



Politechnika Wroclawska

Improving Resilience in Complex Networks

Session 3: What data do we need to measure resilience
of real world systems?

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About me

Areas of interest

- ▶ social systems
- ▶ temporal networks
- ▶ diffusion phenomena in networks
 - ▶ spread of influence
 - ▶ diffusion of information
- ▶ data-oriented approach



Resilience in complex systems

Input paper

- ▶ Does the system representation restrict what type of resilience we study? Or can we find a general modelling framework that encompass a broader focus?
- ▶ Are there viable alternatives to network representations? What are their limitations and what are their advantages when studying resilience?
- ▶ What type of data is needed to employ network representations reliably? How can we deal with incomplete datasets? How would errors in measurements affect resilience measures?



Resilience in complex systems

What do we know?

Everything is obvious*.



Resilience in complex systems

What do we know?

Everything is obvious*

***Once you know the answer.**

Watts, D. J. (2011). *„Everything is obvious: Once you know the answer”*. Crown Business.



Resilience in complex systems

How complex are complex systems?

- ▶ we do not know what exactly drives them
- ▶ external state observation vs. internal processes
- ▶ *some* data available



Auklet flock Shumagins 1986, public domain



Resilience in complex systems

State of a complex system

What influences the state, actually?

- ▶ exogenous (external forces)
- ▶ endogenous (internal processes)



Complex systems representation

From micro level to state

- ▶ social systems are based on interactions between individuals
- ▶ systemic properties emerge based on those interactions
- ▶ resilience is an emerging property of the system
- ▶ if so, micro level is a level we should start with
- ▶ bottom-up approach
- ▶ but some external factors also appear (e.g., regulation)



Complex systems representation

Complex networks' models

- ▶ static
 - ▶ well established
 - ▶ models
 - ▶ boundaries easier to find
- ▶ temporal¹²
 - ▶ ordering of interactions
 - ▶ new measures³
 - ▶ longitudinal data
- ▶ multilayer
- ▶ events' streams

¹Scholtes, I., Wider, N., Pfitzner, R., Garas, A., Tessone, C. J., & Schweitzer, F. (2014). Causality-driven slow-down and speed-up of diffusion in non-Markovian temporal networks. *Nature communications*, 5, 5024.

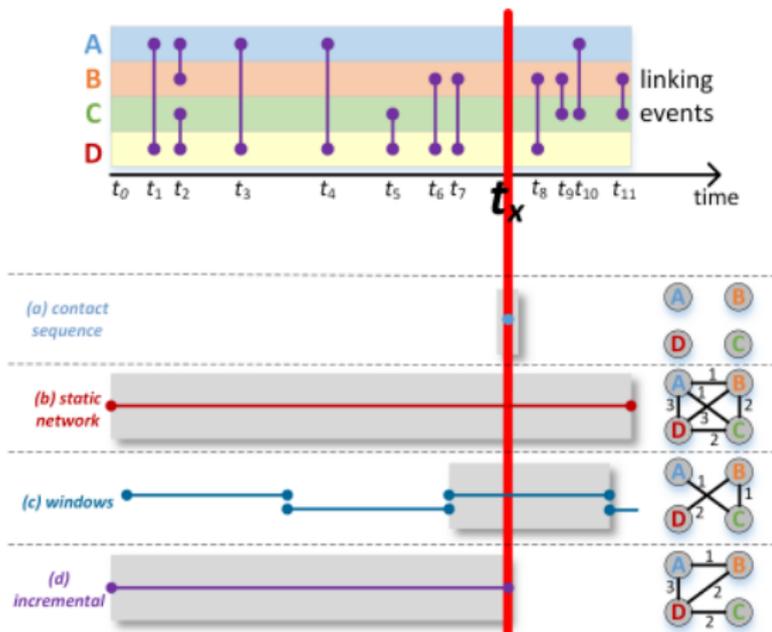
²Michalski, R., Kajdanowicz, T., Bródka, P., & Kaziemko, P. (2014). Seed selection for spread of influence in social networks: Temporal vs. static approach. *New Generation Computing*, 32(3-4), 213-235.

³Pfitzner, R., Scholtes, I., Garas, A., Tessone, C. J., & Schweitzer, F. (2013). Betweenness preference: Quantifying correlations in the topological dynamics of temporal networks. *Physical review letters*, 110(19), 198701.



Complex systems representation

Complex networks models' comparison





Complex systems representation

Modelling obstacles

Commonly, authors group the contacts happening at the same discrete timestep into one graph and present the temporal network as a time sequence of graphs. Since this representation makes it tempting to think of the temporal-network structure as an evolving static network structure, it misses many of the unique points of temporal networks.⁴

⁴Holme, P., & Saramäki, J. (2012). Temporal networks. Physics reports, 519(3), 97-125.



Complex systems representation

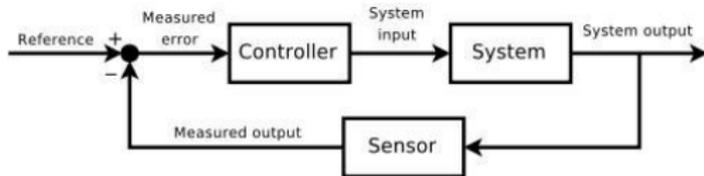
Stochastic modelling & control theory

Stochastic modelling

- ▶ estimating probability distributions of potential outcomes (state)
- ▶ random variation in one or more inputs over time
- ▶ random variation is based on fluctuations observed in historical data

Control theory:

- ▶ set of inputs and outputs

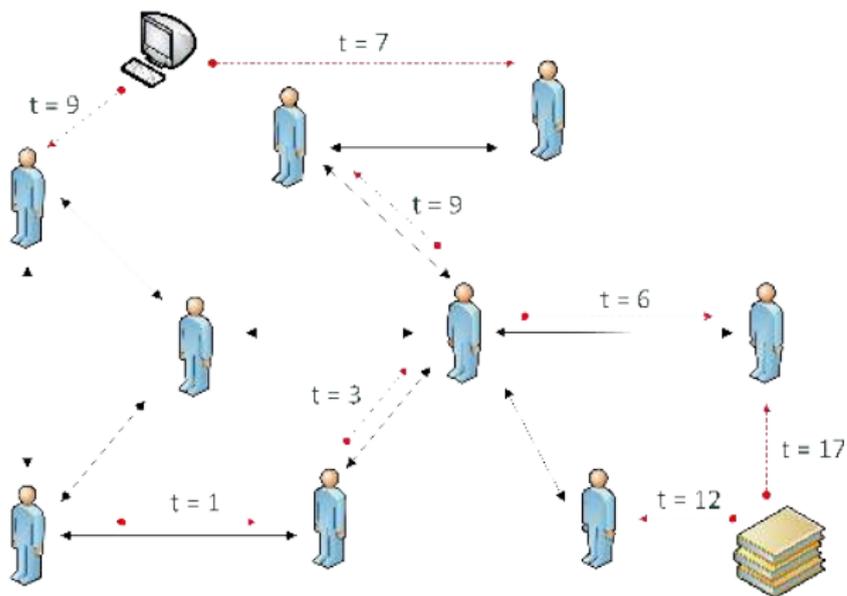


Orzetto commonswiki, GFDL 1.2



Complex systems representation

Complex networks - what is actually known?



R. Michalski, PhD thesis



Complex systems representation

Complex networks - data and outcomes

- ▶ what is a system, actually?
 - ▶ abstracted series of observations
- ▶ what can't we see?
 - ▶ we focus on a chosen model too much
 - ▶ missing data
 - ▶ measurements' errors
 - ▶ all sum up and may lead to wrong conclusions about resilience
 - ▶ social organizations change rapidly, require precise adjustment of a timescale
- ▶ are we neutral to the social system when measuring it?
- ▶ to what extent can we change the system?
 - ▶ we wish we could add/remove nodes or links, but can we?
 - ▶ agent-based modelling



Takeaway message

Resilience, data, models

The models we employ supported by data gathered by observations impact the resilience measures as they are build upon of both.

Avoid post-factum interpretation of why a system failed/sustained/recovered ("it is obvious").