

Network Science (VU) (706.703)

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Lecturer

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Language

- Lectures in English
- Communication in German/English
- Project: German/English

Outline

- 1 Welcome and Introduction
- 2 Course Organization
- 3 Motivation

Course context

- Network Science (VU) (706.703)
- Elective/obligatory course in subject catalogs for CS, SEM, BioMed, CSS
- Catalogs: “Data Science”, “Machine Learning”, “Algorithms and Theoretical CS”, ...

Goals of the course

- To learn about the fundamentals of network science
- To understand the relation between network structure and its function
- To analyze a real-world network
- To simulate a process on a network

Goals of the course

- Student goals: to pass the examination
- Bonus goal for all: to have fun!

Course Topics

- Mathematics of networks
- Measuring network properties
- Graph partitioning and community detection
- Structure vs. Function
 - Network Function
 - Intro to Dynamical Systems
 - Epidemics
 - Dynamical systems on networks

Course Calendar (VU/706.703)

- 06.10.2023: Course organization / Mathematics of networks
- 13.10.2023: Mathematics of networks (cont.)
- 20.10.2023: Mathematics of networks (cont.)
- 24.10.2023: Mathematics of networks (cont.)
- 03.11.2023: Measuring network properties
- 10.11.2023: Measuring network properties (cont.)
- 17.11.2023: Measuring network properties (cont.)

Course Calendar (VU/706.703)

- 24.11.2023: Graph partitioning and community detection
- 01.12.2023: Graph partitioning and community detection (cont.)
- 12.12.2023: Graph partitioning and community detection (cont.)

Course Calendar (VU/706.703)

- 15.12.2023: Network Function / Intro to Dynamical Systems
- 12.01.2024: Epidemics
- 19.01.2024: Dynamical systems on networks
- 26.01.2024: Presentations of student projects
- 30.01.2024: Presentations of student projects

Course Logistics

- Course website:
<https://courses.isds.tugraz.at/dhelic/netsci/index.html>
- Communication/Homework/Project in TeachCenter
- <https://tc.tugraz.at/main/course/view.php?id=3150>
- Slides & videos are available on the course website and TC
- Additional readings, references, links, etc. on the website

Grading

- 4 Exercises + one network analysis project
- Programming
- Each exercise 10 points
- Project 40 points
- Total 80 points
- Minimal requirements:
 - 1 First two homework sheets: minimum of 10 points
 - 2 Last two homework sheets: minimum of 10 points

Grading

- 0-40 points: 5
- 41-50 points: 4
- 51-60 points: 3
- 61-70 points: 2
- 71-80 points: 1

Questions?

- Raise them now!
- Ask after the lecture
- Post a question in TC forum
- Visit me in the office hours
- Send me an e-mail
- As a side note: you should(!) interrupt me immediately and ask any question you might have during the lecture

Networks

Definition

A network is a set of items called nodes and connections between those items called links.

Terminology clarification:

- Mathematics: vertices (vertex) and edges
- Physics: sites and bonds
- Sociology: actors and ties
- **Computer science: nodes and links**

Graphs vs. Networks

- Mathematical graph theory
- Analytical approach to studying of small graphs (typically tens or hundreds of nodes)
- With the emergence of ICT technology we are able to analyze large graphs that exist in nature, societies, technologies, etc.
- Now, we are considering large-scale statistical properties of graphs
- Network science deal with the empirical analysis of large graphs (networks) that occur in different areas

Types of networks

- Nodes connected by links is the simplest type of network
- Different types of nodes
- Different types of links
- Nodes and links can carry weights
- Links can be directed, i.e. pointing in only one direction

Types of networks

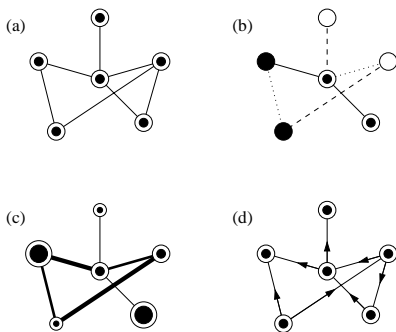


Figure: Various types of networks. From: The structure and function of complex networks, Newman, 2003.

Networks

- *Social networks*. Nodes are people and links are acquaintances, friendship, and so on.
- *Communication networks*. Internet: nodes are computers and links are cables connecting computers
- *Biological networks*. Metabolism: nodes are substances and links are metabolic reactions
- *Information networks*. Web: nodes are Web pages and links are hyperlinks connecting pages

Networks

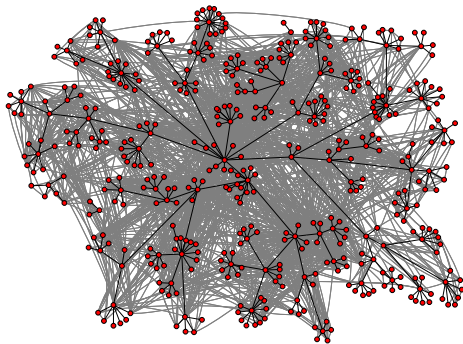


Figure: Social network of HP Labs constructed out of e-mail communication.
From: How to search a social network, Adamic, 2005.

Networks

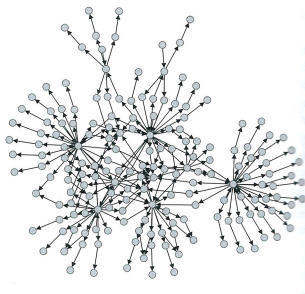


Figure: Network of pages and hyperlinks on a Website. From: Networks, Mark Newman, 2011.

Network science: what is it all about?

- Some phenomena are best understood through relations between individuals
- For example, human communication
- We do not investigate the individuals but the processes that emerge through their interaction with each other

Network science: what is it all about?

- Scientific approach:

```
while(True){  
  observe  
  measure  
  quantify  
  model  
  compute consequences  
  compare with observation  
}
```

Network science: what is it all about?

- Sisyphean task?
- Real driving force: curiosity, which leads to learning and in the long run expertise
- Proper attitude: scepticism
- Richard Feynman: "Science is the organized skepticism in the reliability of expert opinion."

Network science: Success stories

- Page Rank
- Web as a graph
- Network evolution: preferential attachment
- Power law networks
- Six degrees of separation: small world networks

Network science: some highlights

- Centralities
- Spectral clustering
- Epidemics
- Simulation of network dynamics