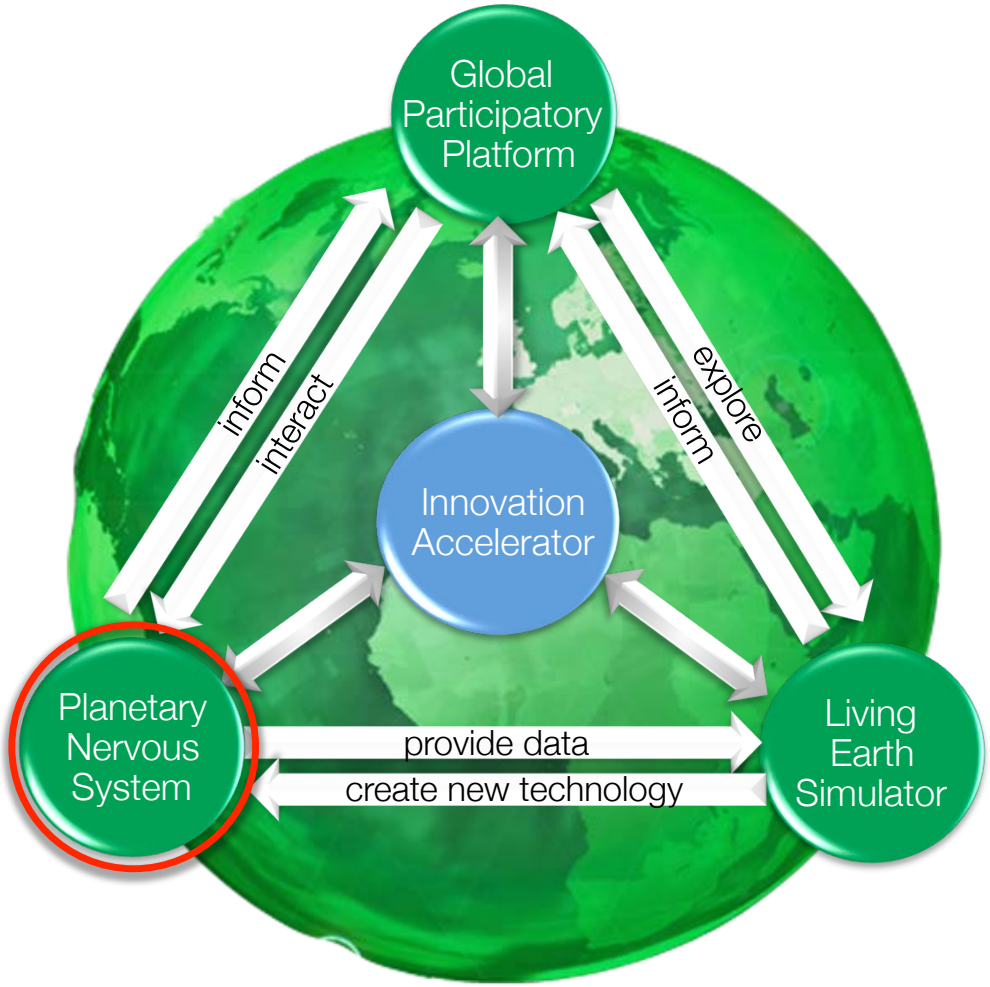

Systems
to sense &
understand

Models
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Crowd-Sourcing 3D Environments

See also Open Streetmap - the free Wiki world map

More Sustainability and Resilience through Collective, ICT-Enabled (Self-)Awareness

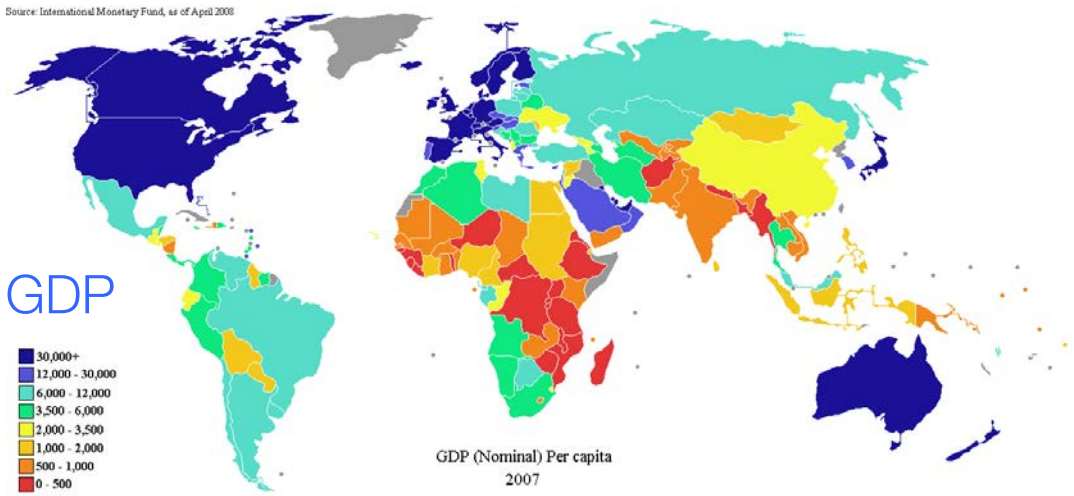
1. Goal: Measure the world's state and 'social footprint' in real time, detect possible threats and opportunities
2. Use smartphones, social media, digital news sources, sensors…
3. Incentives to provide data
4. Control over own data
5. Privacy-respecting data mining

Painting by Maurits Cornelis Escher

Examples: Open streetmap, earthquake sensing and warning

Requires a 'Planetary Nervous System' to answer 'what is' questions and a 'Living Earth Simulator' to answer 'what if' questions.

New Compasses for Decision-Makers

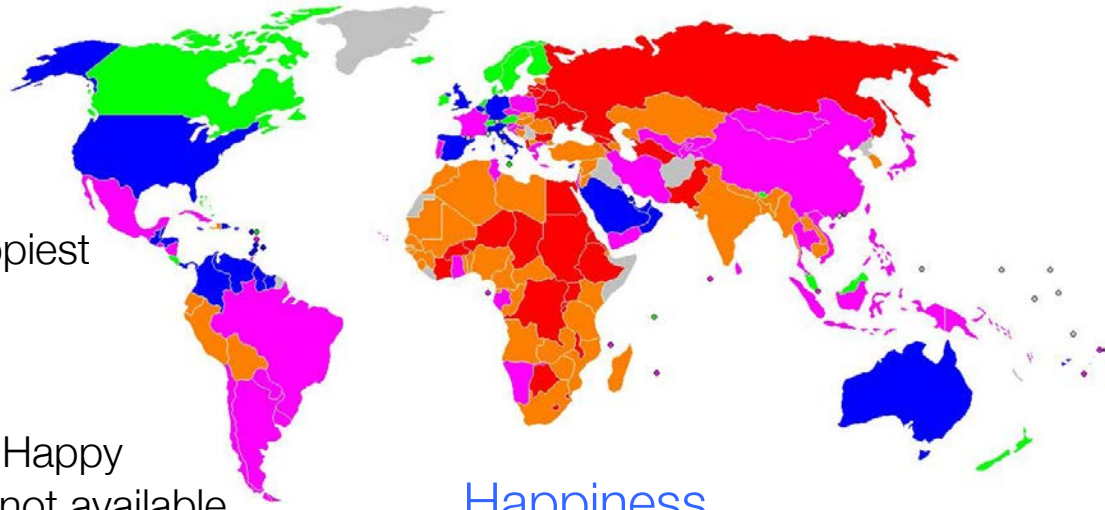


GDP

Consider social capital:

- Solidarity, cooperativeness,
- compliance,
- reputation, trust,
- attention, curiosity,
- happiness, health,
- environmental care…

Goal: Create indices better than GDP/capita, considering health, environment, social well-being, … to promote sustainability



Green = Happiest
Blue
Purple
Orange
Red = Least Happy
Grey = Data not available

Happiness

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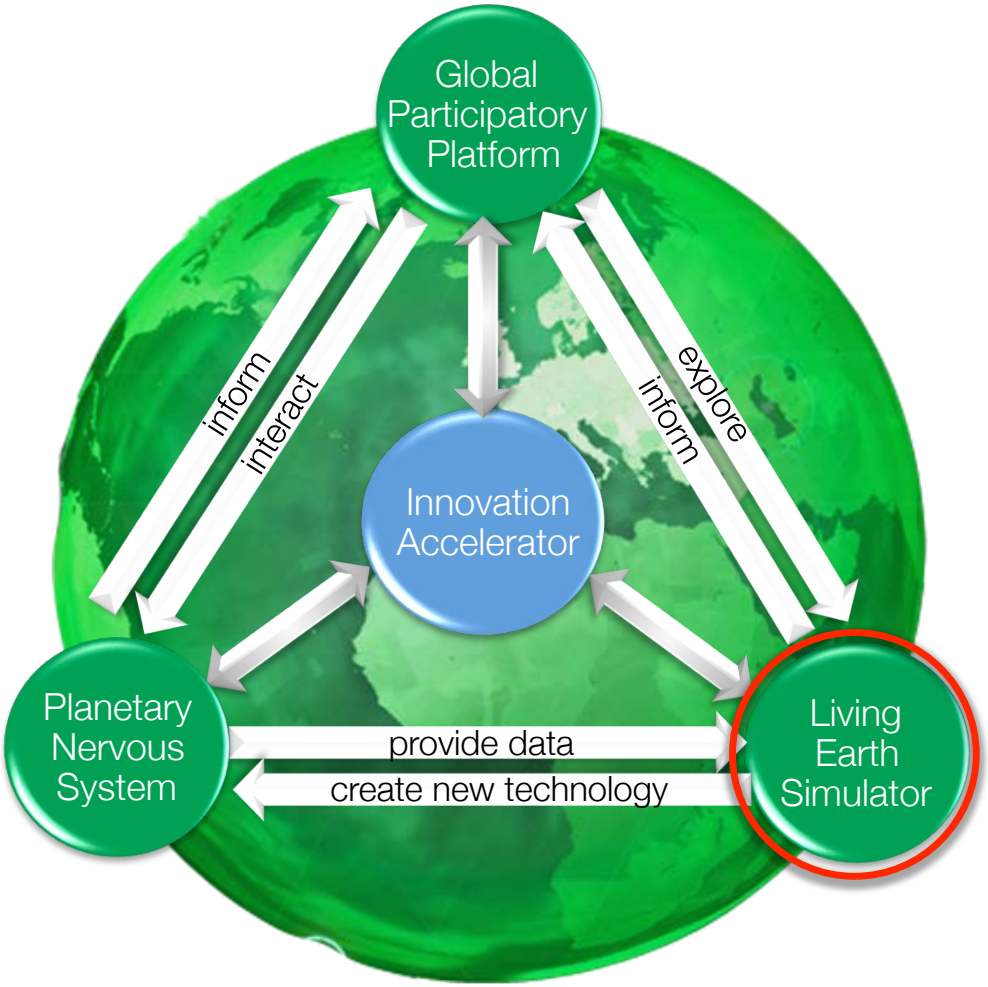
Platforms
to explore & interact



Systems
to sense &
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Models
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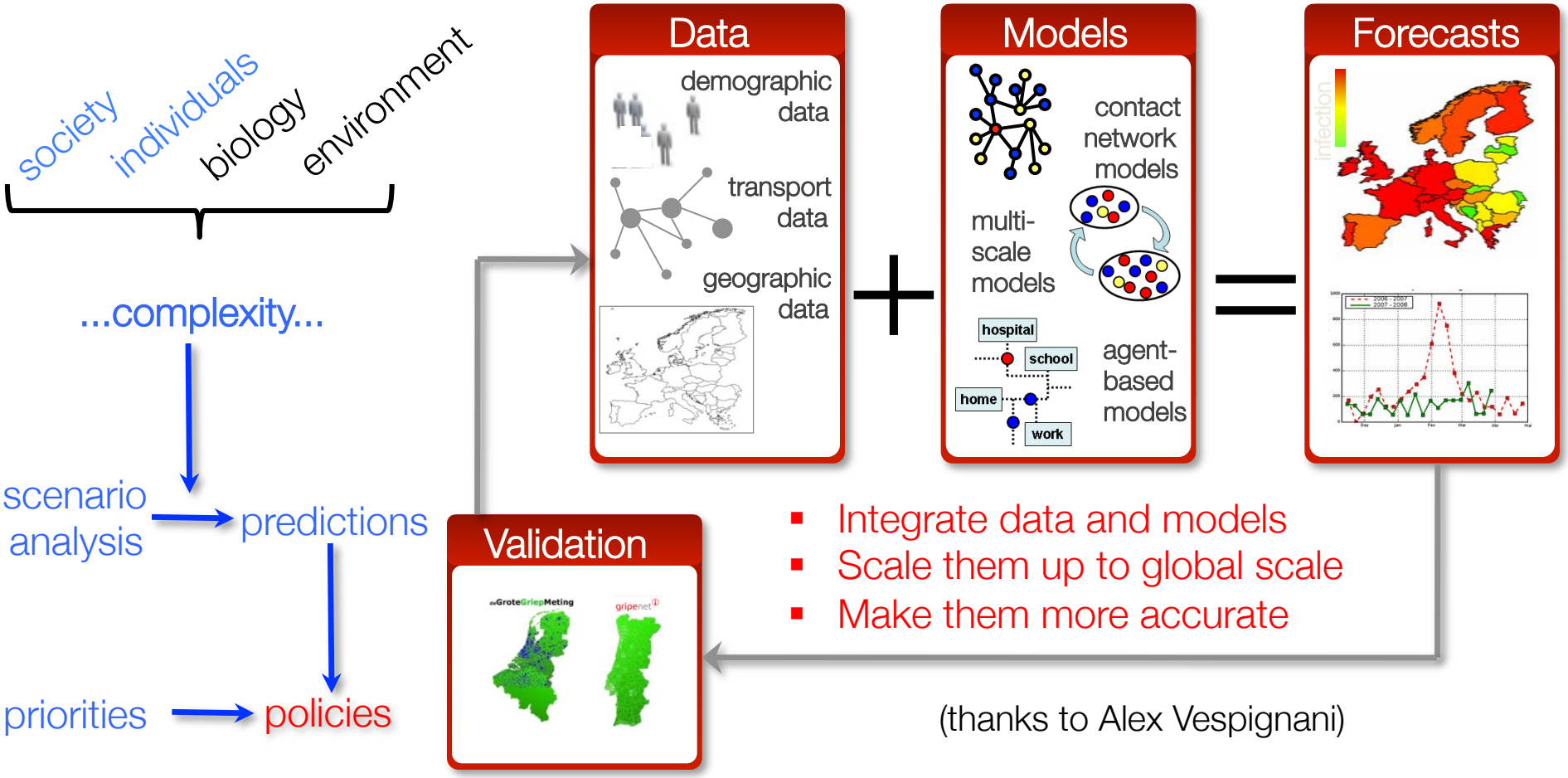
Building FuturICT's Living Earth Simulator

Analysis of "What if …" Scenarios



Possibilities are limited, but even short-term prediction can be useful, as weather forecasts or new traffic light controls show.

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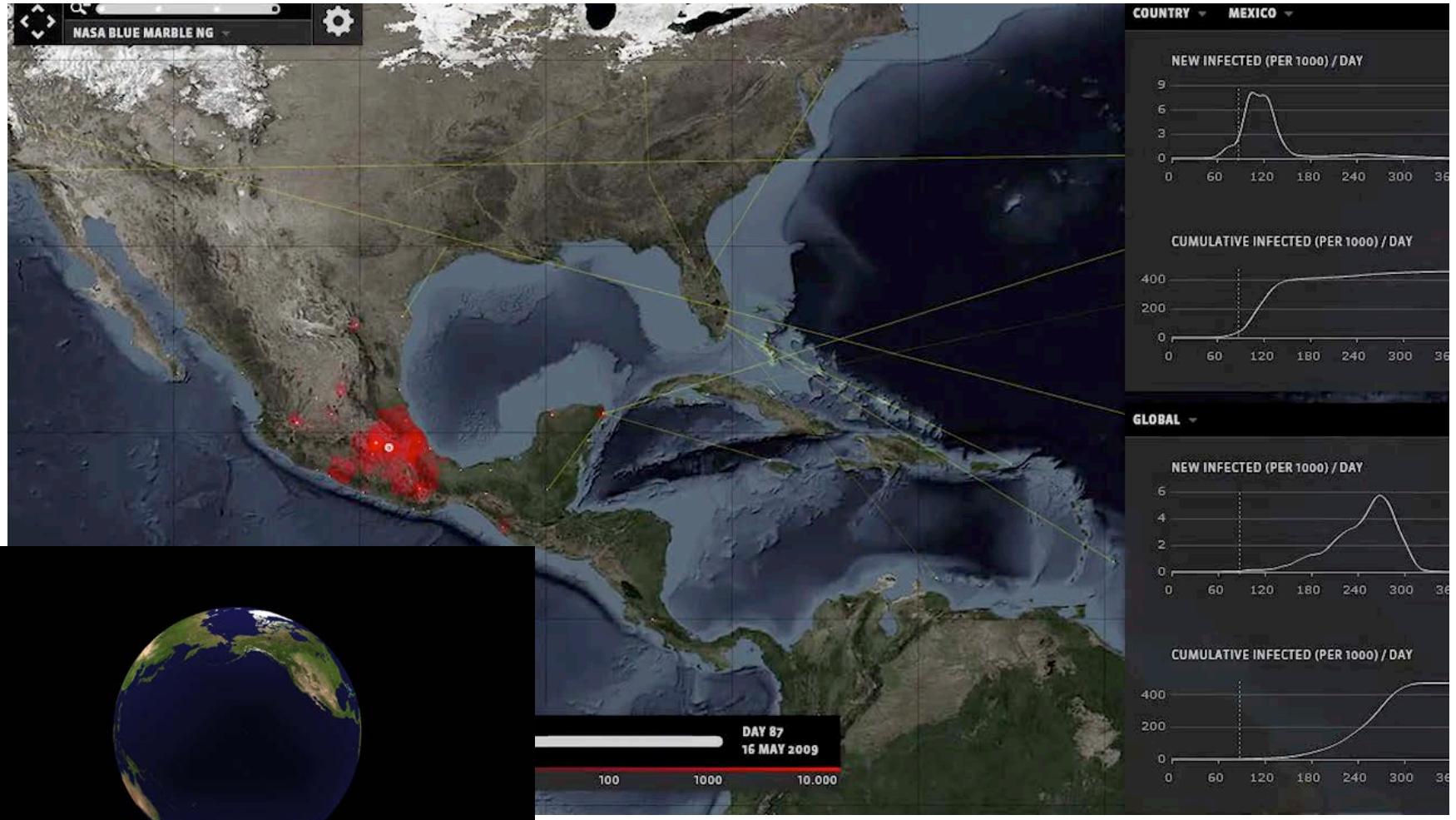
Modelling the global spread of H1N1,

combining models of epidemiology and global travel data



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Building FuturICT's Living Earth Simulator

- Integrate existing models (traffic, production, economic system, crowd behavior, social cooperation, social norms, social conflict, crime, war…)
- Scale them up to global scale
- Increase degree of detail, accuracy (statistical and sensitivity analysis, calibration, validation, identification of crucial and questionable modeling assumptions,…)

Interactive Virtual Worlds for Exploration

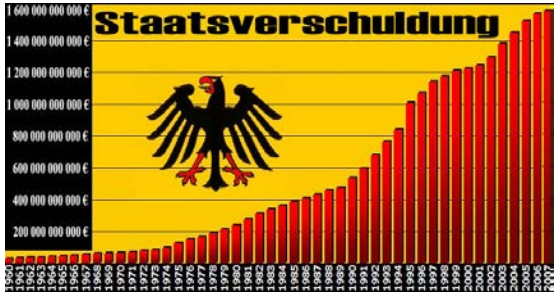
Multi-player serious online games
across diverse platforms

Interactive Virtual Worlds as Experimental Testbed

For example different financial architectures, voting rules, transparency and privacy settings, etc.

Managing Complexity: Is It a Lost Battle?

- In a strongly varying world, strict stability and control is not possible anymore or excessively expensive
- Example: Public spending deficits
- Hierarchically organized structures have a critical size, beyond which they become unstable



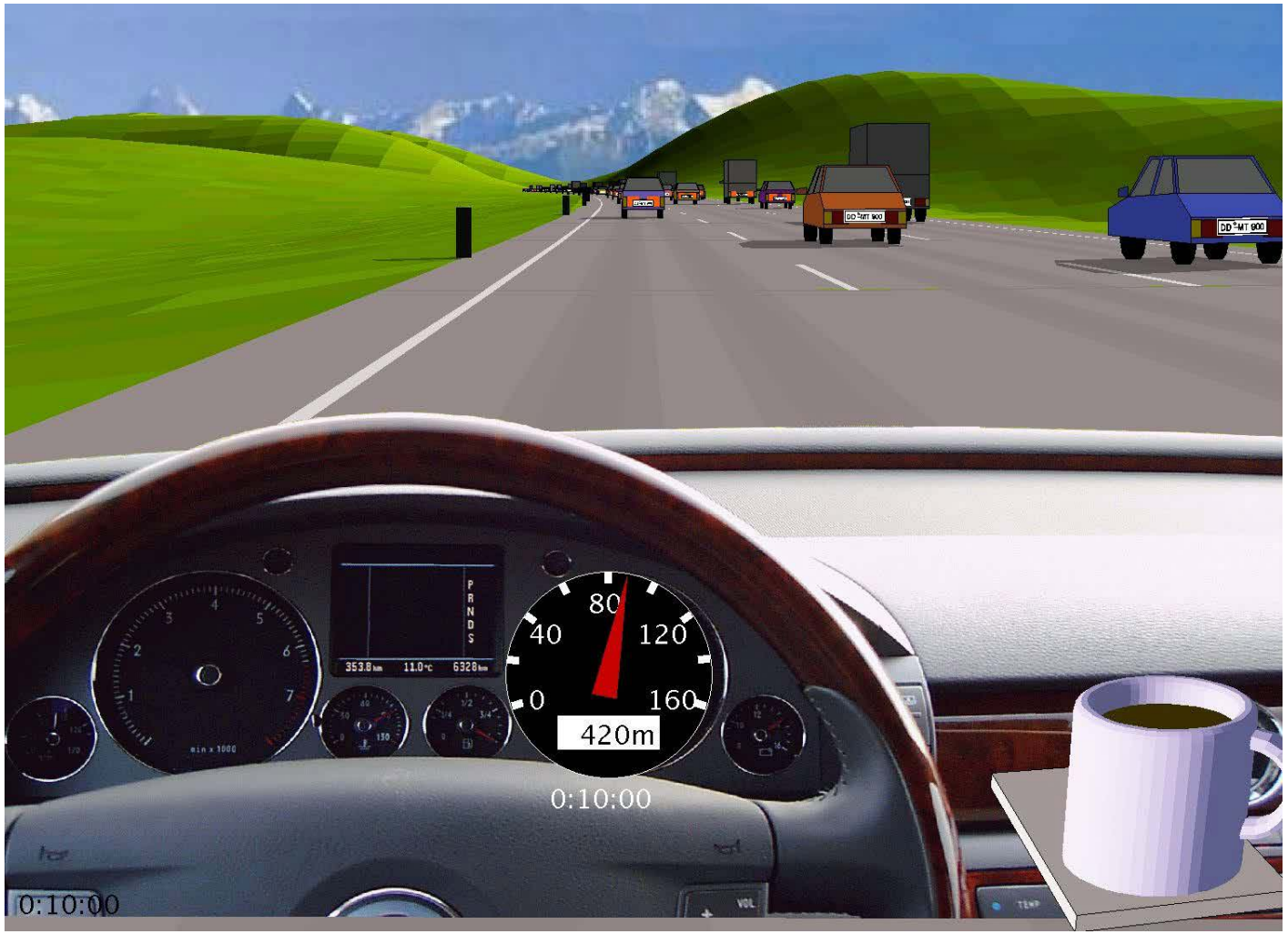
- Examples: Decay of Soviet Union; many failed mergers in the last decade (Daimler-Chrysler, BMW-Rover, Allianz-Dresdner Bank, …)
- A paradigm shift towards flexible, agile, adaptive systems is needed, possible - and overdue!

Boeing 747: Constructed for stable flight

Su-47: Utilizes dynamic instability

How to Utilize Properties of Complex Systems? Don‘t Fight the System, Go With the Flow!

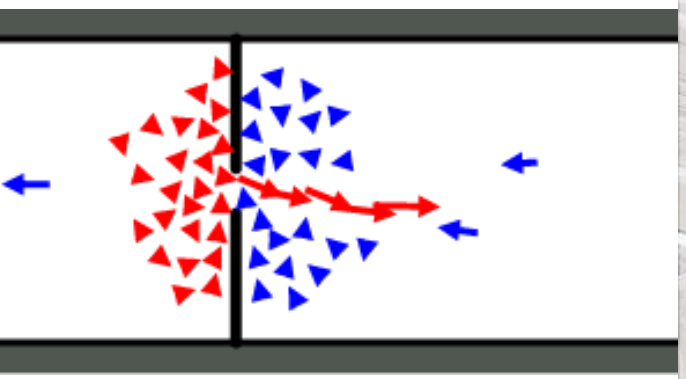
Managing Complexity: Modifying Interactions Allows to Promote Favorable Self-Organization

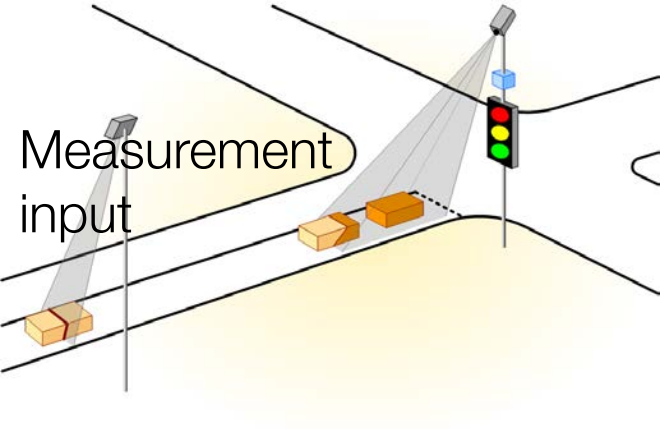


Self-Control of Traffic Lights: Making More Out of Scarce Resources

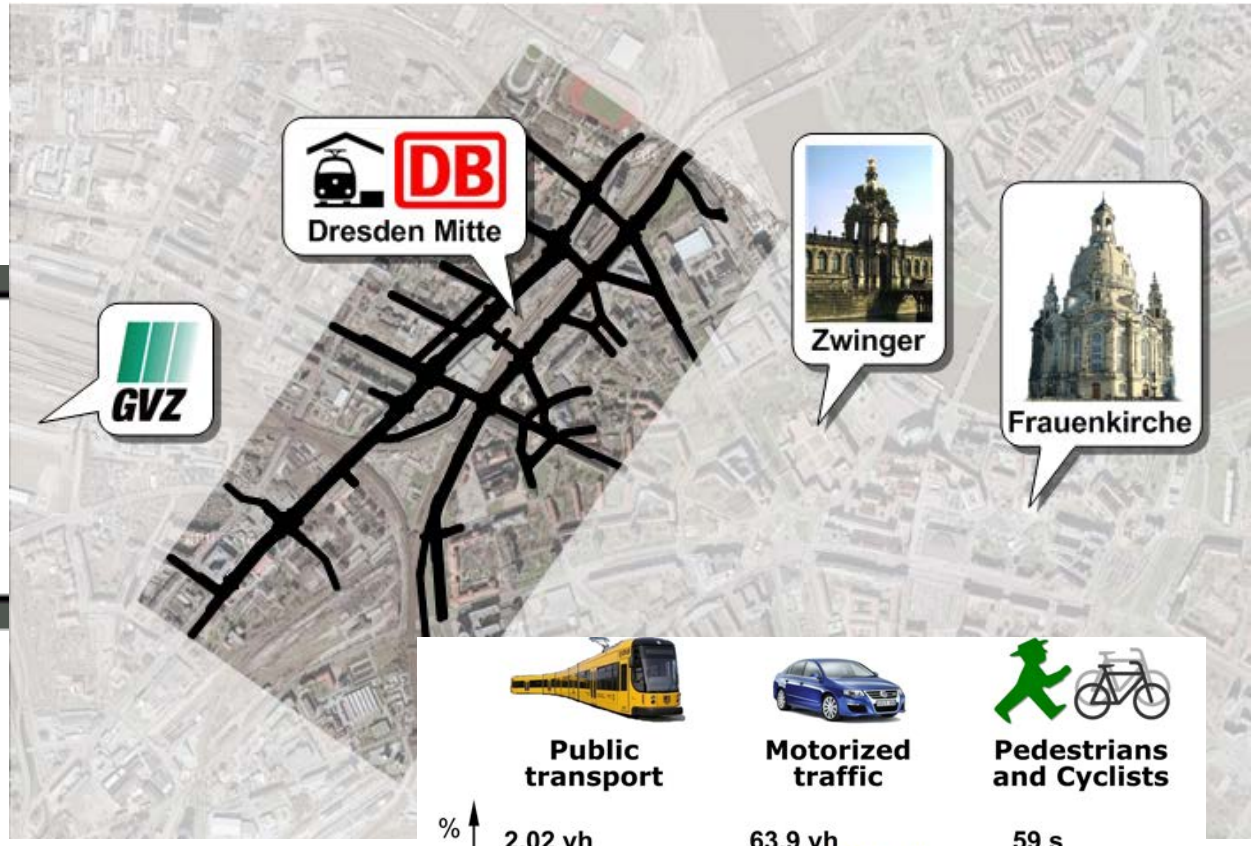
Smarter Cities

Inspiration: Self-organized oscillations at bottlenecks

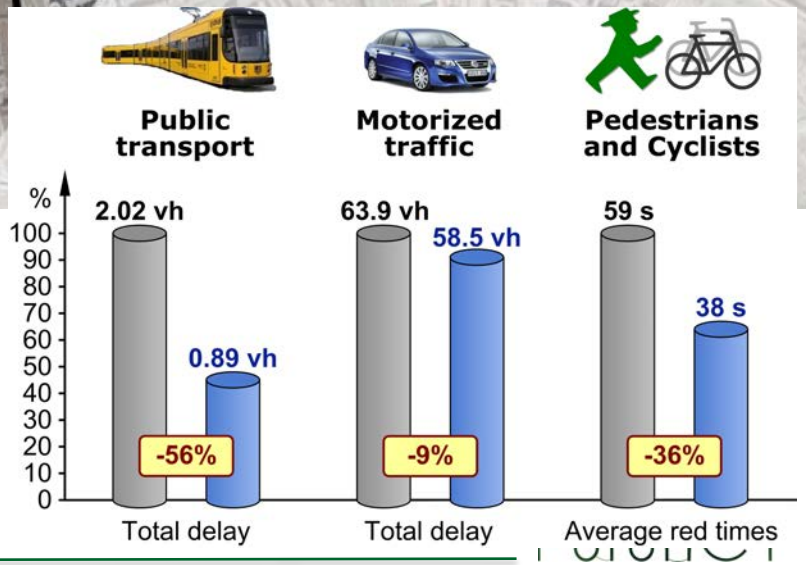




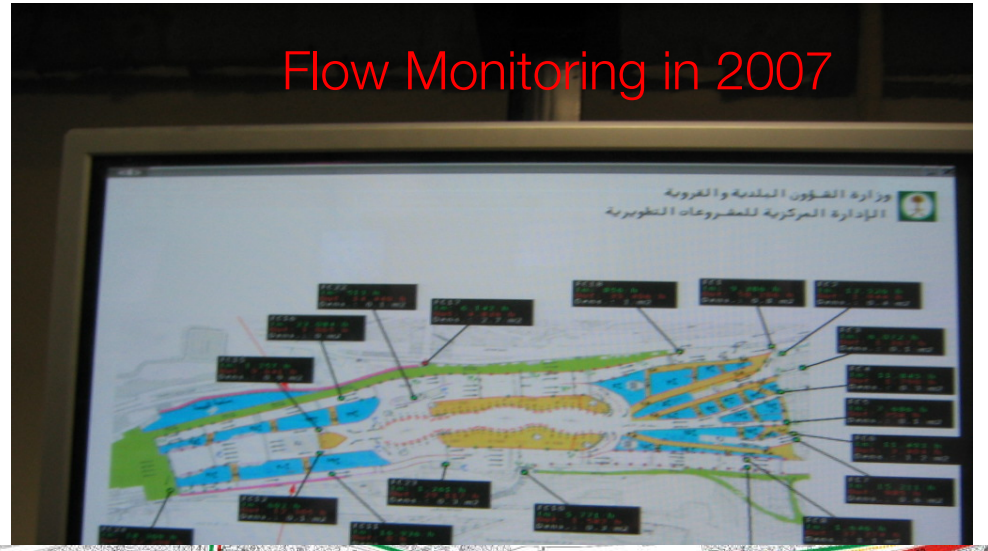
Licensing Opportunity



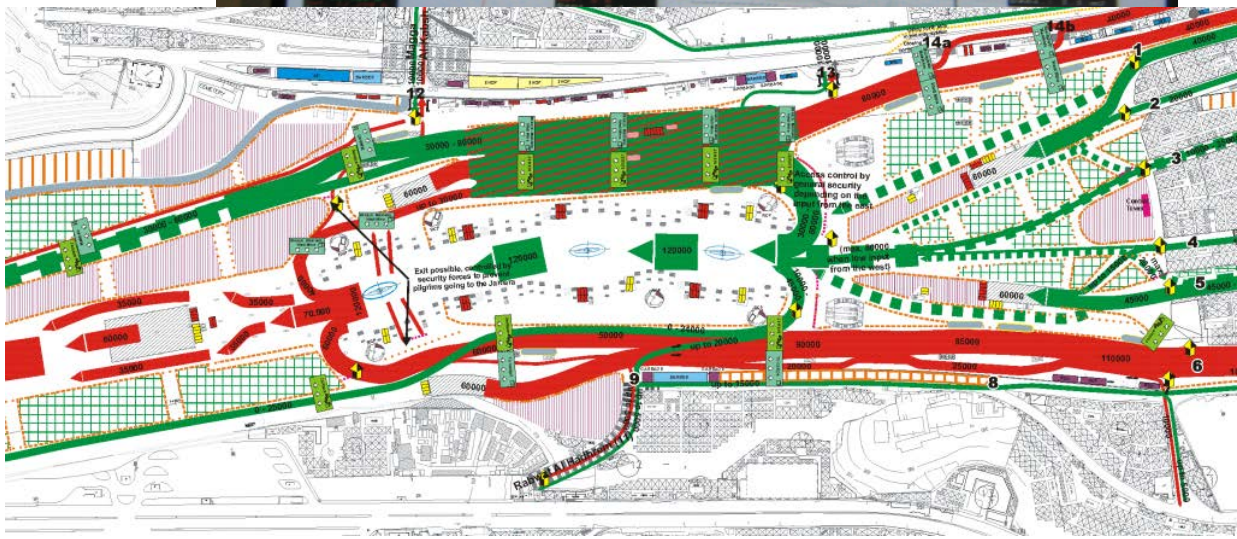
Optimal compromise between coordination and local flexibility



Avoiding Crowd Disasters

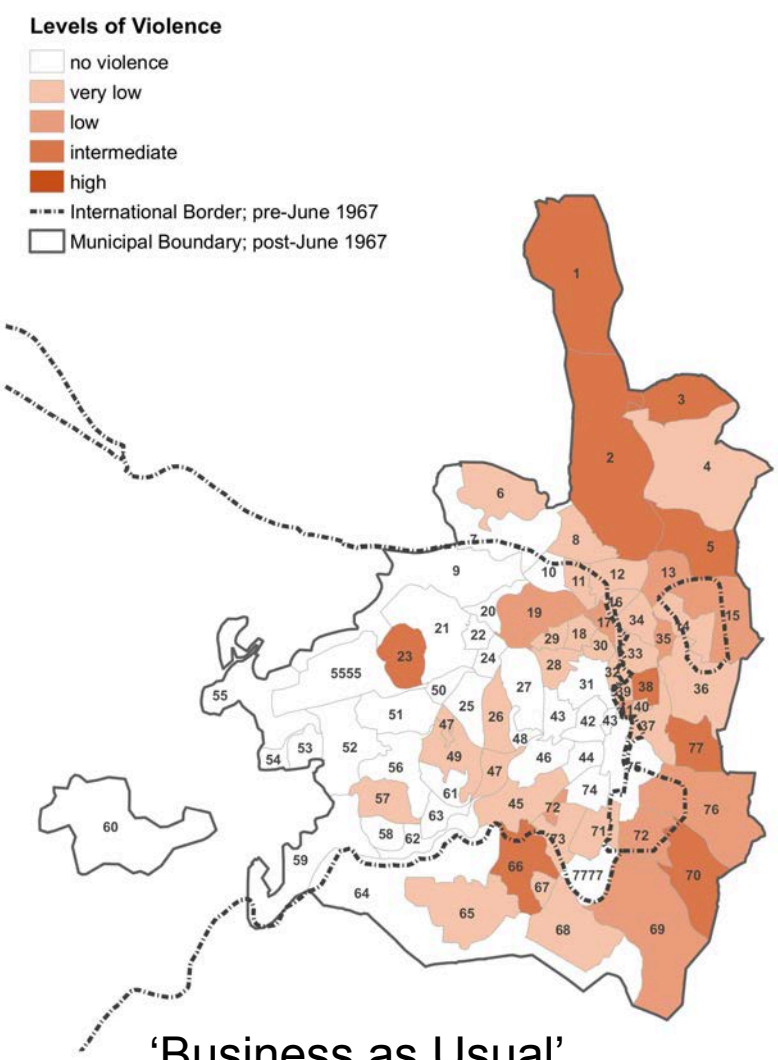


- Avoiding crossing and counter-flows
- Real-time flow monitoring
- Adaptive rerouting
- Contingency plans

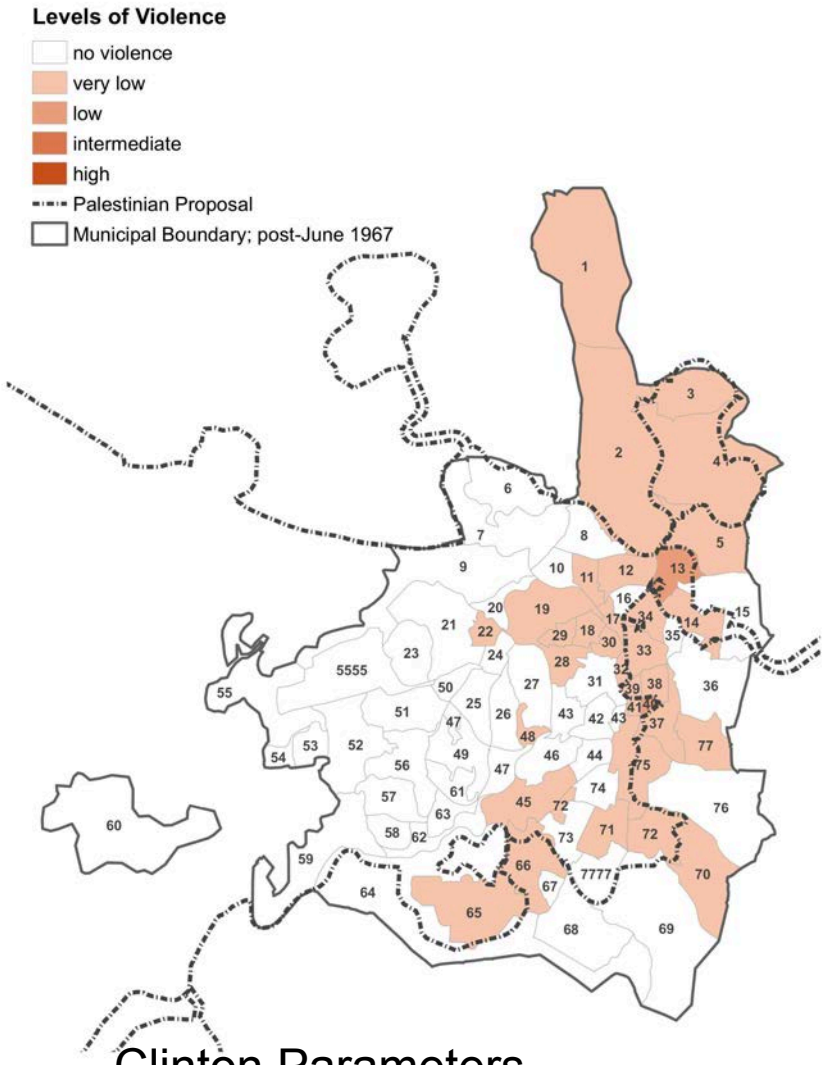


Resilient Flow Organization in 2007

Conflict in the Middle East: Possible Future Scenarios

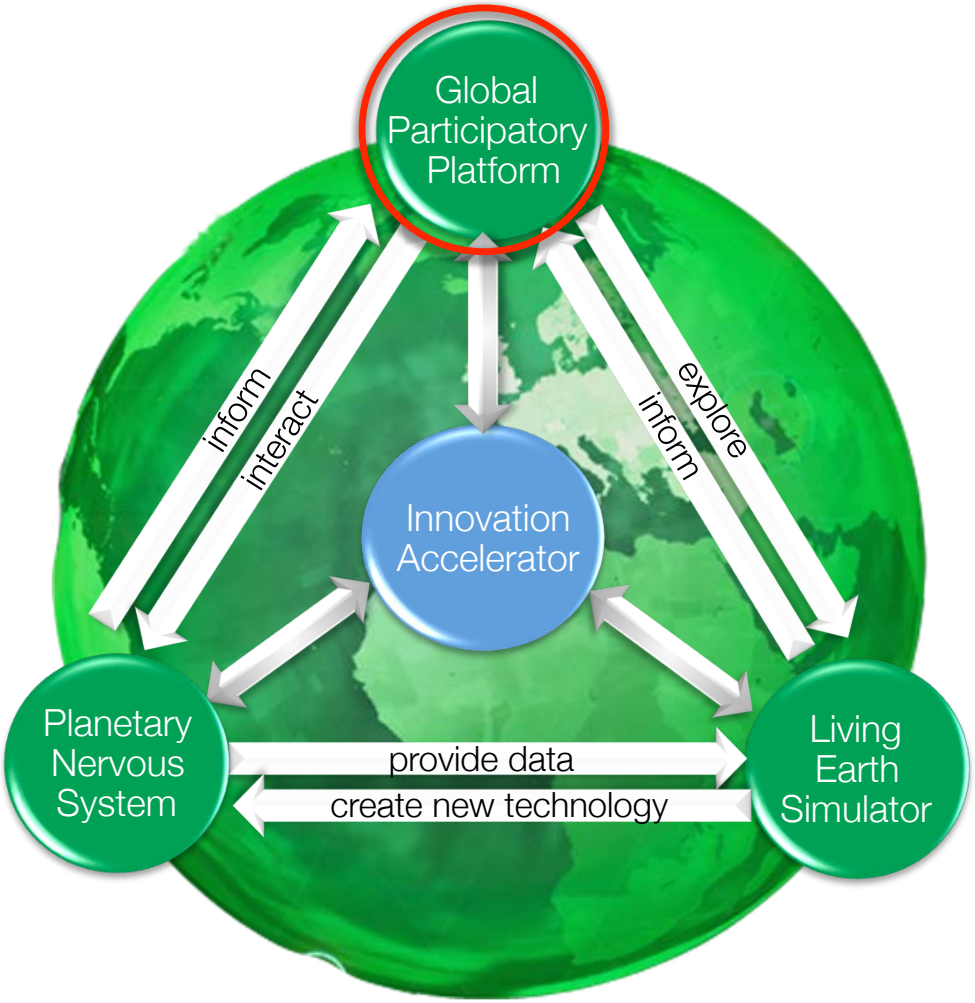


'Business as Usual'



Clinton Parameters

Platforms
to explore & interact



Systems
to sense &
understand

Models
to simulate &
predict

An Open, Transparent Platform for Everyone

- Goal: A ‘data and model commons’, an open platform for everyone
- Potentials: New services and jobs, less barriers for social, economic and political participation
- Problem: A new public good, requiring mechanisms to avoid data pollution, manipulation, misuse, privacy intrusion, cybercrime
- How to promote responsible use?
- Need to develop a Trustable Web, a self-regulating information ecosystem

Socio-Inspired ICT

Understanding the hidden laws and processes of society

Development a new wave of robust, trustworthy and adaptive information systems based on socially inspired paradigms.

Facebook is by now one of the most valuable companies in the world

Fundamental transformational effect on ICT and Computer Science

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1. Collective awareness

2. Social adaptiveness

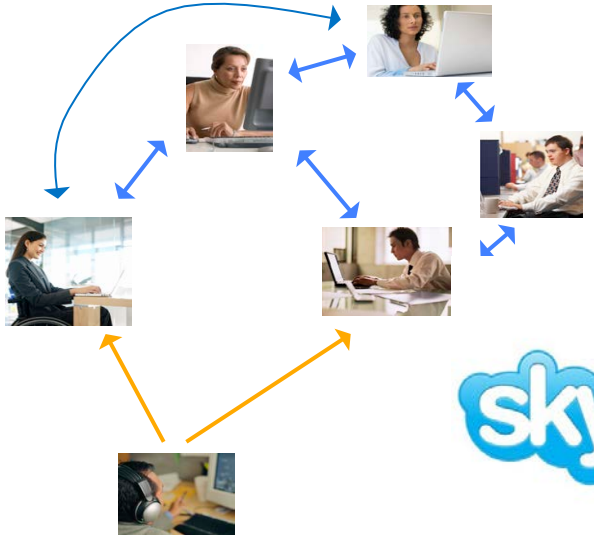
3. Socio-inspired, bottom-up self-organization

Coming Era of Socio-Inspired Innovations

Understanding socially interactive systems facilitates socio-inspired ICT

- Cooperation,
- adaptability and self-regulation,
- conflict resolution,
- resilience,
- trust,
- reputation,
- social norms,
- values, ethics, and
- culture

Example: A 'Trustable Web', reputation-based and self-regulating, to keep cybercrime low



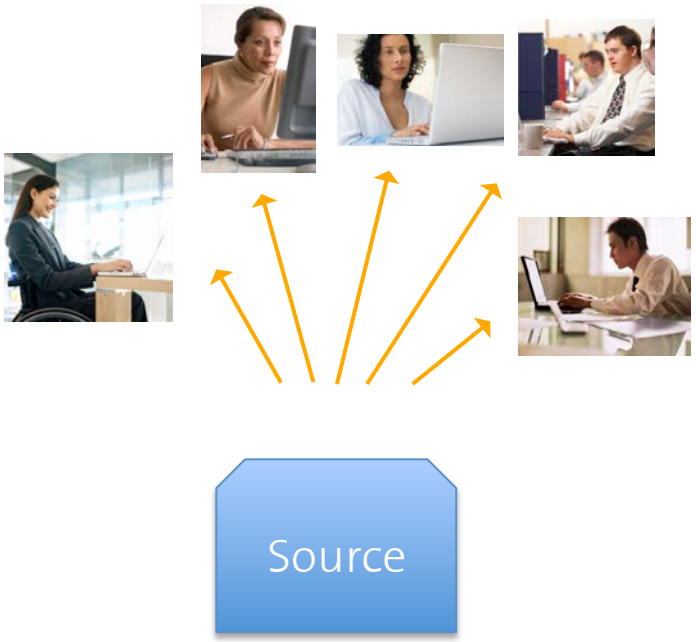
facebook

skype

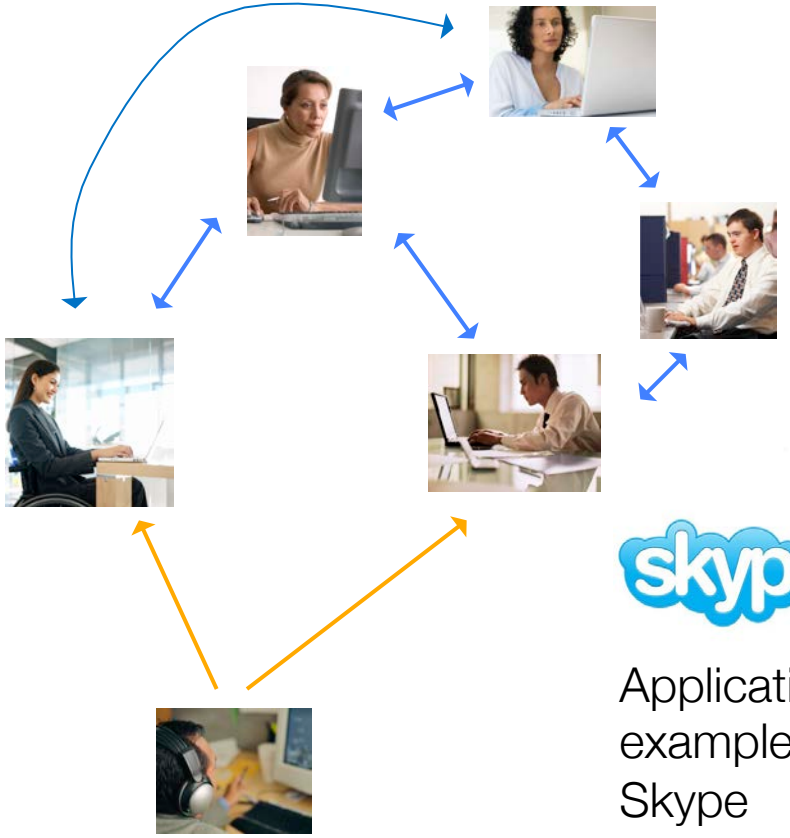
Economic benefits!
New solutions to societal problems!

Client Server Systems vs. Peer to Peer Systems

Client-Server Systems



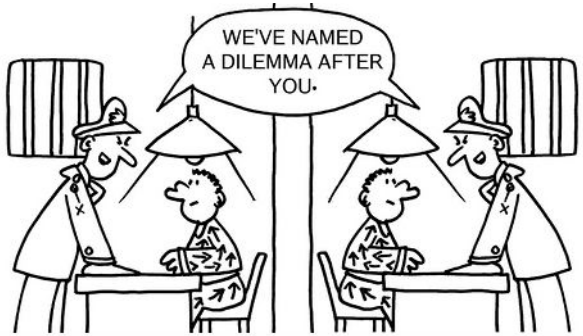
Peer-to-Peer Systems



Application example: Skype

The Dilemma of Social Cooperation

The prisoner's dilemma game has served as prime example of strategic conflict among individuals. It assumes that, when two individuals cooperate, both get the "reward" R, while both receive the "punishment" P< R, if they defect. If one of them cooperates ("C") and the other one defects ("D"), the cooperator suffers the "sucker's payoff" S < P, while the payoff T > R for the second individual reflects the "tempation" to defect. Additionally, one typically assumes S+T < 2R.



Player 1 \ Player 2	Cooperate	Defect
Cooperate	R_1 R_2	S_1 T_2
Defect	T_1 S_2	P_1 P_2

For example:

$S_1 = S_2 = S = -5$

$P_1 = P_2 = P = -2$

$R_1 = R_2 = R = -1$

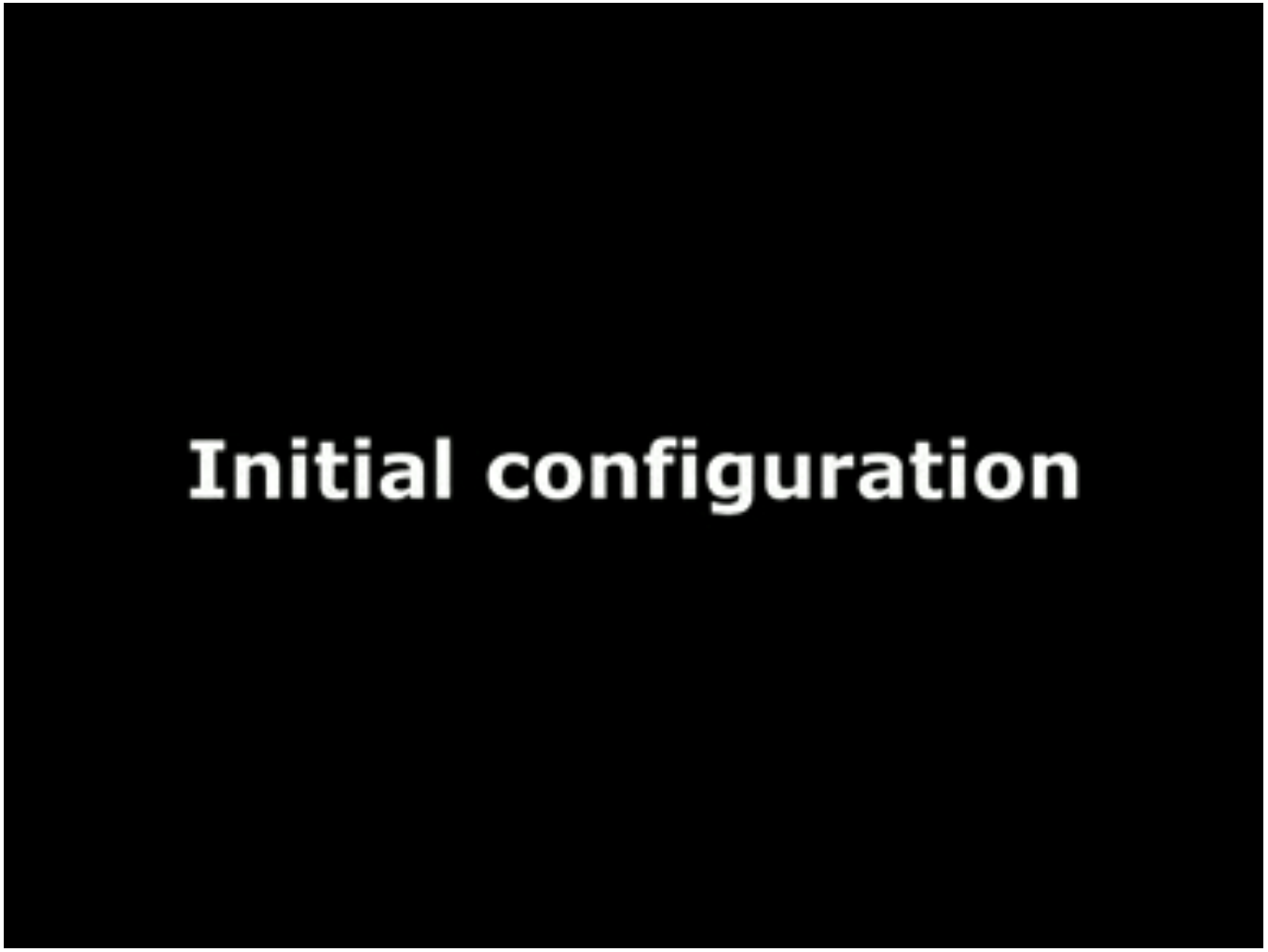
$T_1 = T_2 = T = 0$

Many "social dilemmas" are of a similar kind (see public goods game)

Emergence of Cooperation in Social Dilemma Situations

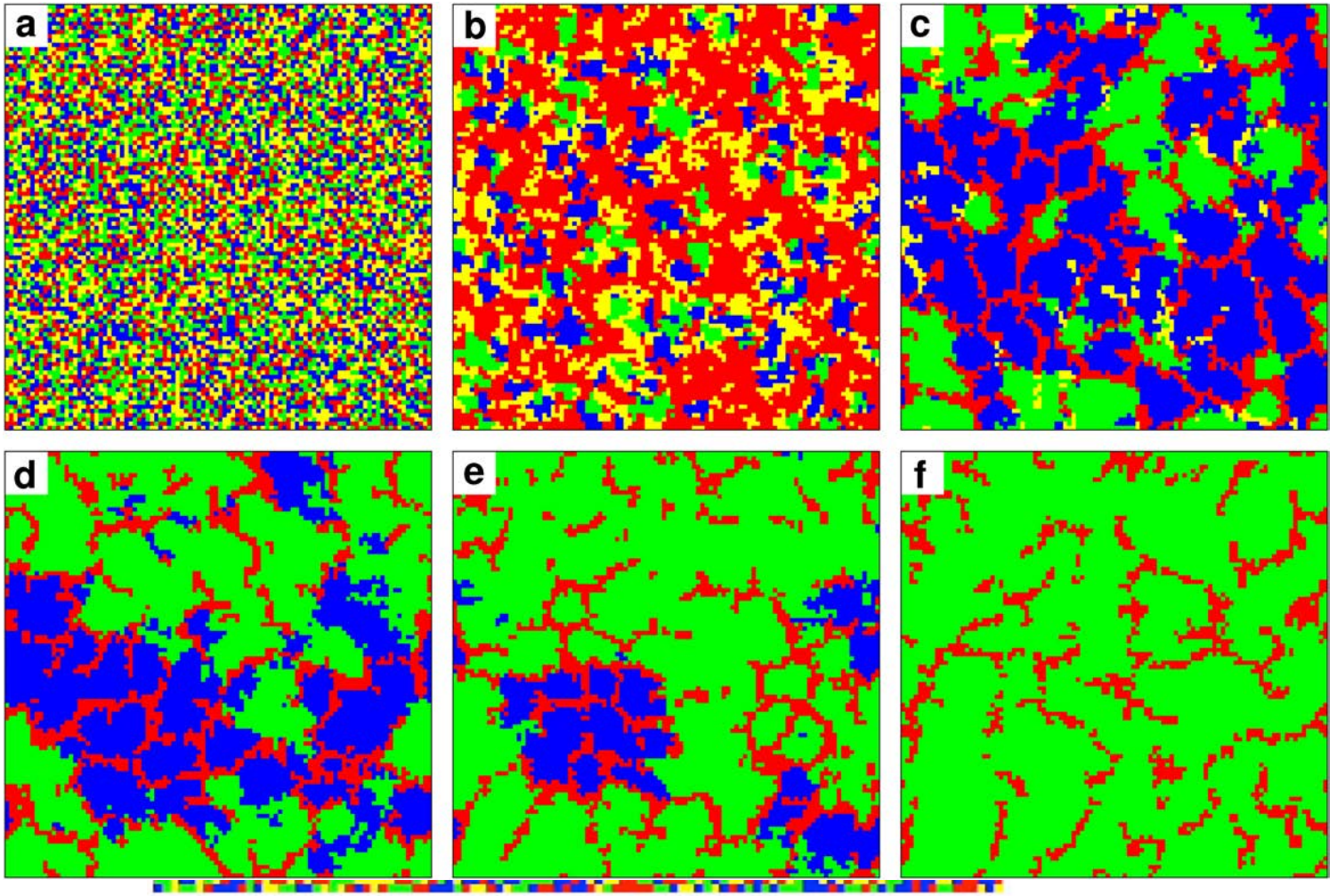
Overfishing, global warming, misuse of social benefit systems, tax evasion, free-riding

Red, yellow: defectors (cheaters)
Blue, green: cooperators



Imitation of the best-performing neighbor, success-driven mobility, and trial-and-error together can cause an outbreak of cooperation, but no subset of these social mechanisms

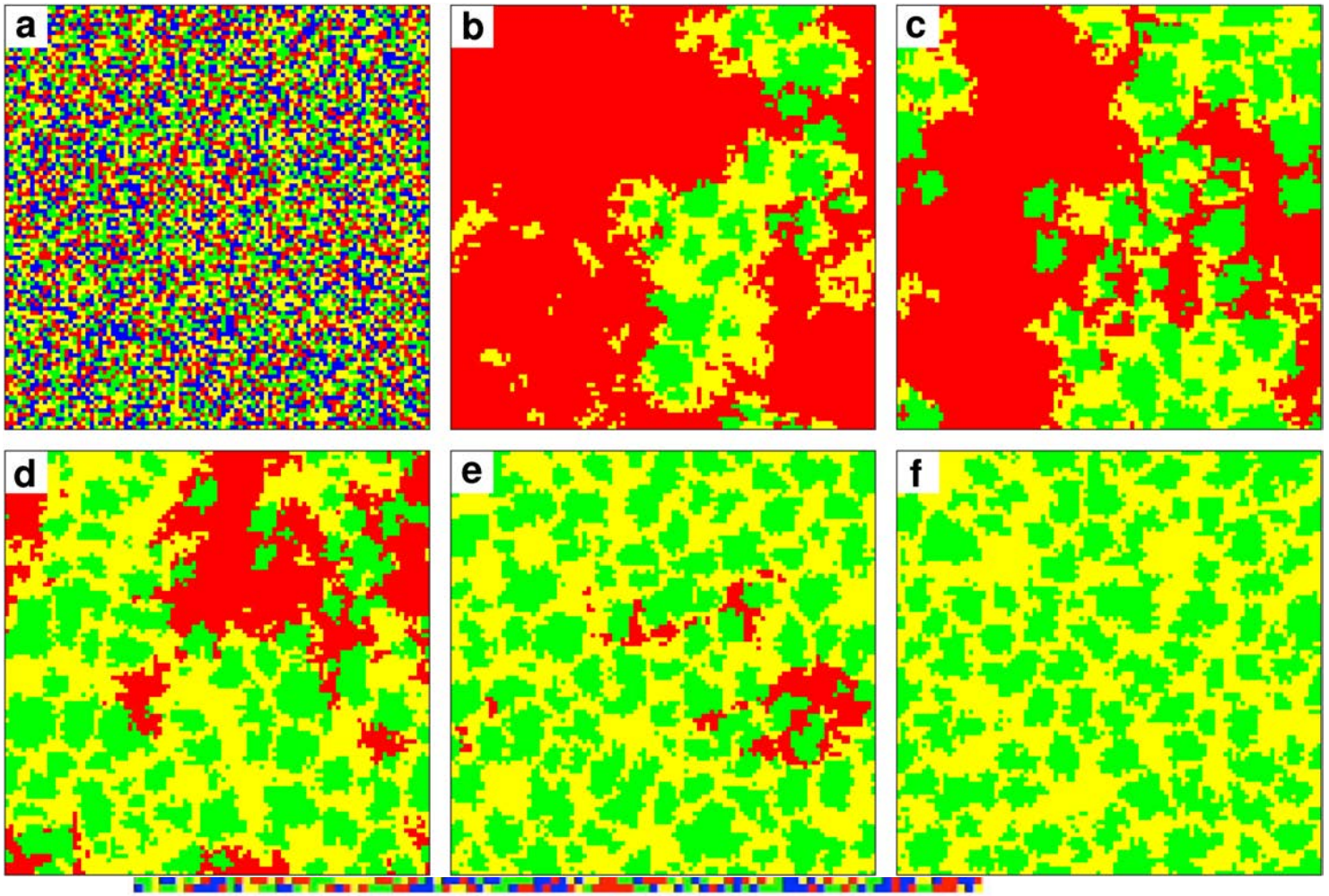
How the Costly Sanctioning of Free-Riders Can Survive and Moral Behavior Spreads



D = Defectors (Free-Riders), M = Moralists, I=Immoralists

C = Non-punishing Cooperators (Second-Order Free-Riders)

The “Unholy” Alliance of Moralists and Immoralists



D = Defectors (Free-Riders), M = Moralists, I=Immoralists

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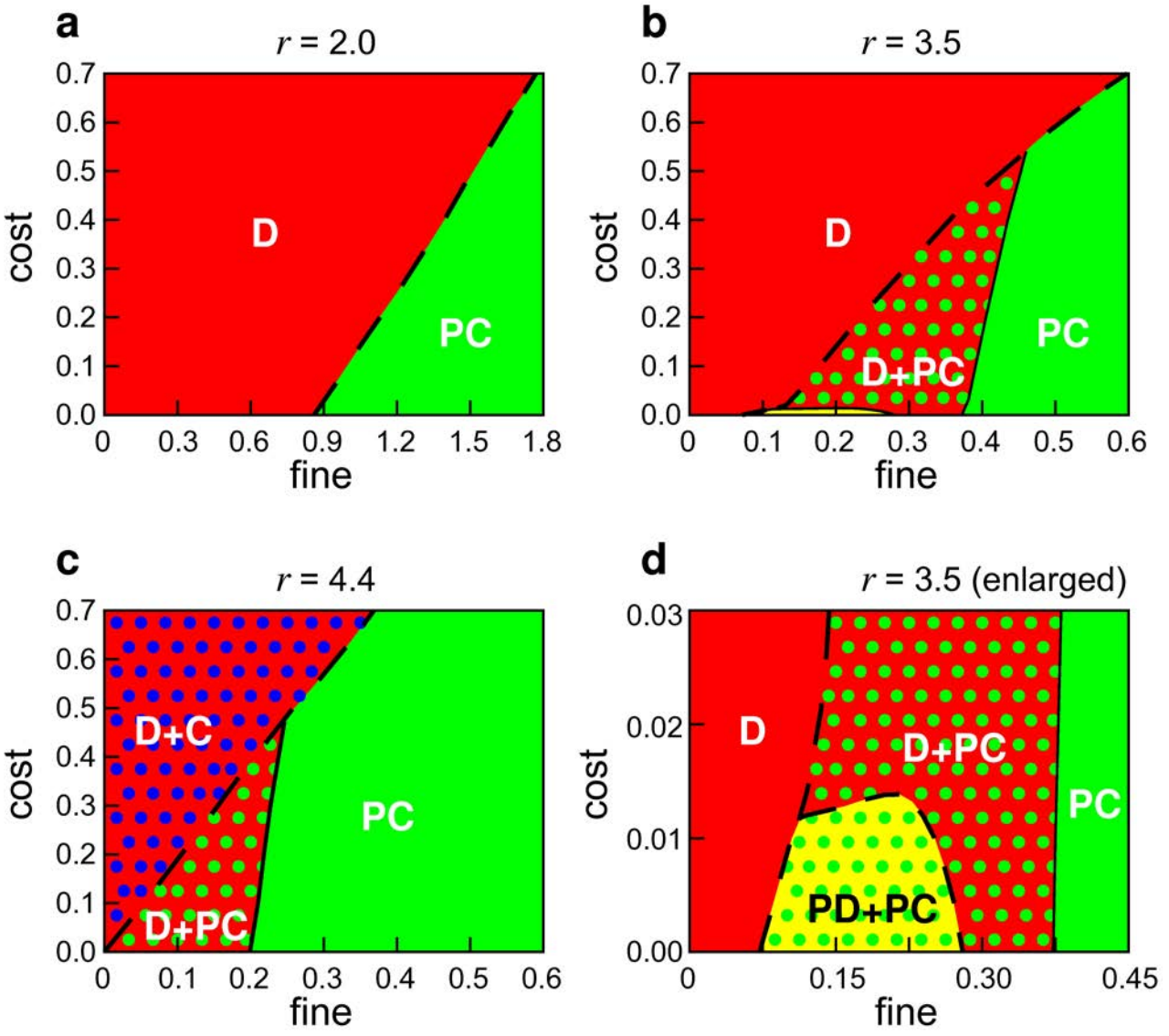
Overcoming the Tragedy of the Commons by Spatial Interactions



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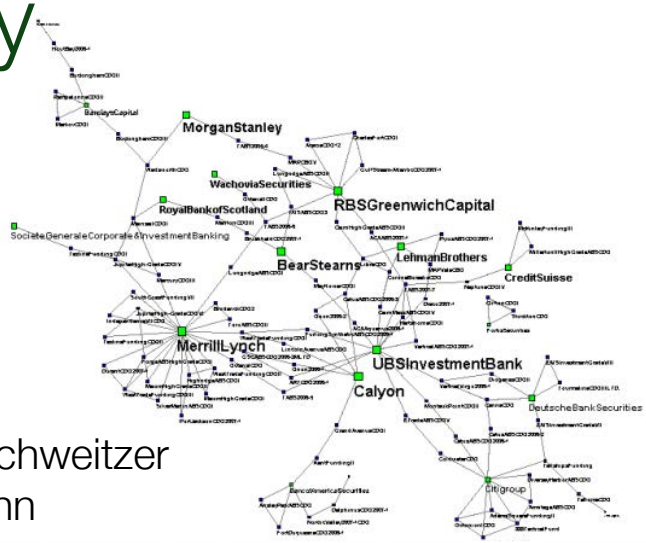
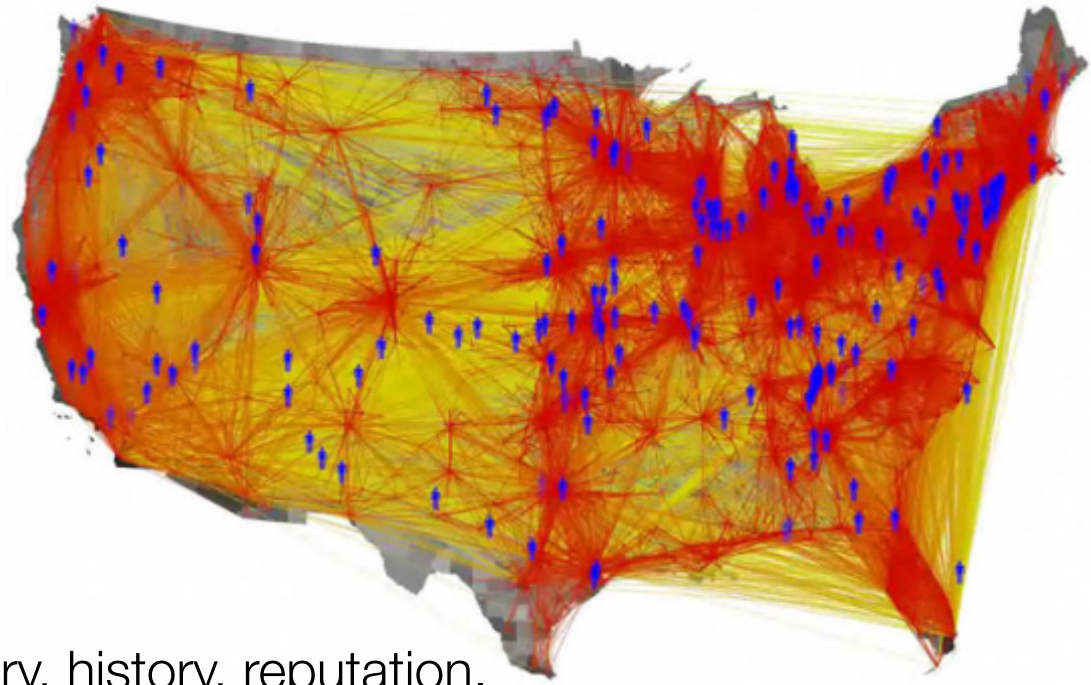
Social Money

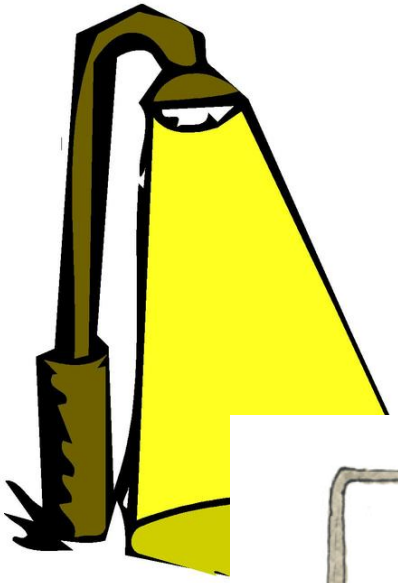


Thanks to Frank Schweitzer
and Dirk Brockmann



Treat money as nodes
in a money flow network
rather than as a one-
dimensional entity (scalar),
give it multi-dimensionality, memory, history, reputation.

Stop Searching Where the Light Is!



Big Data = Big Opportunities, also for Science

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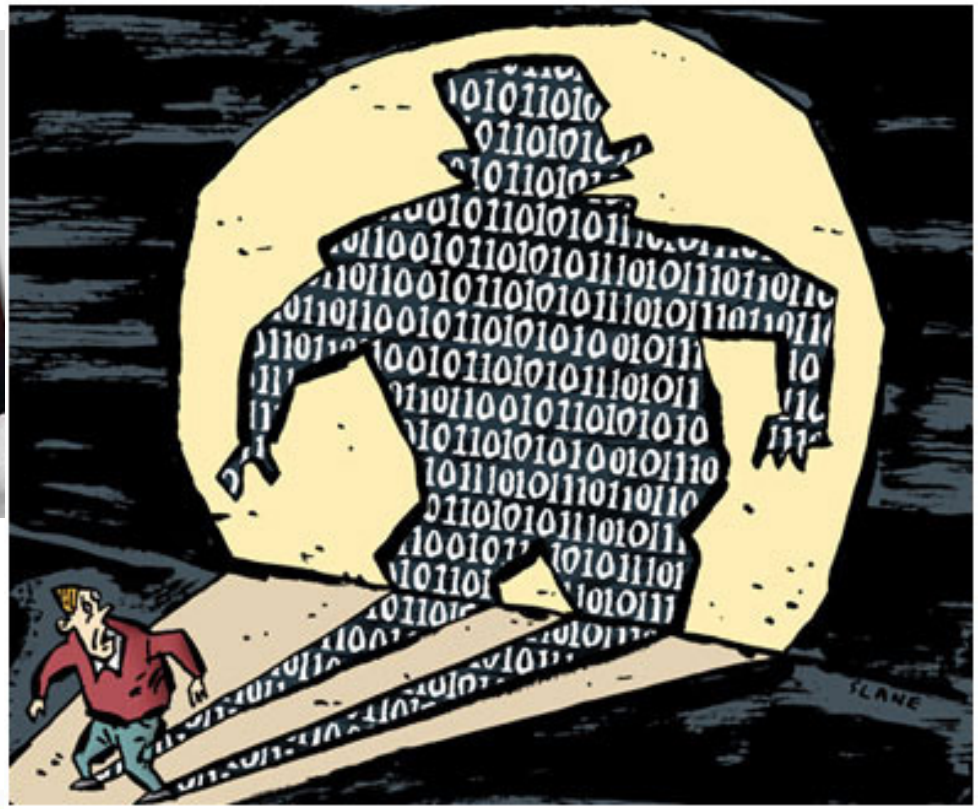
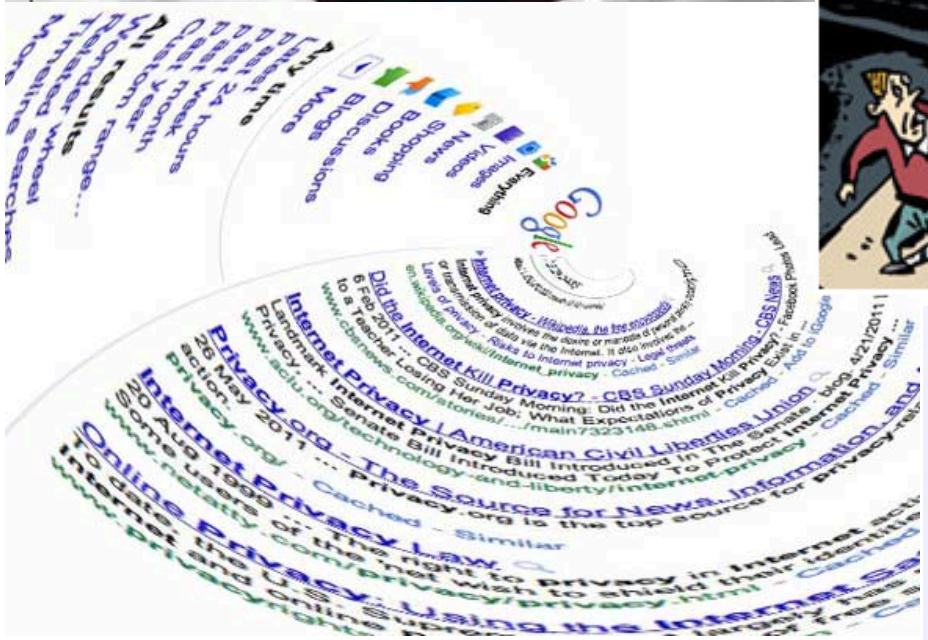
Big Data = Big Challenges





Cybercrime
- Privacy
- Data security

3 workshops on ethics, own research focus.

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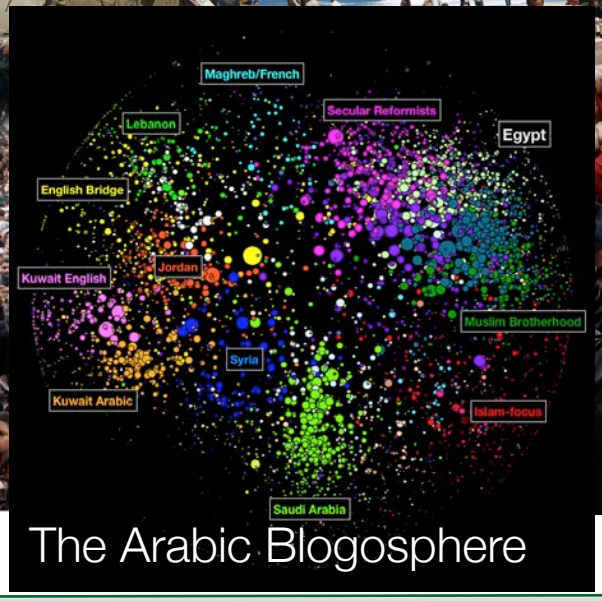
Are These Really Twitter Revolutions?

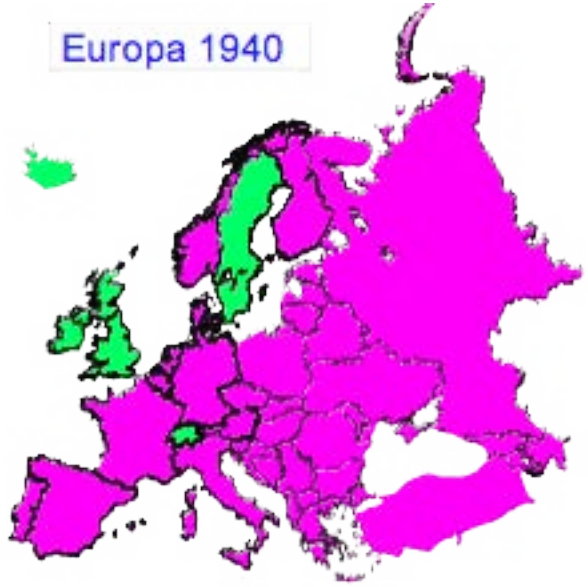
twitter

facebook



The Arabic Blogosphere

Political Cascading Effects

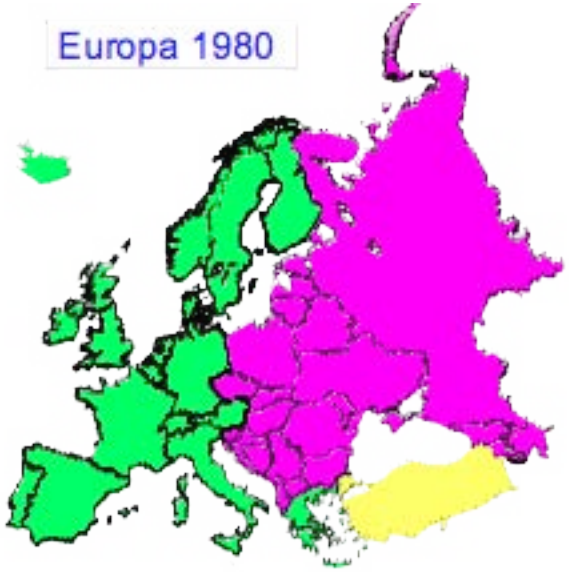


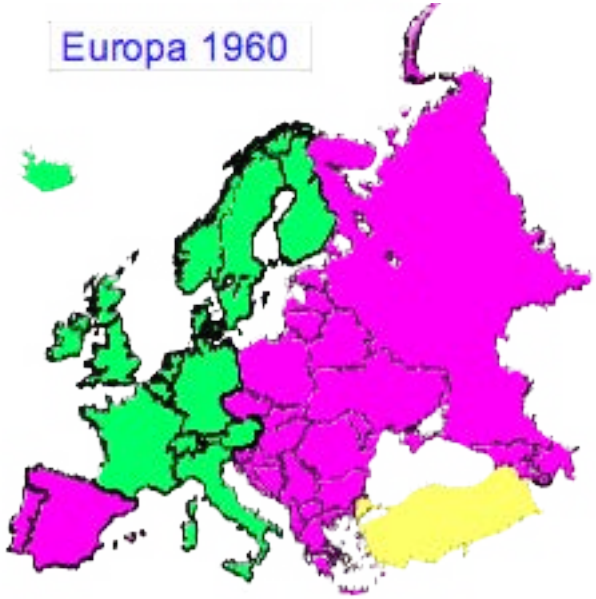
Transition from hierarchies to democracies
(source: Jürgen Mimkes)

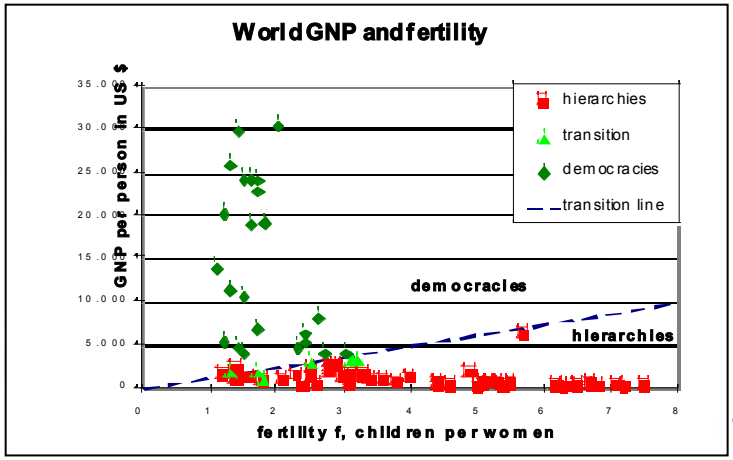
hierarchy

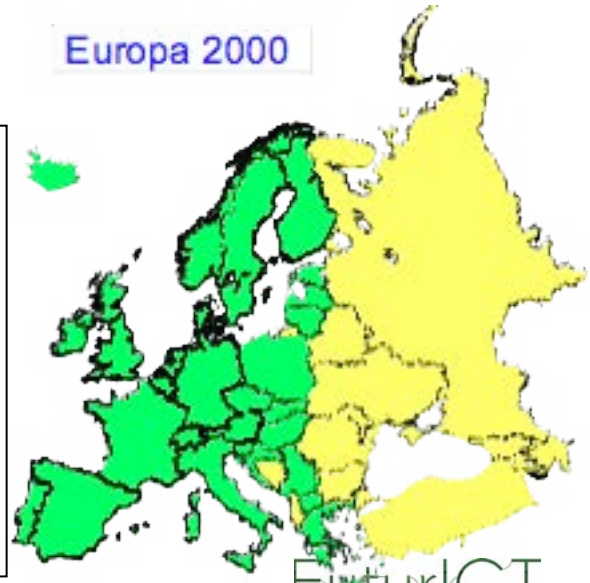
transition

democracy









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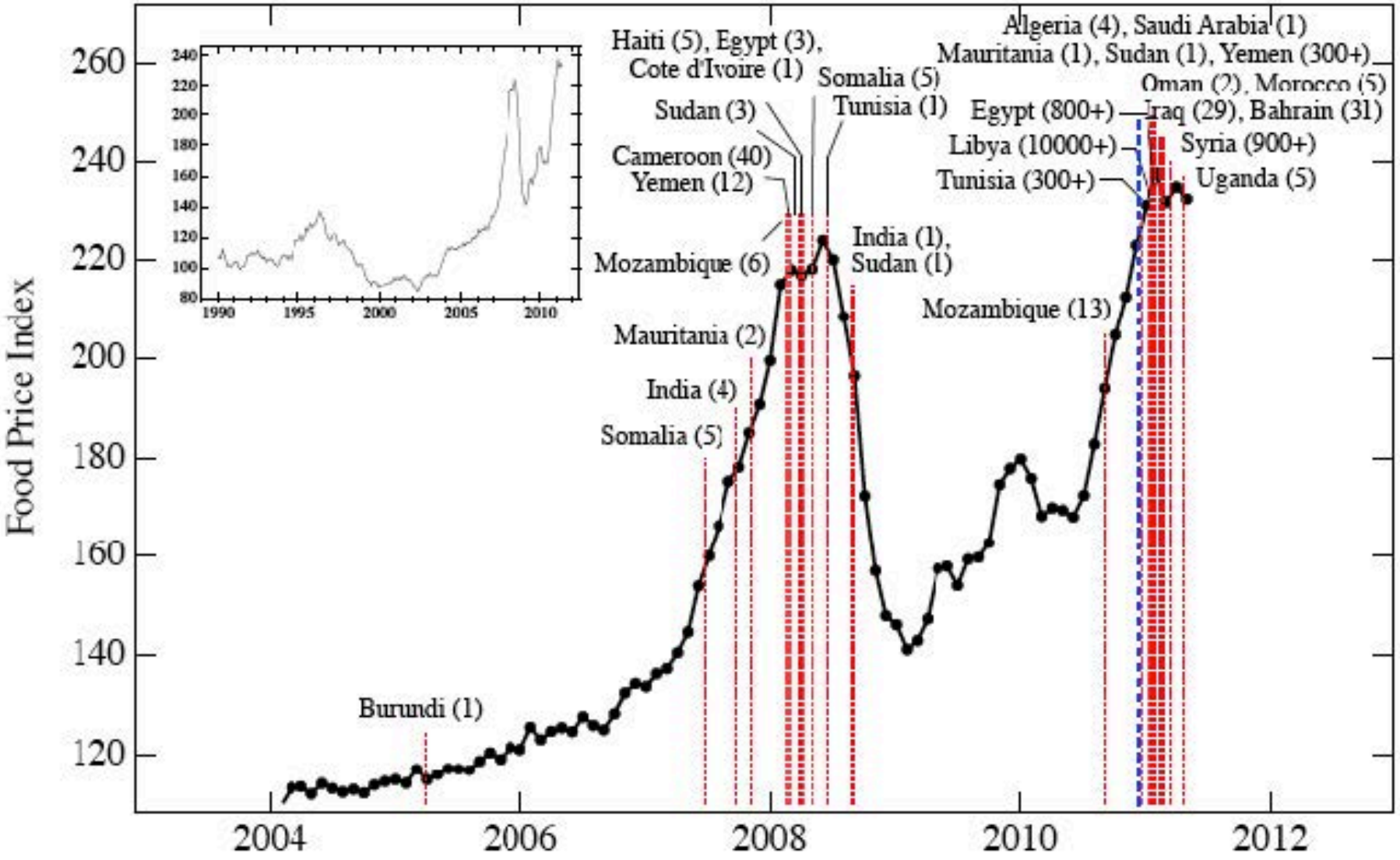
Food Prices as Triggers of Social Unrests



Is Surveillance A Good Solution?

"The internet has totalitarian potential."

- The Internet cannot be controlled top down (we cannot even control the financial system)
- Rather apply principles of decentralized self-regulation (as in our immune system)
- Build on transparency, reputation systems

Why Privacy Is Important

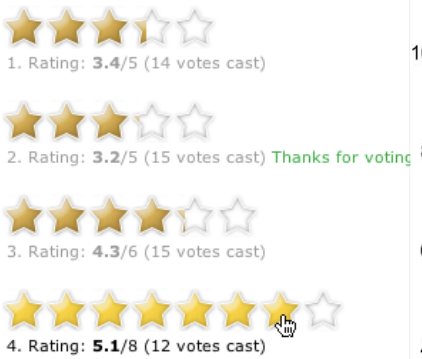
Example: My diary and trust

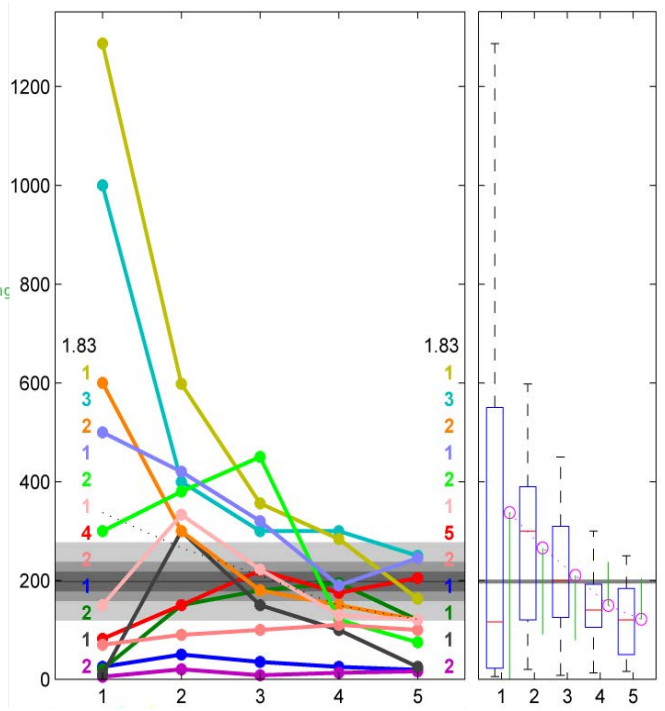
Free space is needed for individuals to recover and for society to innovate and evolve.

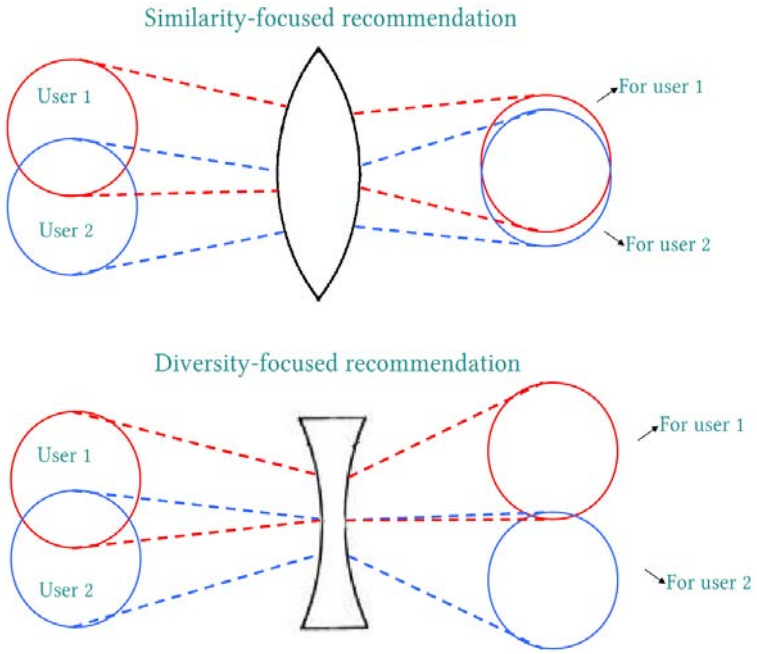
- Public and private are two sides of the same medal
- Privacy is a pressure relief system that allows people to adapt to expectation of others during public exposure
- Protection of minorities, protection of socio-diversity
- Reduction of conflict
- If there is no protected private space, people will stop thinking independently, which undermines the wisdom of crowds
- If there is no privacy, there is no intimacy, i.e. partnerships and friendships as we know them

The Crucial Question Is, How One Can Get Ethical Dimensions into our Systems

Value sensitive design!







Source: Yi-Cheng Zhang *et al.*

Avoid conformity and herding effects, protect socio-diversity

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Computers Think for Us: The Filter Bubble

Google Search for Egypt

Scott: Egyptian Protests

Daniel: Travel Information

Risk of manipulation and over-confidence.
Supporting egocentric consensus may promote segregation and conflict between groups with different preferences.

Eli Pariser

These questions may have fundamental societal implications.
They deserve and require scientific study!

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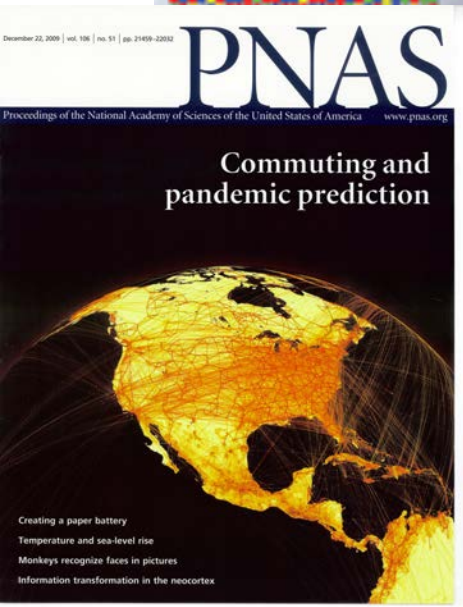
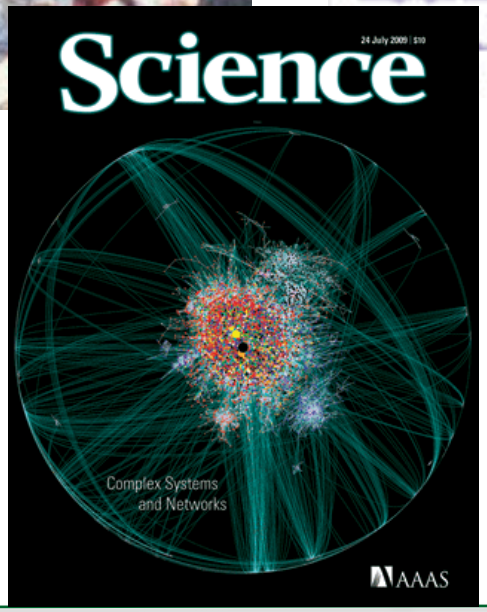
FuturICT Is Big Science





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