Managing Complexity ?

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To manage a system means that you are able to predict the possible outcomes of actions you take

If you can not predict the outcome of management actions - you do not manage or control the system: you are subject to luck, fate, external events

What kind of systems can you predict ?

• Very small ones: physics of a few bodies: planet-sun, quark-quark, rocket-enemy

why ? can manage to handle laws of physics

• Very large ones: gases, solid bodies

why ? do not interact strongly $\rightarrow$ describe laws of physics with laws of statistics

• Managing CS has been out of scope since beginning of mankind

why ? too large to handle governing 'laws', too small for statistics to work, too interconnected

What are Complex Systems ?

- CS are made from many elements
- Elements are strongly interacting with each other
- CS depend on details of the system: who interacts with whom
- CS often pose chicken-egg problems

$\rightarrow$ So far: very hard to handle in predictive ways

Why is it so hard to predict complex systems?

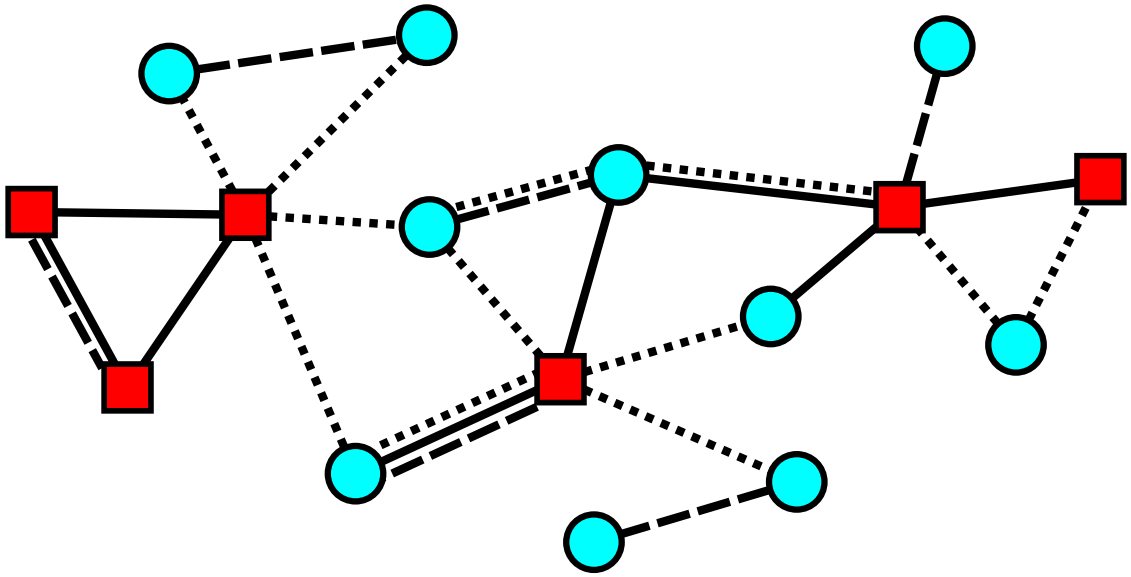
- Mathematical and statistical tools break down
- Too big to handle
- Not enough data available
- No concept of the backbone of CS – networks

Typical Complex Systems

- Living systems
- Social systems
- Economic/financial systems
- Firms + organisations

all these systems are evolutionary and are based on networks

CS are co-evolving multiplex networks



- States of individuals/firms change as a function of NW interaction
- Network changes as a function of the states of the agents

first point only: physics

second point: makes it a complex system: society, eco-system, market, ...

The game changer: The computer + new math

- Network theory: quantify causal processes on networks
- Data availability: electronic fingerprints everywhere
- New statistics: new inference methods and superstatistics
- Storage and computation costs practically nothing

If you do not have all of the above $\rightarrow$ back to start: can NOT manage CS

If you can map a CS into a dynamical NW $\rightarrow$ can manage CS

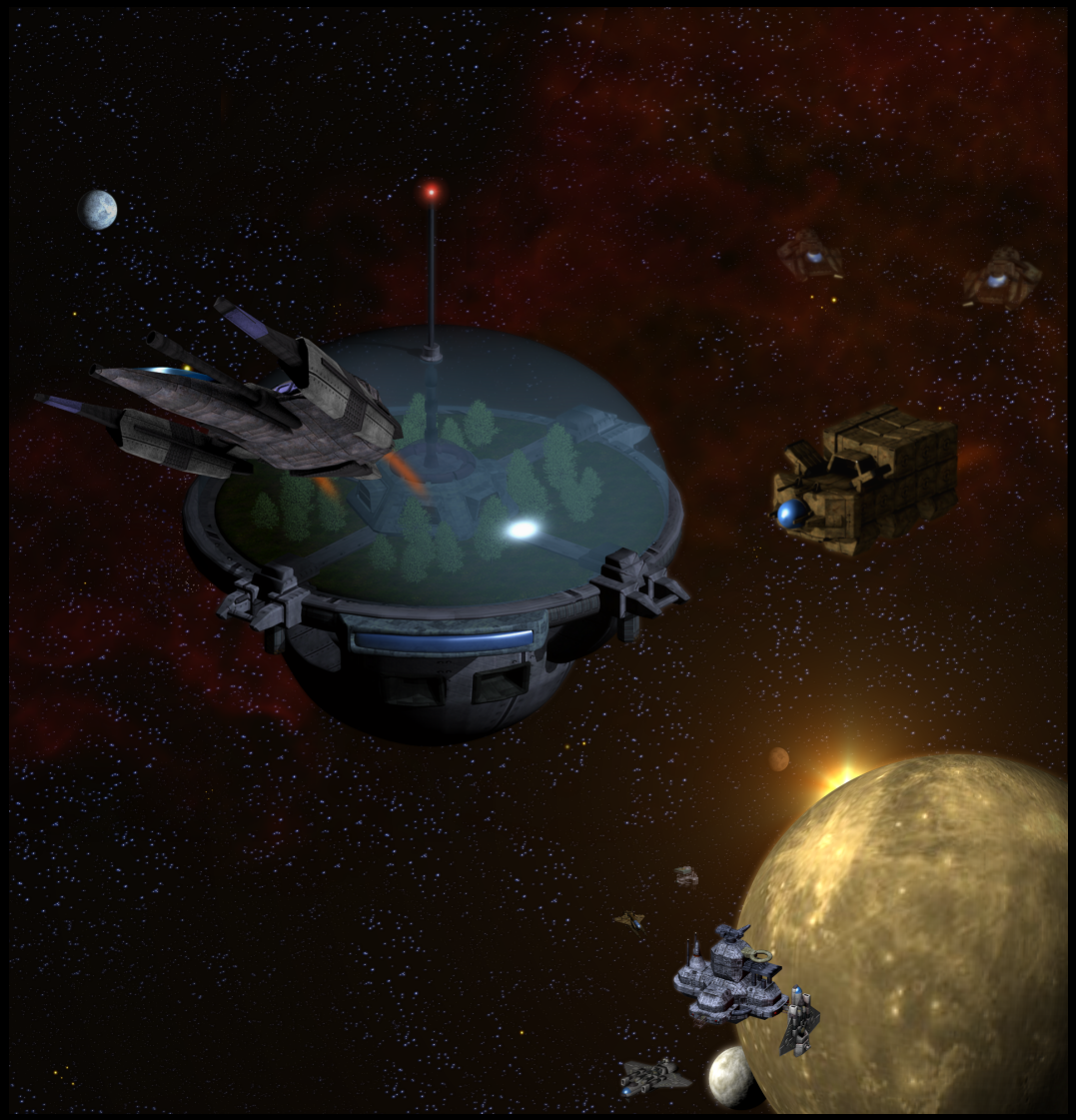
Theory of CS: combination of dynamical systems and NWs

Networks

- Network: connections of points by lines
- Usually NW has structure + random components
- Any data that can be stored in database can be represented as network
- Network theory: quantify stability, efficiency, hierarchy, clustering, ...
- Novel mathematics: networks become technically manageable

Networks are dynamical: here sits the devil !

- Networks change over time
- Dynamical processes happen on networks
- Dynamical processes happen on networks which change (chicken–egg)
- Networks are not independent: they influence each other $\rightarrow$ Multiplex



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Example I
What if we know everything? What can we predict?

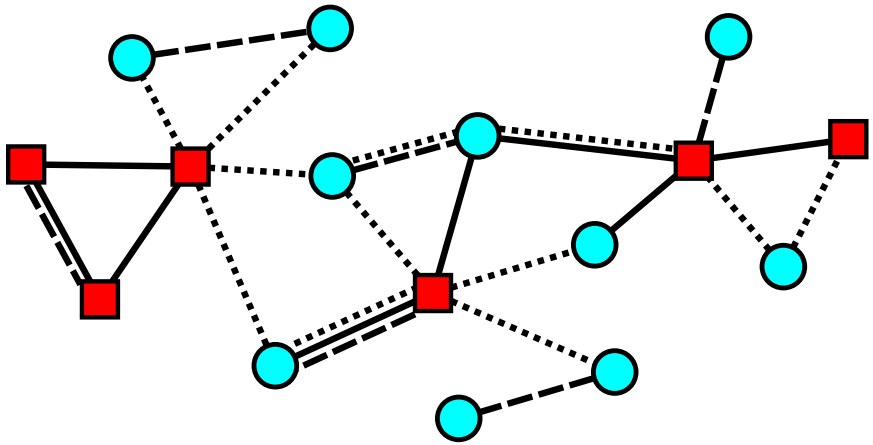
- then we have solved the data problem $\rightarrow$ good!
- only problem: what to do with all that information?

Massive Multiplayer Online Game – pardus.at
a toy for the new data generation

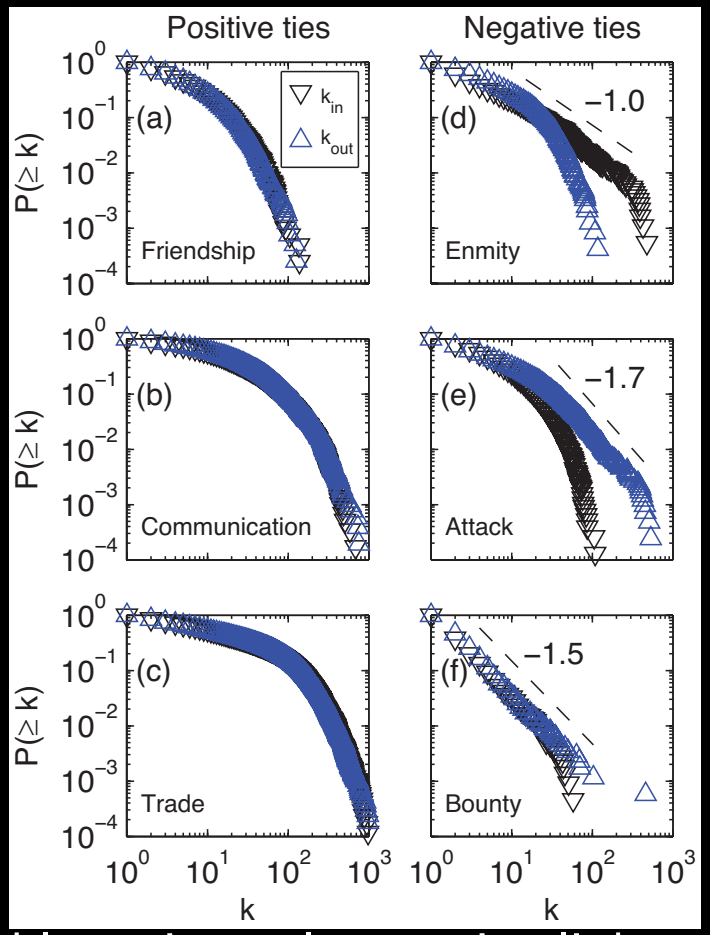
Complete knowledge on a human society

Have all data of all 500.000 players of all of their actions and interactions performed in a '*second life*' like virtual world *www.pardus.at*

- have complete knowledge of an entire human society
- have time evolution of the co-evolving multiplex and states

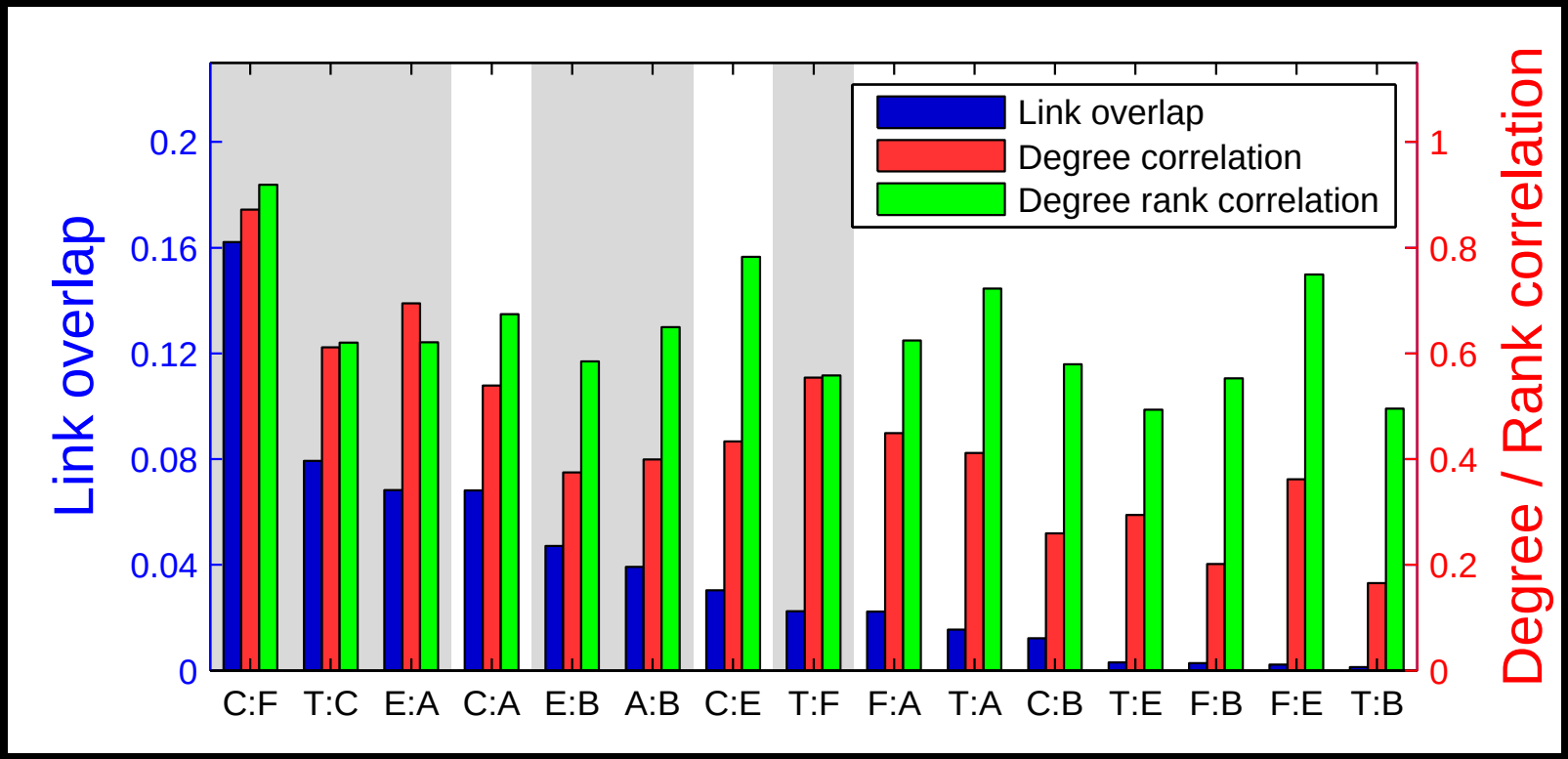


The properties of the subnetworks



- Positive links are highly reciprocal, negative links are not
- Power-law degree distributions indicate aggressive actions
- Positive links cluster

Network–network interactions



How does one network shape and influence the other?

Proceedings of the National Academy of Science USA (2010)

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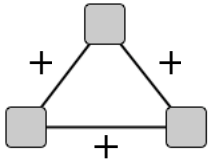
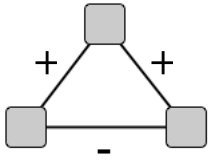
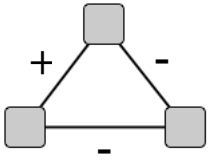
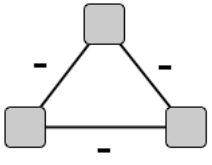
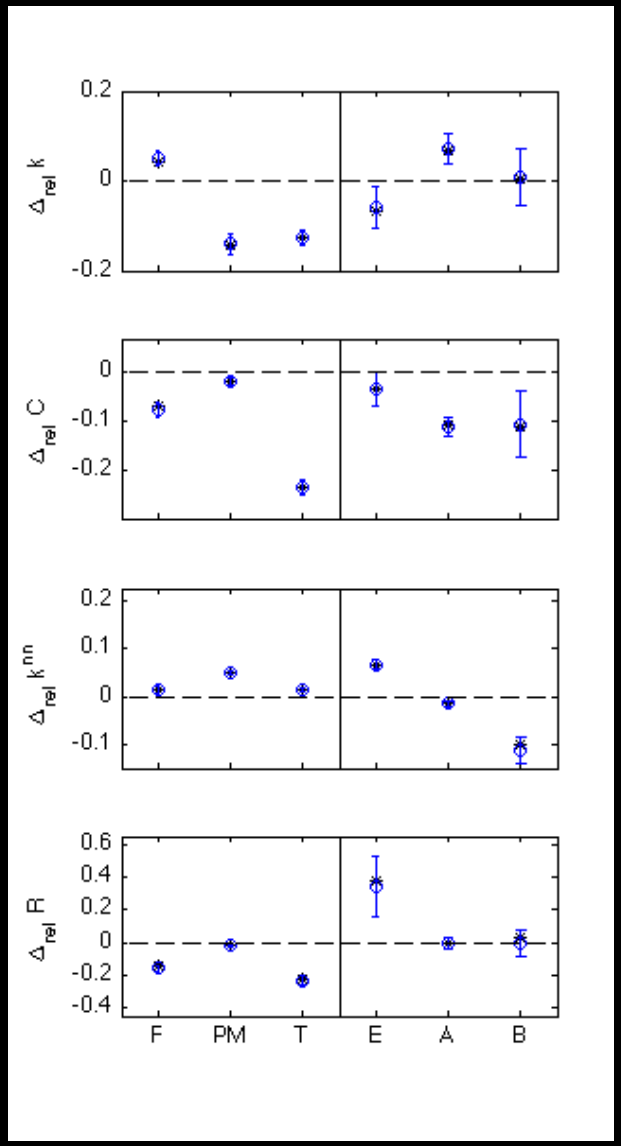
How humans organize to stabilize their social NWs

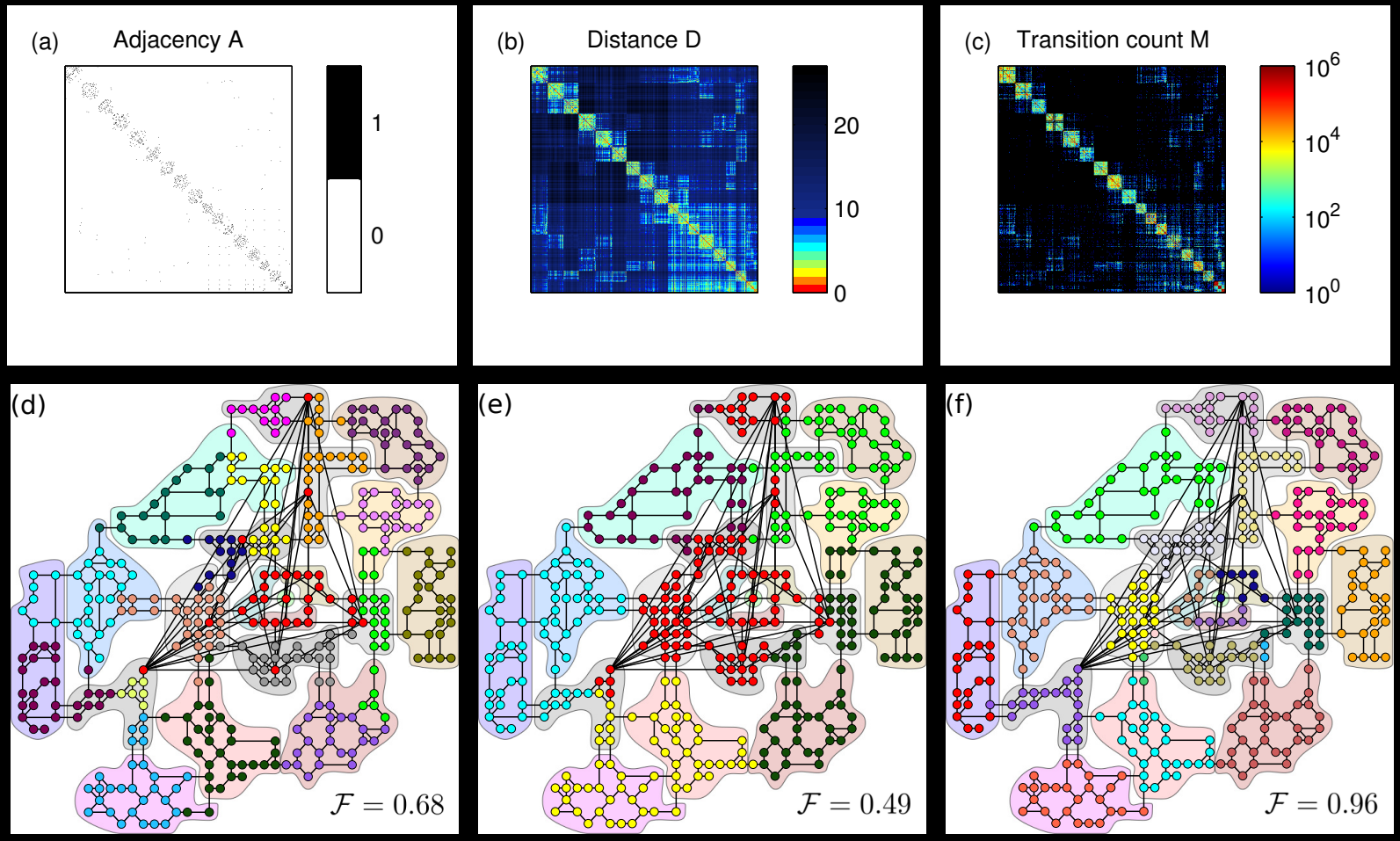
				
Strong formulation of balance	B	U	B	U
Weak formulation of balance	B	U	B	B
N_Δ	26,329	4,428	39,519	8,032
N_Δ^{rand}	10,608	30,145	28,545	9,009
z	71	-112	47	-5

Social balance theory – test empirically with natural science quality

Gender differences in 'networking'



Predict: Where will you go next ?



Scientific Reports (2012)

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Alternative representation of humans – behavioral code

Actions every (human) player can engage in life (game)

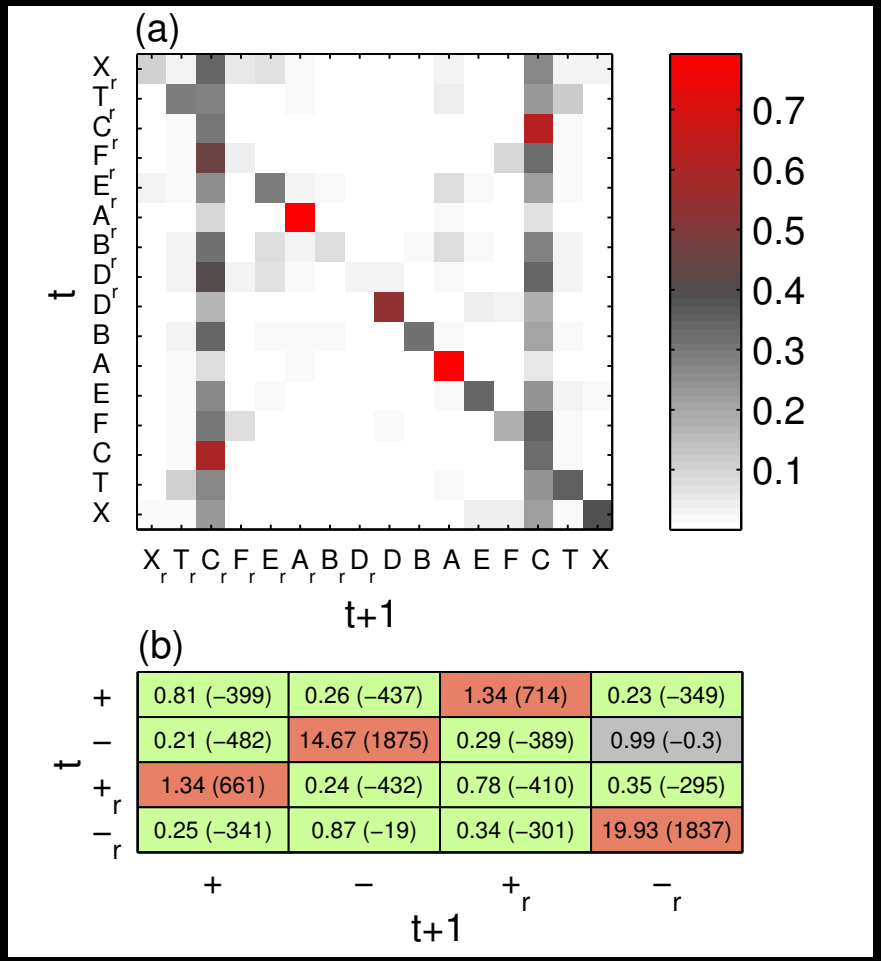
C ... communicate
T ... trade
F ... establish a friendship link
X ... remove an enemy link
A ... attack
B ... place a bounty on someone
D ... delete a friendship link
E ... establish an enemy link
.
.
.

Action-streams

→ Analyze the code as if it was the genome

PLoS ONE (2012)

Predict: What is your next action ?



PLoS ONE (2012)

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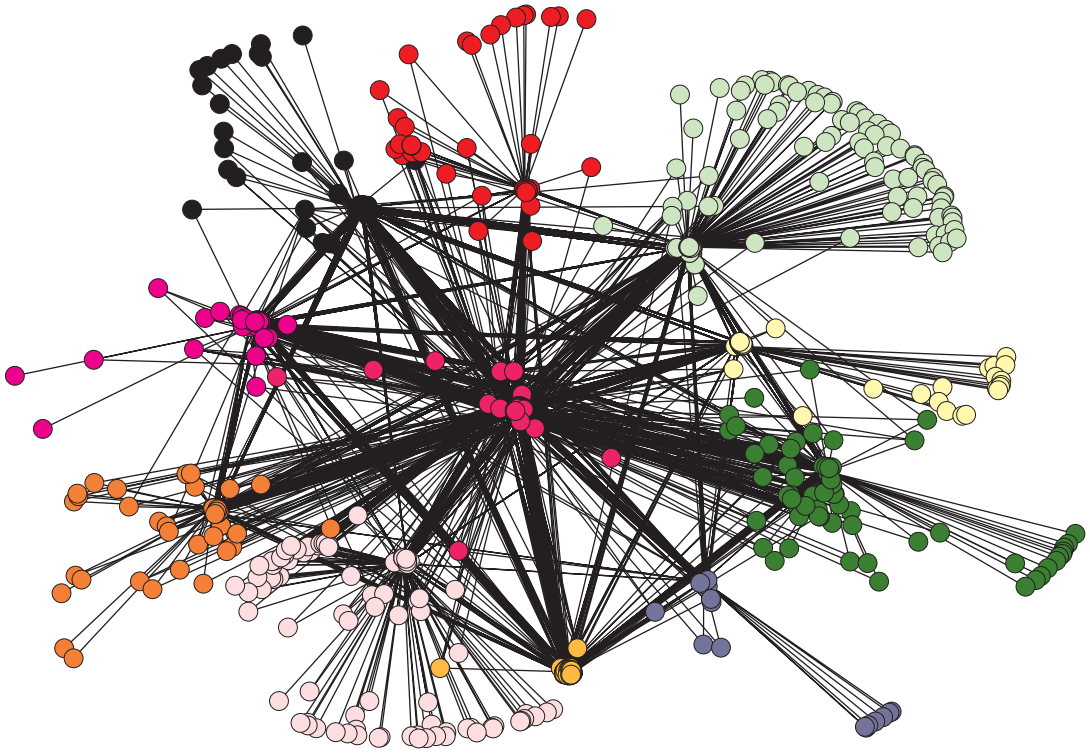
Example II
Complexity in financial networks and systemic-risk management

- If you lend something to somebody: want to know creditworthiness
- In a network can not do that, unless know riskiness of EVERYBODY
- No rational decision making on lending possible without transparency
- Central Banks have almost complete information

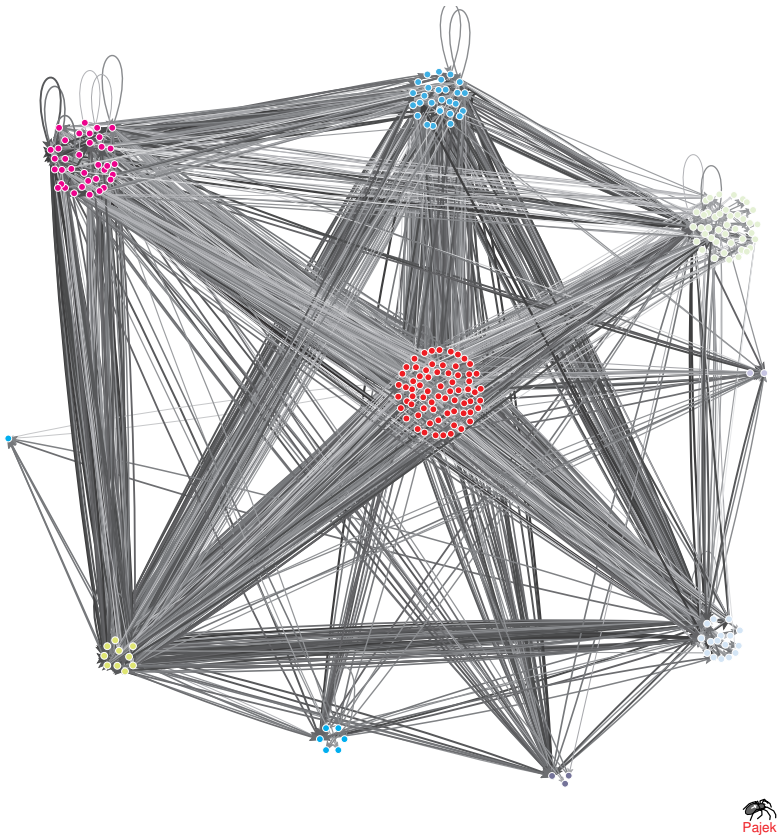
Interbank credit NW of Austria



Asset-liability NW of all Austrian banks, October 2003

Quantitative Finance (2005)

All financial flows between Austrian banks

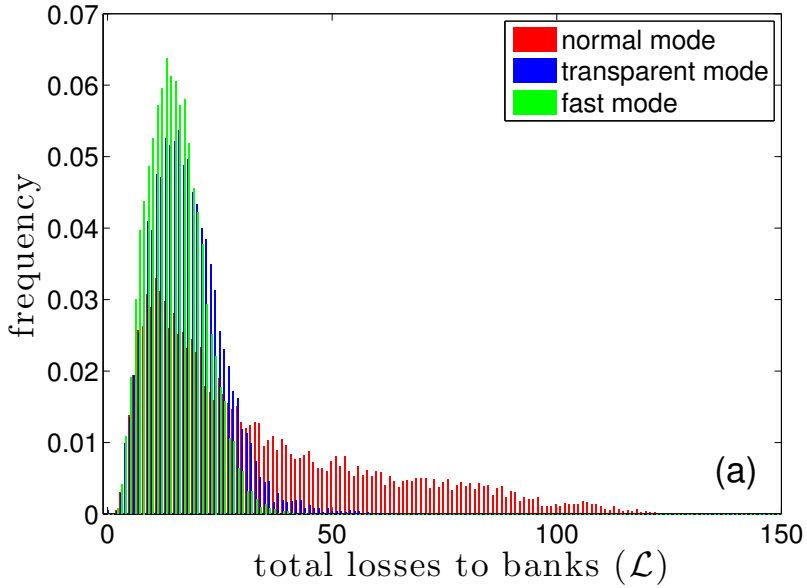


aggregated 2005-2006, 211 Banks, 4.187.943 transactions, volume 11.07 trillionEUR

European Physics Journal B (2009)

Financial networks – management of systemic-risk

- With this information → define a systemic risk measure: DebtRank
- Can regulate the interbank system that it becomes systemically risk free
- Idea: forbid borrowing from systemically risky banks



http://www.bloomberg.com/news/2013-02-10/fix-finance-by-shedding-light-on-its-complexities.html

Example III
What is complex in a firm or corporation ?

- Corporation is an evolutionary network of communication-flows
- Management controls these flows and tries to re-arrange the NW
- With and without management: the network evolves = re-arranges

→ CS tools assist to:

- know the network (reality check)
- find ways to re-arrange it (optimize)
- monitor its change after managerial intervention

Note: it is not easy to tell a network how to re-arrange !

Why CS in corporations?

Imagine new CEO entering a firm with say more than 1000 employees

- Knows organigram. Knows what departments should do + hierarchy
- Does not know: what departments are in reality
- Are departments structured in reality as the CEO thinks they are?
- How hierarchical is the firm in reality?
- Do re-structuring interventions work?
- Do optimal solutions to organization structure exist, given real structure

→ **Answer to this: communication flows**

Communication: the nervous system of a firm

- Telephone bill: every call = one line

ID caller | dpt caller |ID called | dpt called | time | duration

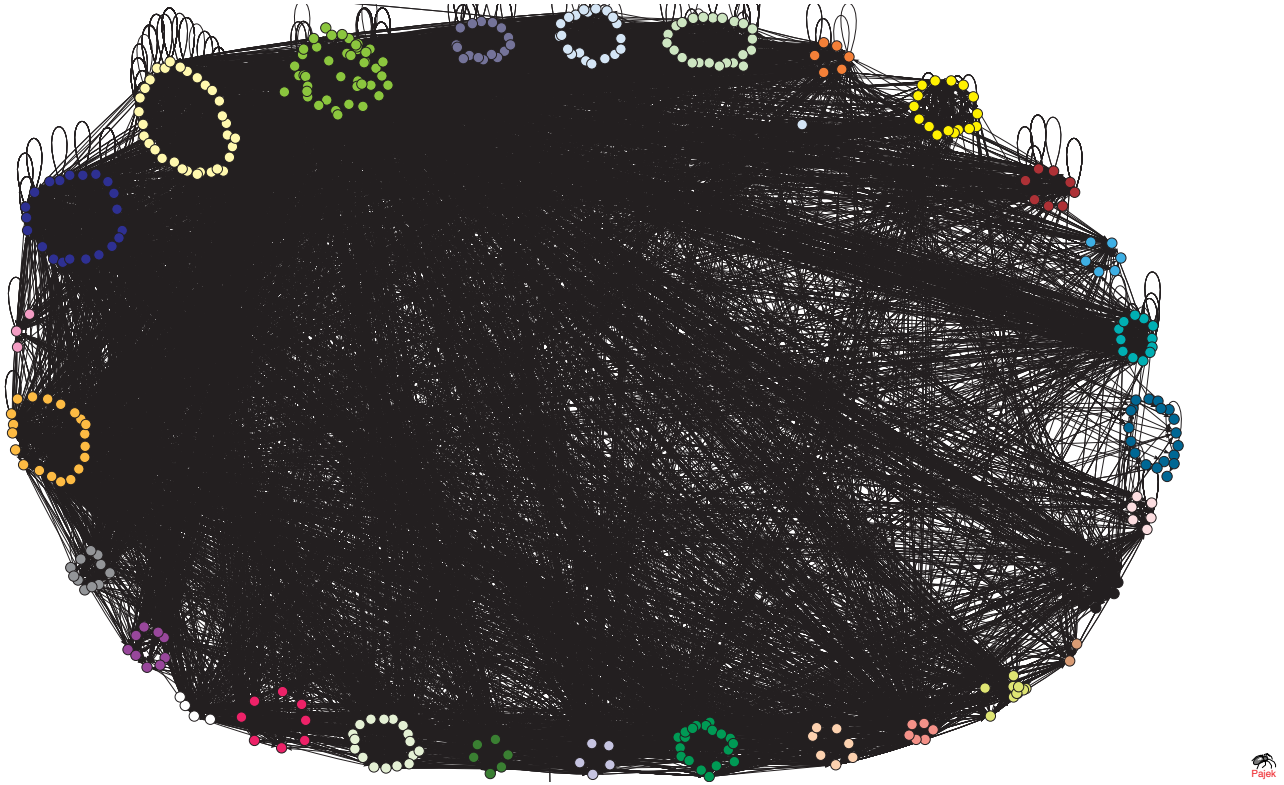
10000 50 50404 7 16 10 2009 14 01 00 00 14
10003 50 50091 2 04 11 2009 10 28 00 00 04
10003 50 50032 2 04 11 2009 16 27 00 01 10
10004 50 50404 7 30 09 2009 08 27 00 02 58
.....

- emails: log-files on server: every mail = one line

ID Sender | dpt sender | ID recipient | dpt recipient | kB | time sent

100001 1 508193 50 9486 2009 11 03 07 13 15
100001 1 508193 50 3444 2009 11 03 07 13 15
100001 1 509485 50 2996 2009 11 03 13 27 11
100001 1 509485 50 3122 2009 11 03 13 27 11
.....

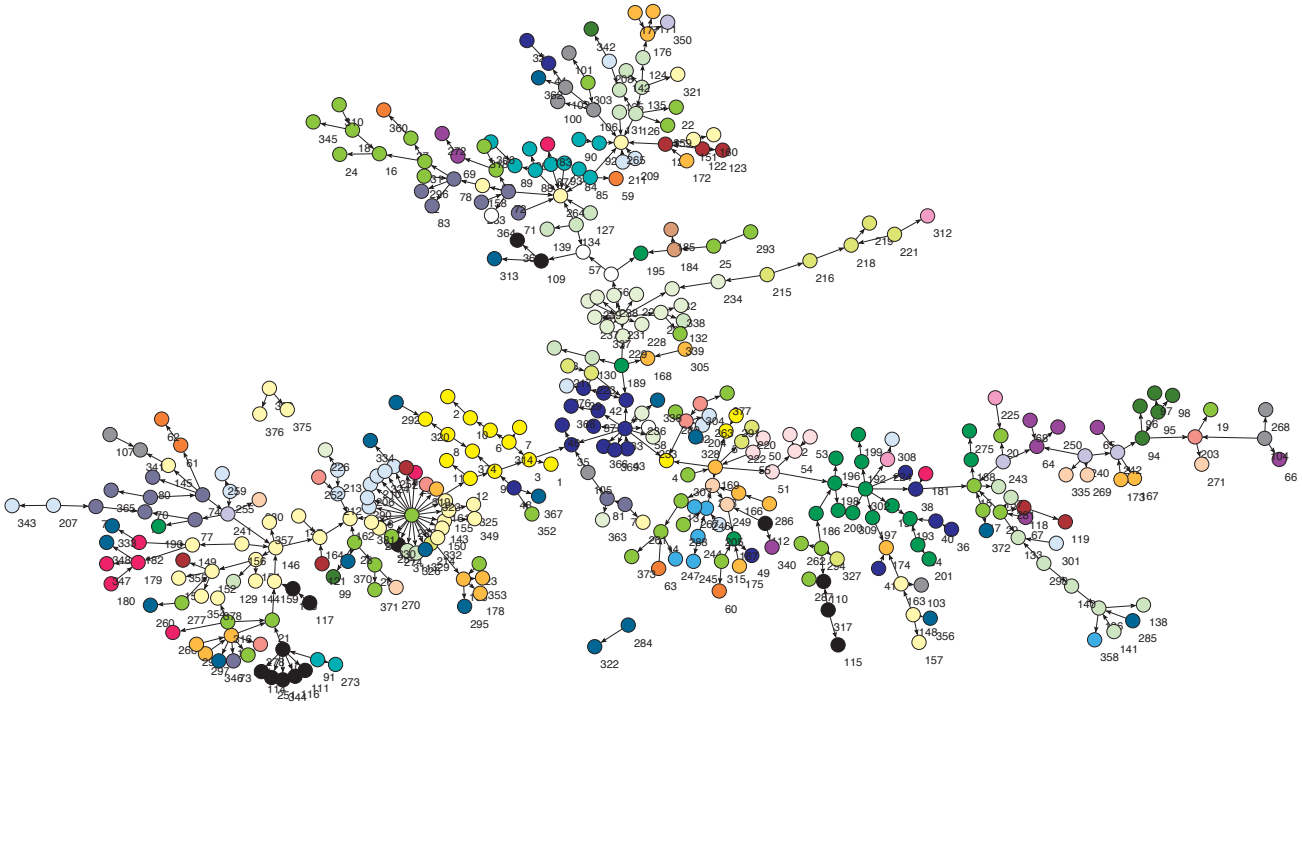
emails of corporation, december 2011



- what do we see? nothing ! $\rightarrow$ network theory

with kind permission from Günther Weiss

emails: max. spanning tree – departments, dec 2011

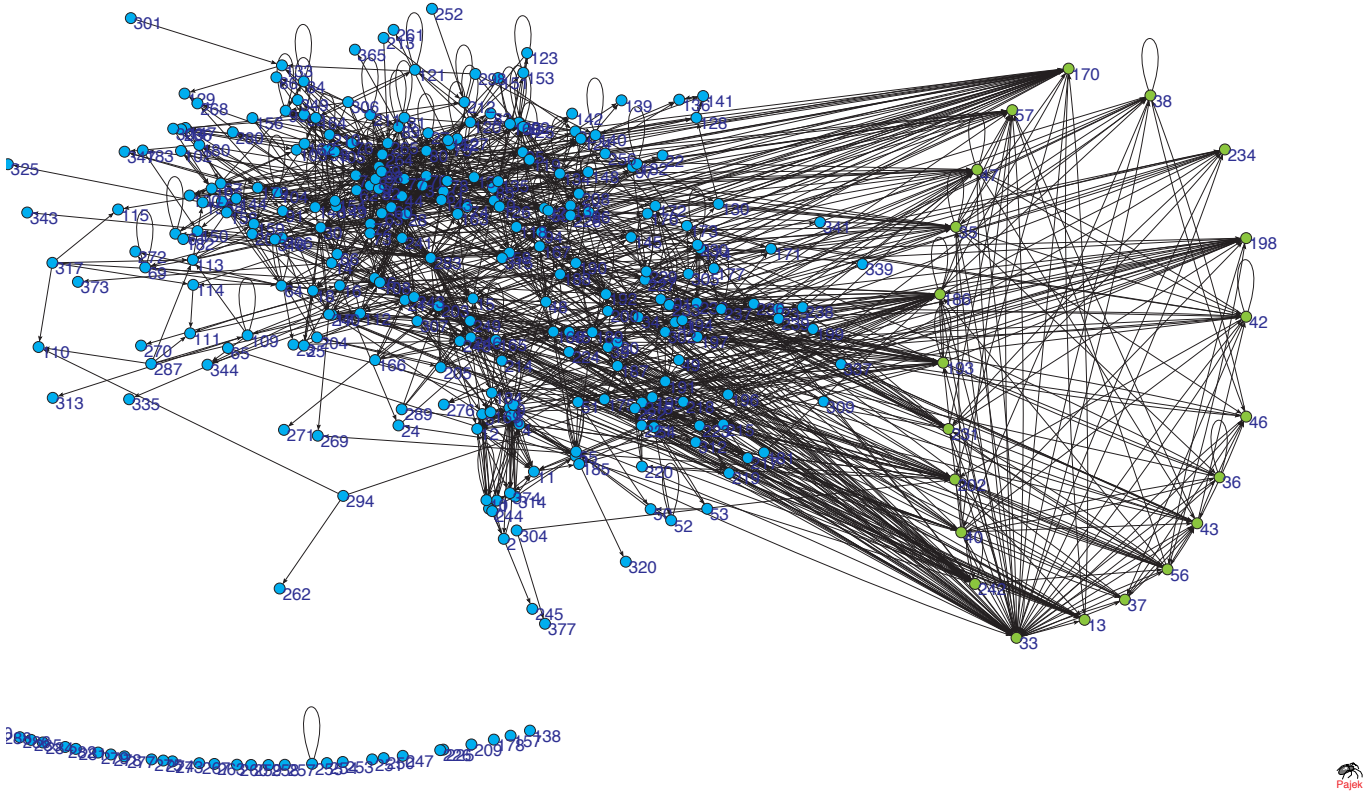


- Support to questions: what is state of the firm – is restructuring needed?
- Degree of clustering → rethink dept. structure? monitor restructuring?

with kind permission from Günther Weiss

Destroy the core and you collapse !

- Loss of core often leads to collapse of network



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Conclusion

- Complexity arises through inter-connectedness: networks
- Science: complexity catastrophe possible: quick & drastic changes
- If can map CS to dynamical co-evolving NW $\rightarrow$ can manage it
- Can manage systemic-risk (risk of drastic change - collapse)

Conclusion II message for strategic management

- Communication-network monitoring
  - know your corporation
  - restructure departments
  - monitor restructuring events

- Core-detection of a corporation
  - verify keystone-emlpoyees
  - identify potentials easy to realize: AC cycle analysis
  - identify cores

- Problems with these techniques:
  - Legal issues, privacy rights, anonnymization, and data storage