

Managing complexity by understanding multiplex networks

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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 neither manage nor control the system: you are subject to luck, fate, external events and developments

What can you predict ?

The future? Developments of markets? Sales of competitors?

certainly not...

... but it would be great if one could predict outcomes of your actions

It helps if you know what your firm is: *know thyself*

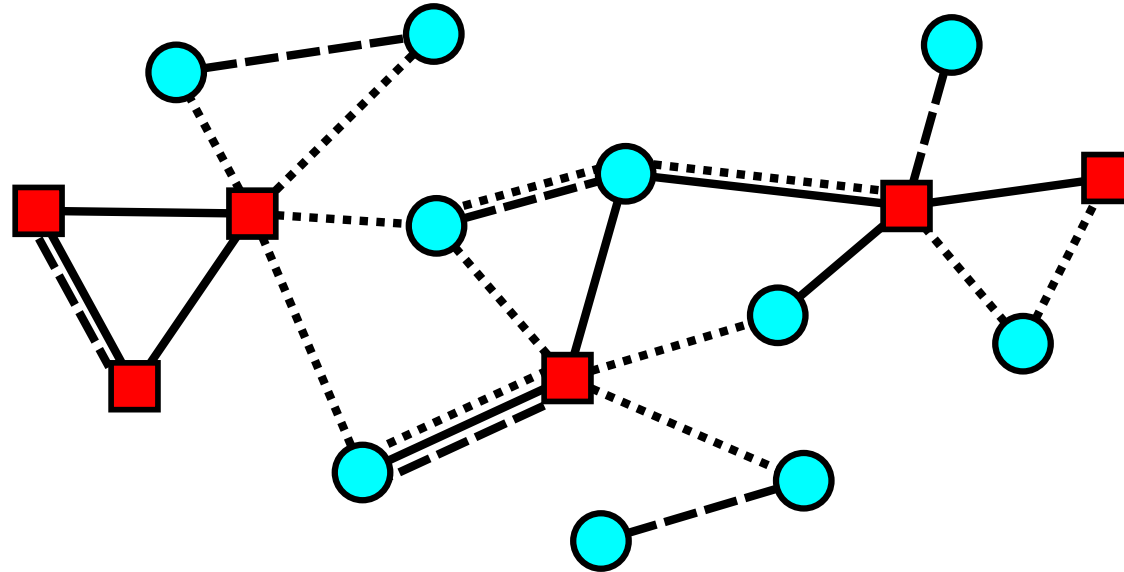
What kind of systems can you predict ?

- Very small ones: physics of a few bodies
- Very large ones: describe laws of physics with laws of statistics
- Managing CS has been out of scope since beginning of mankind

Why is it so hard to predict complex systems?

- Mathematical and statistical tools break down (inter-connected)
- They are evolutionary
- Not enough data available
- No concept of the backbone of CSs – networks

What are Complex Systems ?



CS are co-evolving multiplex networks !

- (1) States of individuals/firms change as a function of network interaction
- (2) Network changes as a function of the states of the agents

point (1): physics

point (2): **makes it a complex system**: society, eco-system, market, firm ...

The game changer: computer + new math + new data

- Network theory: quantify causal processes on networks
- Big-data availability: electronic fingerprints everywhere
- Novel statistics for strongly connected systems – superstatistics

If not *all* of the above → back to start: you can NOT manage CS !

Our claim: If you can map a CS into a dynamical NW → can manage CS

Theory of CS: combination of dynamical (evolutionary) systems and NWs



What is a firm?

- **Traditional view:** Firm produces something, chemicals, cars, cameras, etc.

purchase – production – sales and distribution – administration

- **Less ancient view:** A firm is a network of information flows

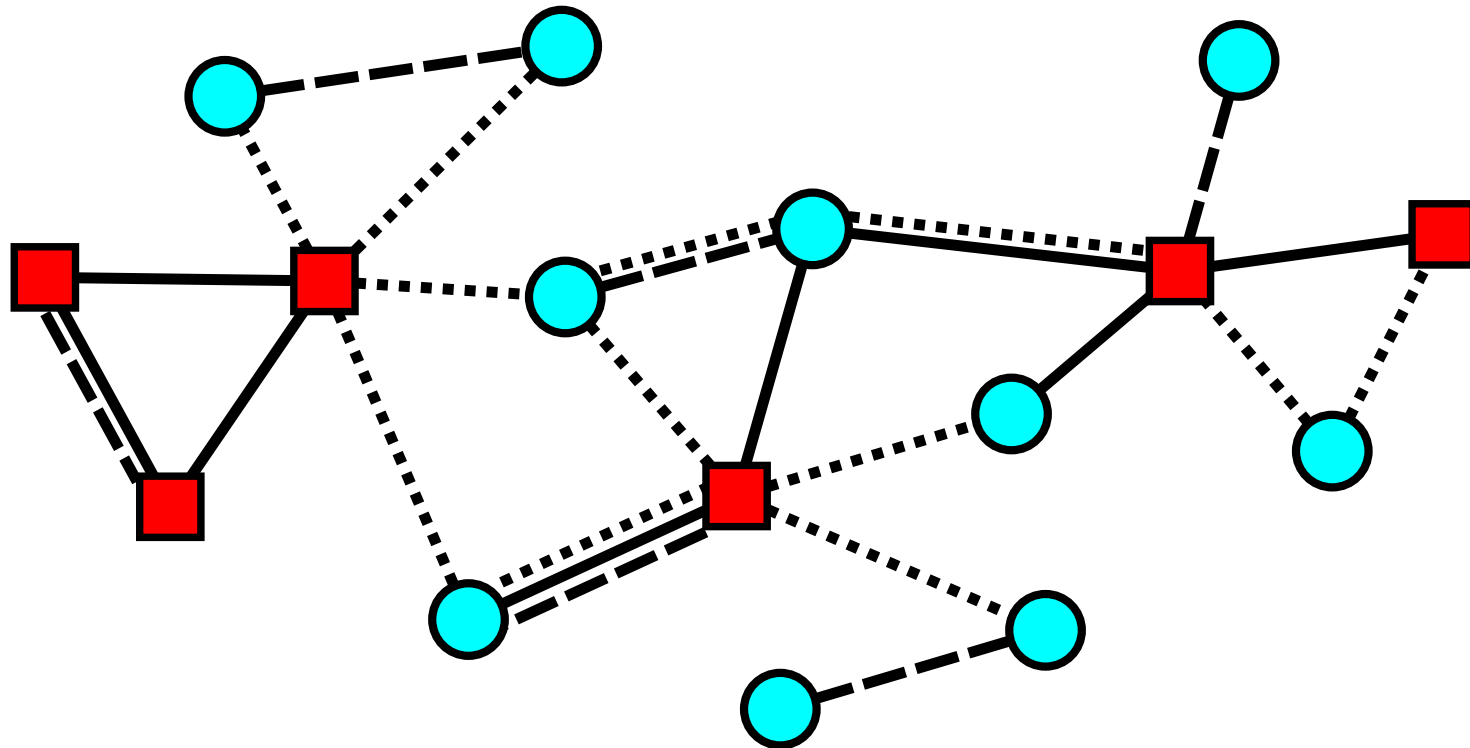
To illustrate the point: **What is a conference?**

Sequence of talks and coffee breaks? **Or** Network of information flow ?

A conference: Forum Alpbach Industry Talks 2007



A firm is a co-evolving multiplex structure



Why CS methods in firms or corporations ?

- Corporation is an evolutionary network of communication flows
- **Management controls 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 !

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**

Optimal network ?

- The right people should communicate with each other (departments)
- Information flow should be direct
- Information flow should not be clustered
- Information flow should be redundant (how much ?)

Communication: the nervous system of a firm

- Telephone bill: every call = one line

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

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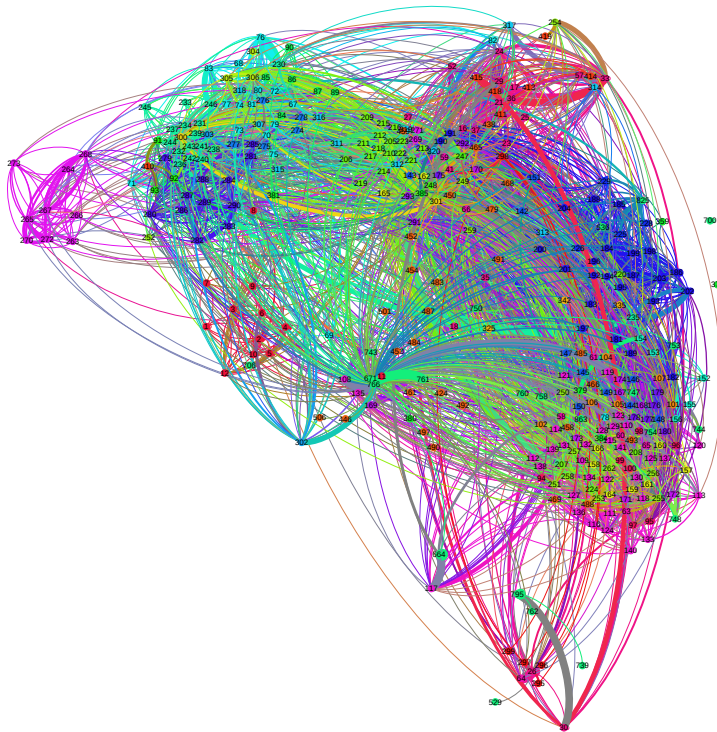
- emails: log-files on server: every mail = one line

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

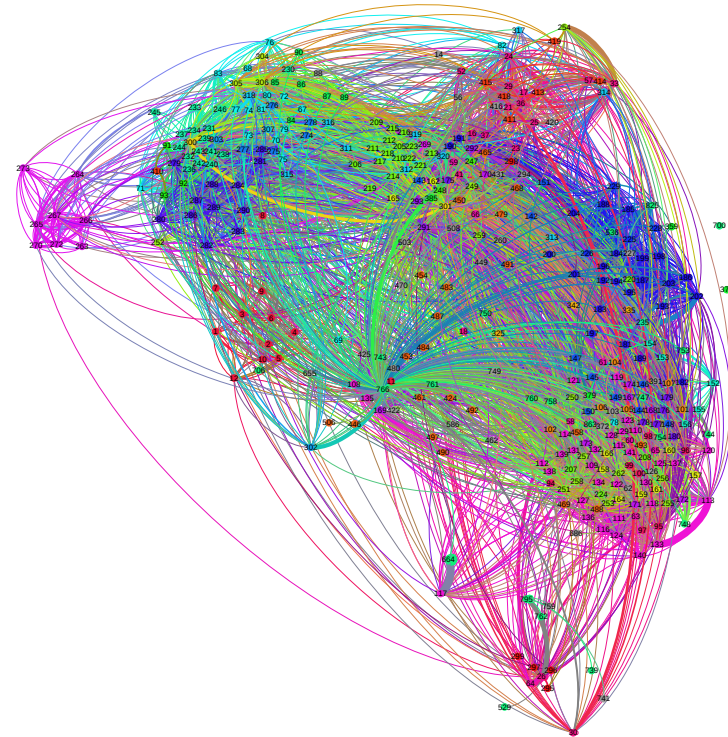
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100001 1 508193 50 3444 2009 11 03 07 13 15
100001 1 509485 50 2996 2009 11 03 13 27 11
100001 1 509485 50 3122 2009 11 03 13 27 11
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email networks of firm (historical data)



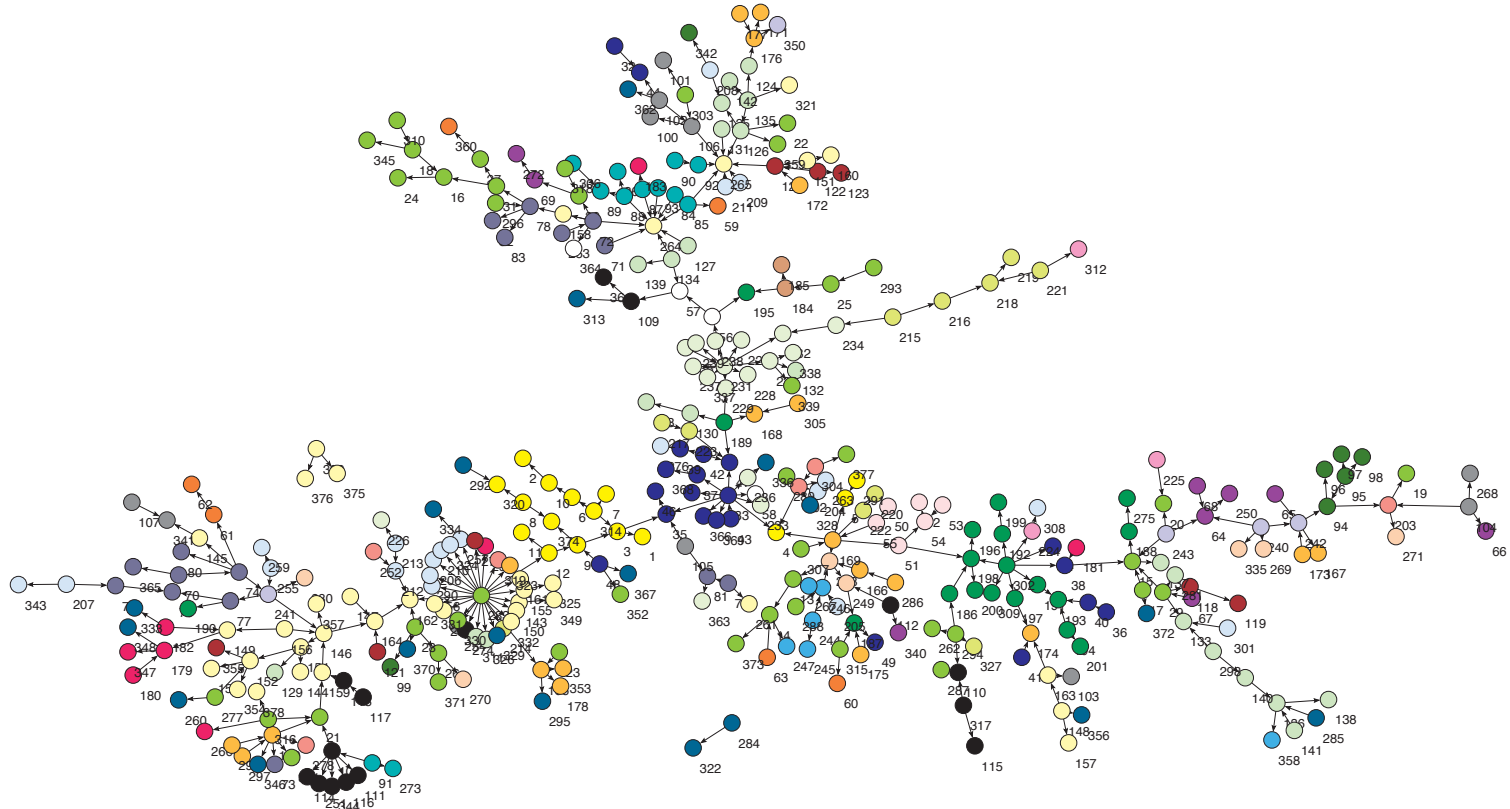
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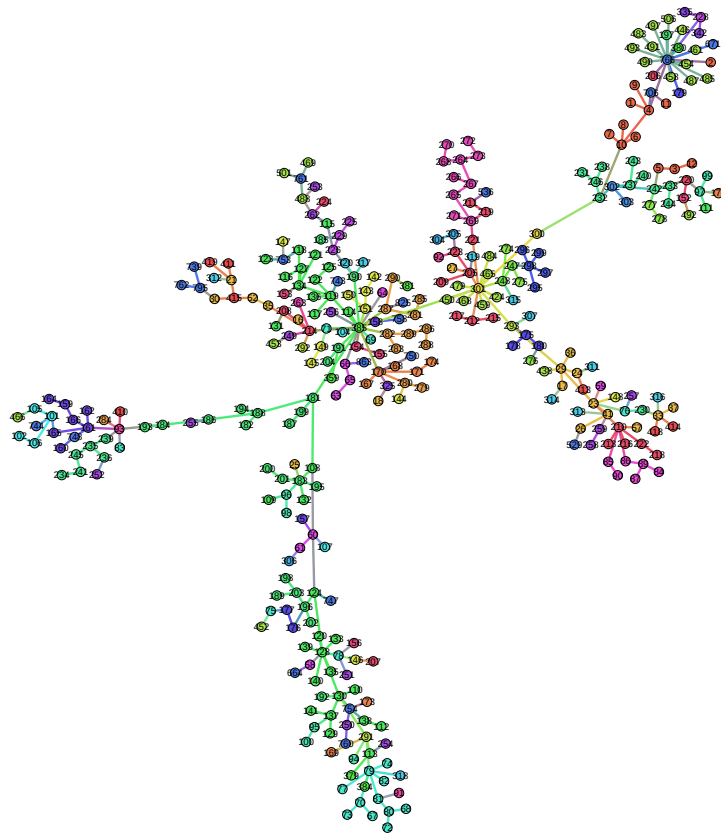
week 15

with kind permission from Günther Weiss

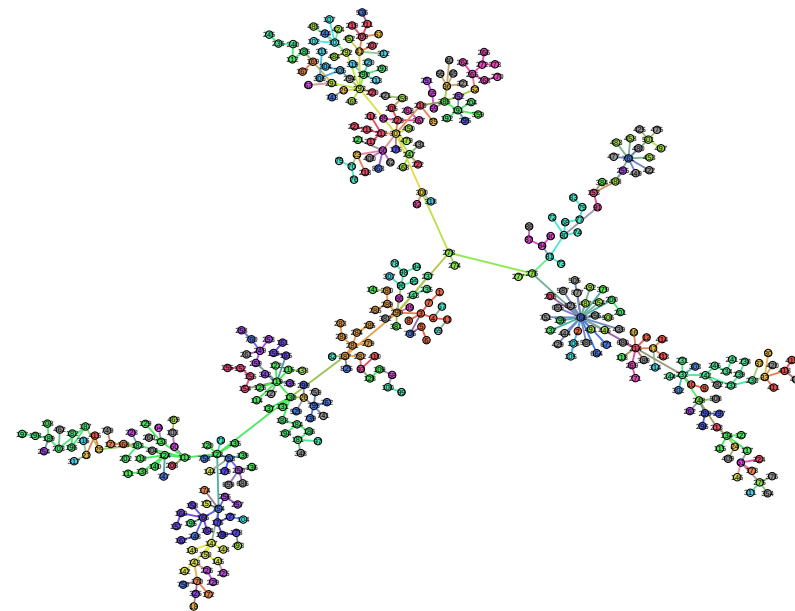
emails-projections → departments 2011



emails-projections 2013

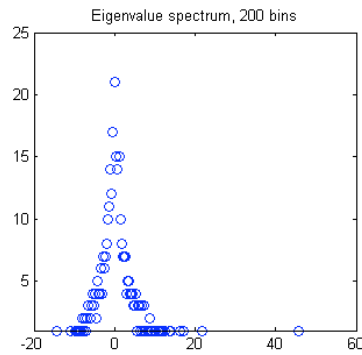
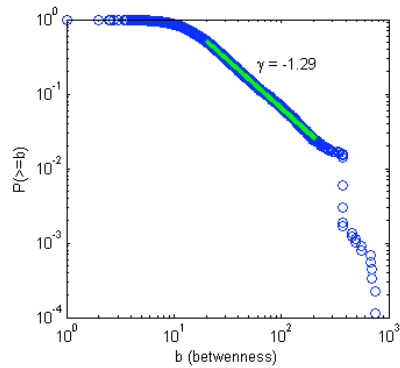
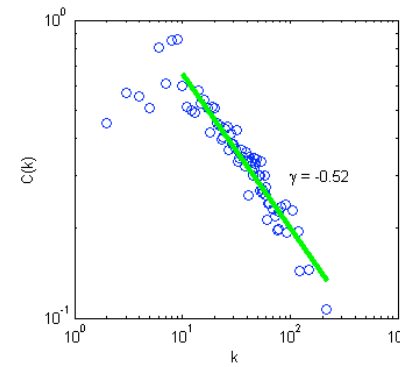
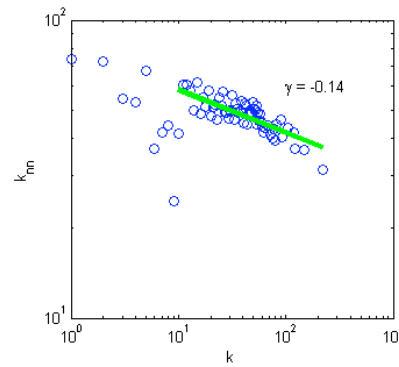
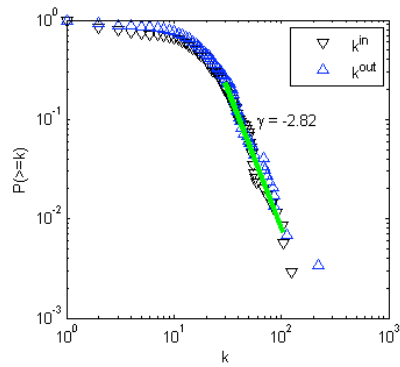


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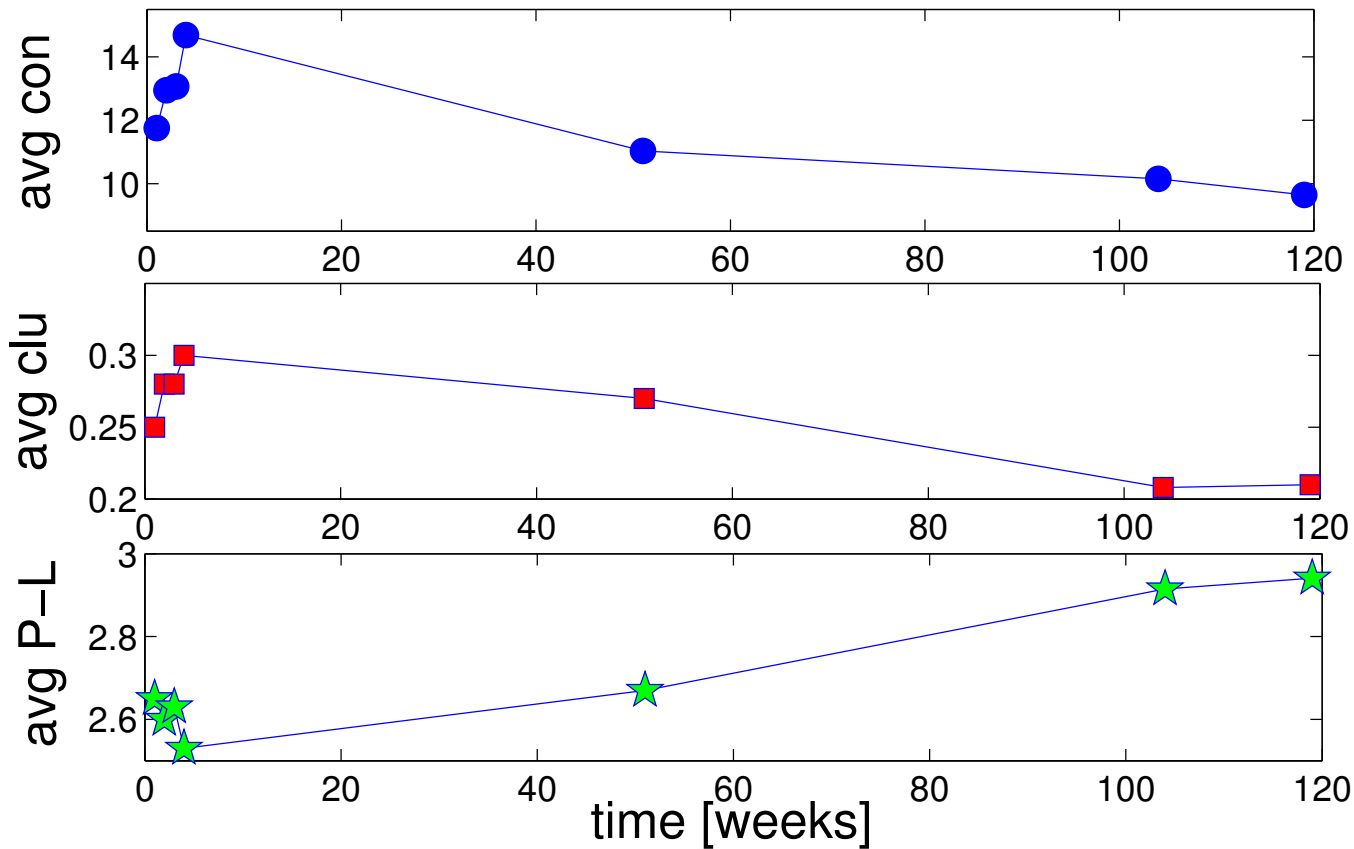
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Network measures: quantify change



L (# links): 6543
 N (# nodes): 378
 C (clustering coeff.) and C/C_c : 0.36, 5.70
 E_{loc} and E_{glob} (efficiency): 0.80, 0.11
 D (diameter) and D_{eff} : 6.00, 2.85
 g (avg. geodesic) and g/g_c : 2.37, 1.26
 k_{avg} (avg. degree): 23.55
 r_{undir} (assortativity) and $r_{C(k)}$: -0.12, -0.06
 ρ (reciprocity): 0.62
 s (rel. size of giant comp.): 0.99

Network re-structuring over time



Why?

Danger of Buerocratization: Parkinson's Law

C. NORTHCOTE PARKINSON'S DATA:

Bureaucracy grows even though its reason for existence vanishes

ADMIRALTY STATISTICS

Year	Capital ships in commission	Officers and men in R.N.	Dockyard workers	Dockyard officials and clerks	Admiralty officials
1914	62	146,000	57,000	3249	2000
1928	20	100,000	62,439	4558	3569
Increase or Decrease	-67.74%	-31.5%	+9.54%	+40.28%	+78.45%

COLONIAL OFFICE

1935	1939	1943	1947	1954
372	450	817	1139	1661

2 Principles

- 1) the buerocrat produces work for her colleagues
- 2) the buerocrat maximizes the number of his subordinates

Can compute: when does **buerocratic infarction** occur?
(Infarction = more internal work is produced than can be worked off)

Input: communication flows + true hierarchical pyramid

Summary usefulness of CS tools for management ?

- Complexity arises through inter-connectedness: networks
- If can map CS to dynamical co-evolving NW → technically manage it
- Conceptualize firm as a multiplex network of communication flows
- Questions to the firm network
 - actual structure of the firm? departments, hierarchies, ...
 - effective communication flows?
 - relate efficiency with network structure
- Monitor outcomes of mgmt decisions on communication network
 - re-structure departments
 - monitor re-structuring events
 - identify core-employees
 - identify ineffective comm. flows (cycles) → try to break cycles