Network Science (VU) (706.703)

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Lecturer

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Outline

1 Welcome and Introduction

2 Course Organization

3 Motivation

Course context

- Network Science (VU) (706.703)
- Elective course in subject catalogs for both CS and SEM "Data Science", "Machine Learning", "Algorithms and Theoretical CS"
- Elective course for CS "Mathematical Foundations"
- Elective course for SEM "Current Societies"

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 Logistics

- Course website:
  https://courses.isds.tugraz.at/dhelic/netsci/index.html
- Communication/Homework/Project in MS Teams
- Slides & videos are (will be made) available on the course website
- Please download the videos, do not stream them!
- Additional readings, references, links, etc. on the website

Course Calendar (VU/706.703)

- This term the course is fully online
- Every Monday 11:00-12:00 and 13:00-14:00 there will be a Q&A session
- We will also work on further interesting problems in these sessions
- As a preparation for the Q&A sessions you have to watch the videos

Course Calendar (VU/706.703)

- Week 1: Intro
- Week 2: Math 1 - Math 5
- Week 3: Math 6 - Math 10
- Week 4: Measures 1 - Measures 4
- Week 5: Measures 5 - Measures 7
- Week 6: Community 1 - Community 3
- Week 7: Community 4 - Community 5
- Week 8: Function of Networks, Dyn. Sys. 1 - Dyn. Sys. 2
- Week 9: Epidemics, Dyn. Sys. on Networks

Grading

- 4 Exercises + one network analysis project
- Programming
- Each exercise max 15 points
- Project max 20 points
- Total max 80 points

Grading

- Minimal requirements:
  1. First two homework sheets: minimum of 16 points
  2. Last two homework sheets: minimum of 15 points
  3. Project: 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?

- Come to the Q&A sessions
- Post a question in MS Teams
- Visit me in the office hours

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
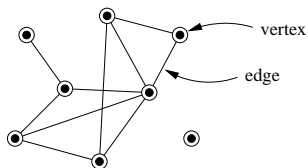- **Computer science: nodes and links**

Example of a simple network

Figure: A small network with 8 nodes and 10 links. From: The structure and function of complex networks, Newman, 2003.

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
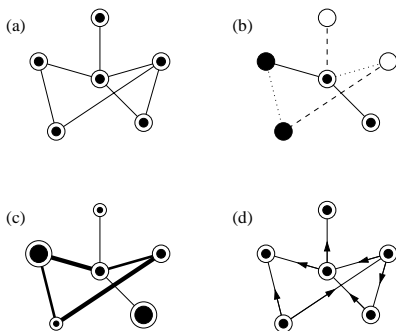
Types of networks

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
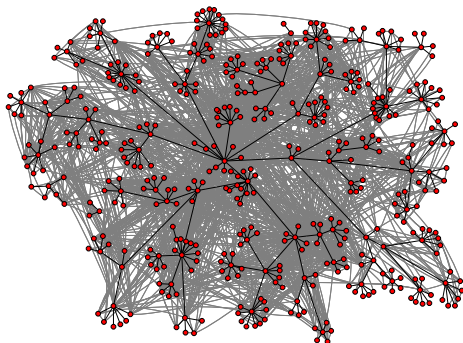
Networks

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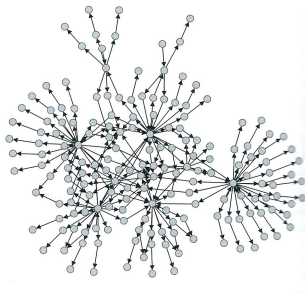From: How to search a social network, Adamic, 2005.

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 conseqeunces
   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