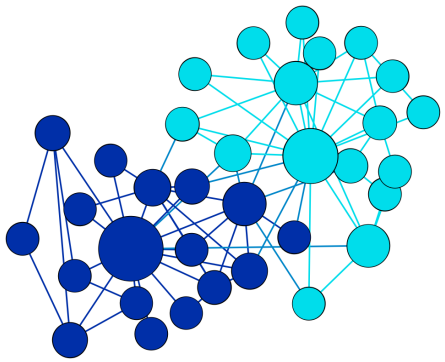
Network Science

Pedro Ribeiro

DCC/FCUP

2024/2025



Who am I?

Name: Pedro Ribeiro
Office 1.47 (FC6 - DCC building)
Personal Website: http://www.dcc.fc.up.pt/~pribeiro/

PhD in **Computer Science**

Main research interests:

- Complex Networks, Network Science, Graph Mining, Data Science
- Algorithms and Data Structures, Complexity
- Parallel and Distributed Computing
- Computer Science Education and Programming Contests

Competitive Programming

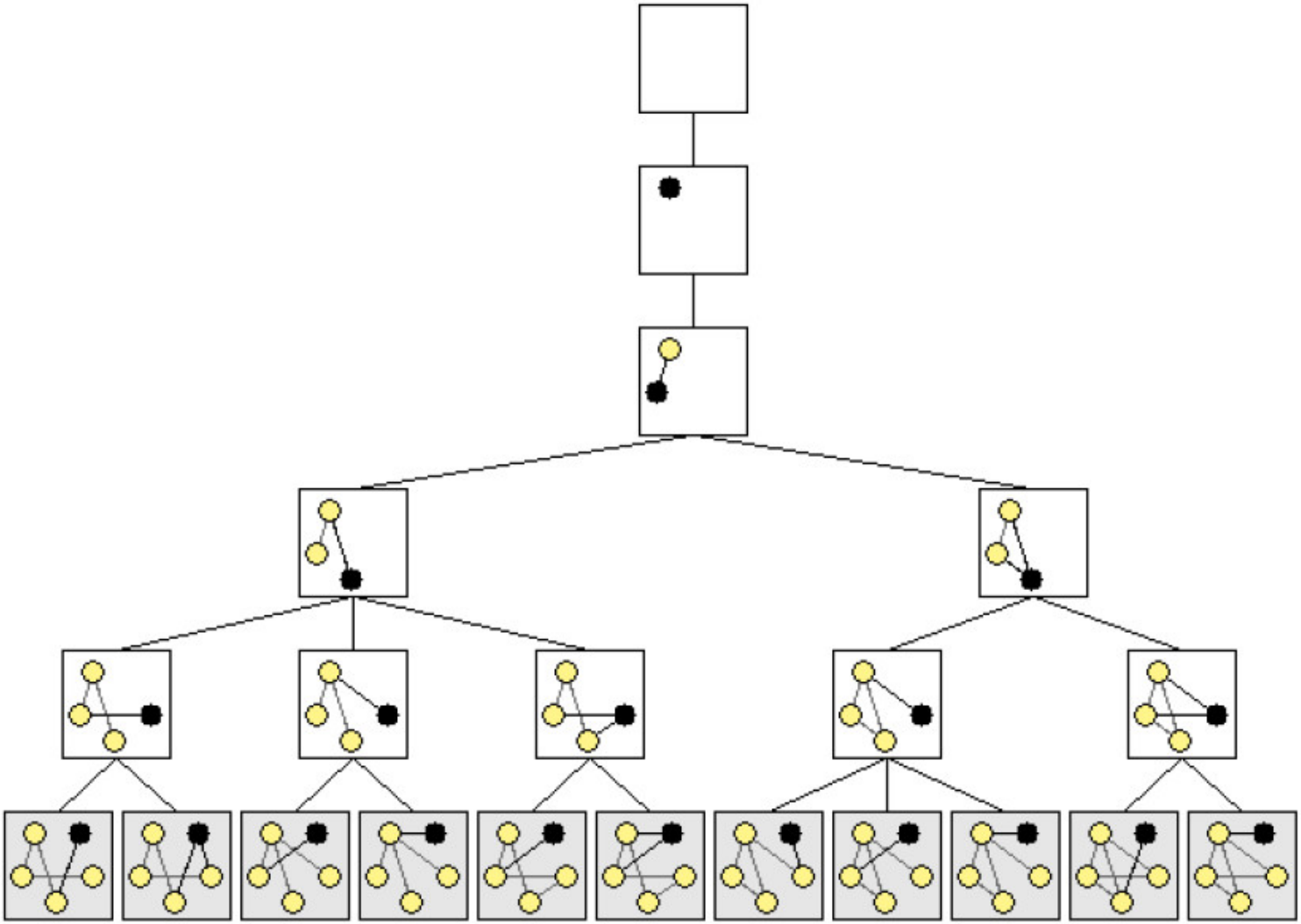
I'm involved in many **algorithmic programming contests**:
(organization, problem creation, mentoring and training, ...)

- Pre-Universitary Students (Basic and Secondary Education)
  - National and International Informatics **Olympiads** (e.g: ONI, IOI)
  - **Bebras** - Computational Thinking International Challenge
- University Students
  - National and Internacional **ICPC** contests (e.g: MIUP, SWERC, EUC)

PhD in Computer Science (2011)

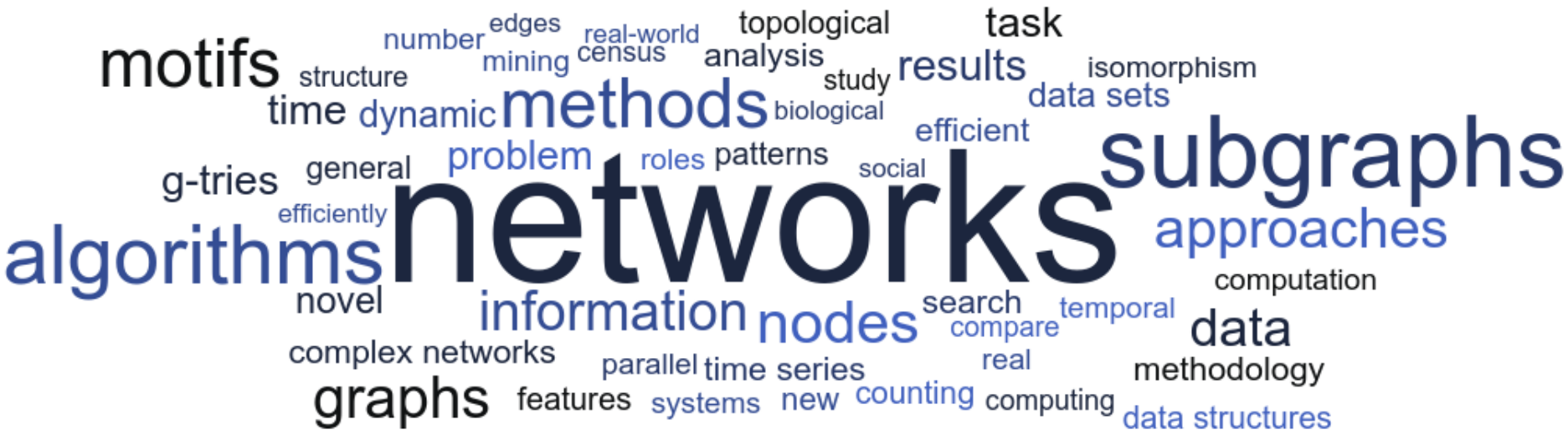
Thesis: Efficient and Scalable Algorithms for Network Motifs Discovery

PhD: G-Tries



Publications

A word cloud of my publications abstracts:



http://www.dcc.fc.up.pt/~pribeiro/pubs_by_year.html
https://scholar.google.com/citations?user=DbR0sO4AAAAJ

Some of my former students

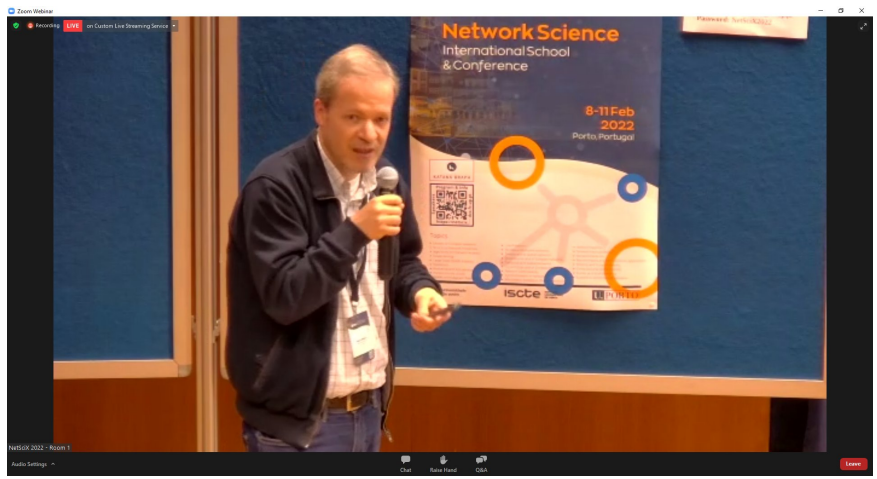
- **PhD Students**
  - **Ahmad Naser eddin** (2019-2024)
    Anti-money Laundering using Graph Techniques
  - **Vanessa Silva** (2018-2023)
    Multidimensional Time Series Analysis: A Complex Networks Approach
  - **Jorge Silva** (2016-2021)
    Towards measuring scientific impact using network science
  - **David Aparício** (2014-2020)
    Network Comparison and Node Ranking in Complex Networks
  - **Miguel Araújo** (2012-2017)
    Communities and Anomaly Detection in Large Edge-Labeled Graphs
  - **Sarvenaz Choodbdar** (2010-2015):
    On the Characterization and Comparison of Complex Networks

Some of my former students

- **MSc Students**
  - P. Vieira (23/24): *Studying GNNs and their Capabilities for Finding Motifs*
  - D. Ferreira (23/24): *Football passing sequences and networks for goal prediction*
  - J. Ferreira (21/22): *Subgraph Patterns in Spatial Networks*
  - F. Justiça (21/22): *Time series forecasting via Network Science*
  - M. Lamas (21/22): *Characterizing Music through Complex Networks*
  - I. Novo (21/22): *On the Summarization of Complex Networks*
  - B. Pinto (20/21): *Subgraph Patterns in Colored Networks*
  - H. Branquinho (19/20): *Counting Subgraphs in Streaming Networks*
  - F. Bento (19/20): *Characterizing the Passing Networks of Football Teams*
  - L. Grácio (18/19): *From Supergraph Counting to Subgraph Generation*
  - A. Meira (18/19): *Subgraph Patterns in Multiplex Networks*
  - M. Martins (18/19): *Condensed Graphs: Towards a General Approach for Faster Subgraph Census*
  - A. Cascais (17/18): *Adaptive Parallel Subgraph Sampling in Large Complex Networks*
  - *(...)*

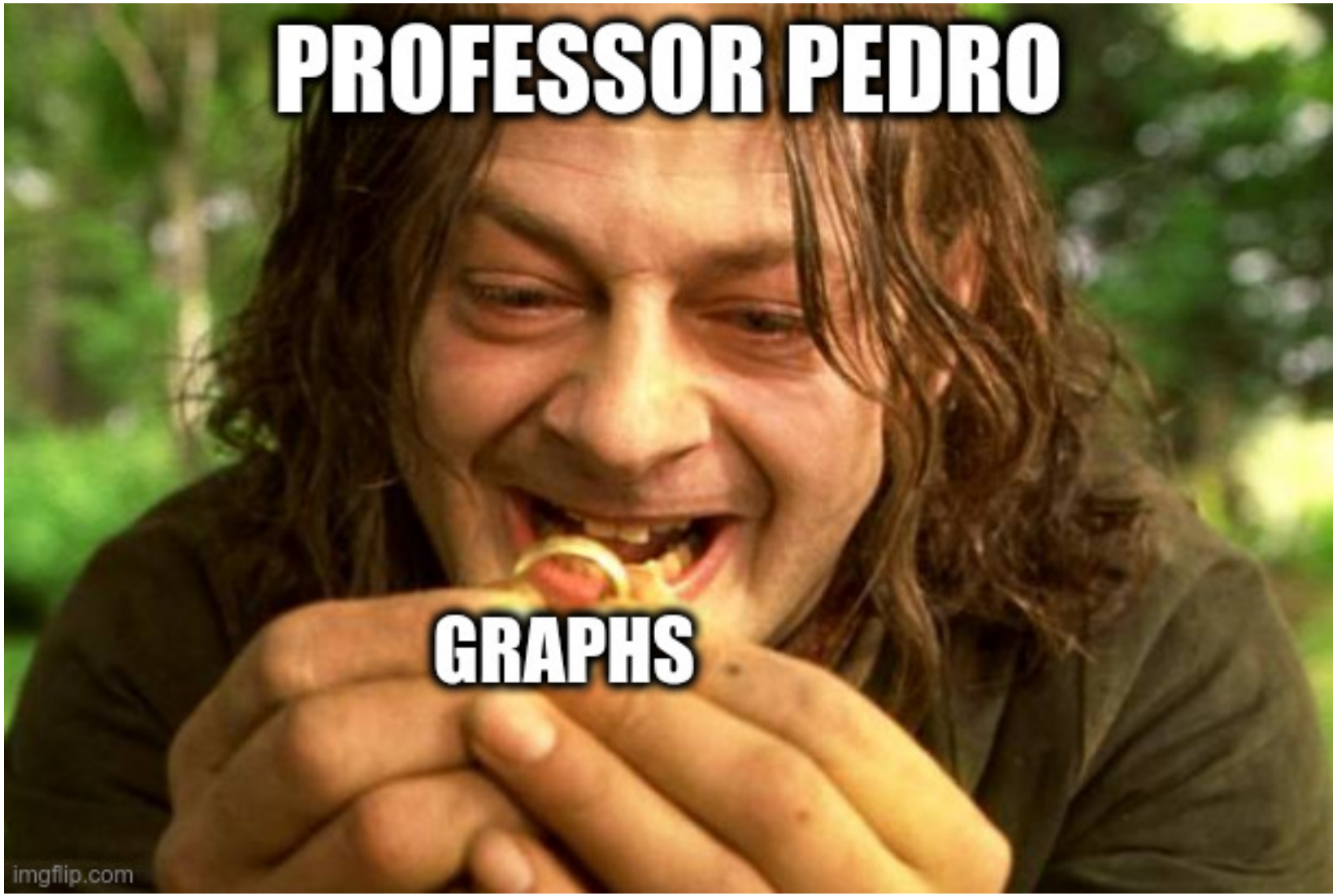
Network Science Events

http://netsci18.dcc.fc.up.pt/



https://netscix.dcc.fc.up.pt/

Graphs



General Information

- **Site:** http://www.dcc.fc.up.pt/~pribeiro/aulas/ns2425/
- **Classes:**
  - **Tuesday:** 09:00-12:30 (Auditorium FC1 0.29)
- **Class Organization:**
  - Theoretical Exposition: auditorium (+ pre-recorded videos)
  - Pratical approach with homeworks and projects
  - Communication: Discord
- **Class participation:** There is no minimum enforced attendance

Evaluation

- Homeworks **(30%)**
- Test **(30%)**
- Project **(40%)**

There will be no final exam.

There are no minimum grades in any of the evaluation components, but failure to deliver and present the project will result on a **RFC** evaluation (missing an evaluation component).

Homeworks and Test

Homeworks: group (max: 3 persons) homeworks (at least 2 weeks for each) to be delivered by email. You will apply some concepts in practice (potentially using a computer to analyze small datasets).

Mini-Test: one individual test (pen and paper) to be done "on site" during monday class with a duration of 2h30m

Predicted dates:

- **1st Homework (15%)** - March
- **2nd Homework (15%)** - April
- **Mini-Test (30%)** - May

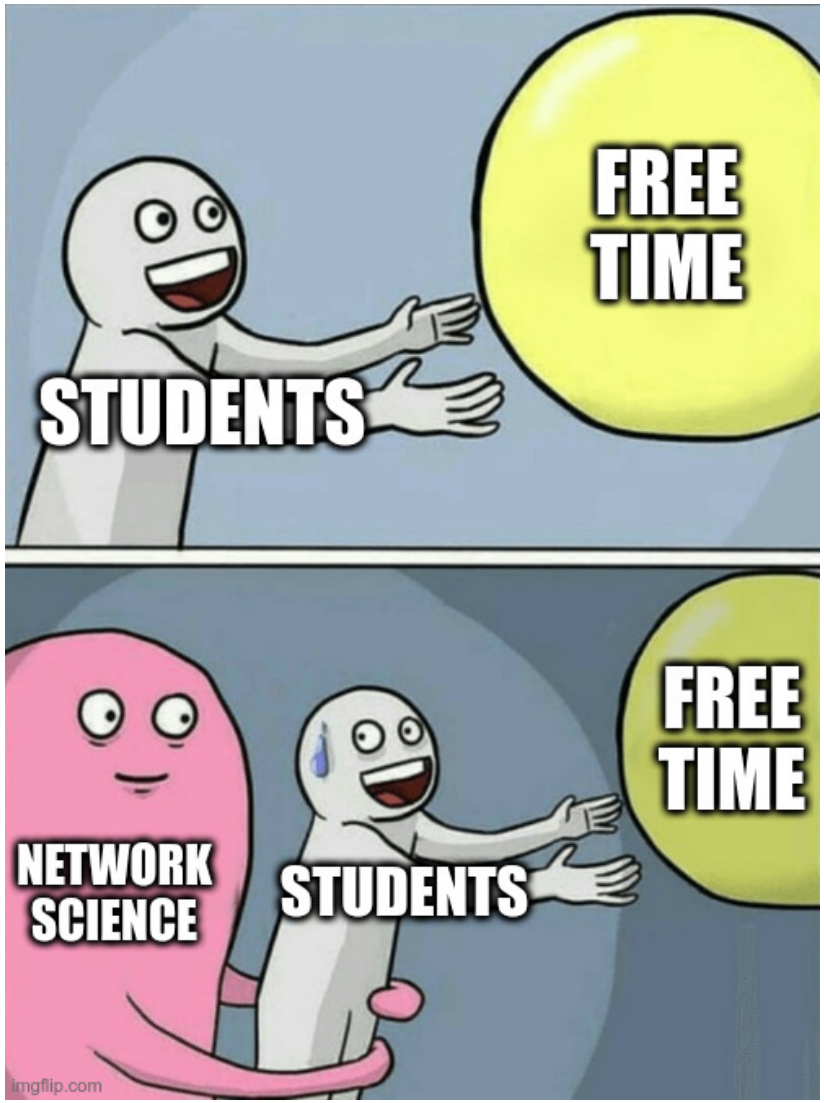
Project

- This is a **group** assignment (maximum: 3 students)
- **Analyze a network dataset** using the concepts you learned
- You can use your own built dataset or create a new one
- Focus can be on the **analysis itself** (ex: new insights), on the **implementation** (ex: compare efficiency) or any other combination
- You are strongly encouraged to **speak with your instructor to validate your project** idea before starting your work.

What do I need to deliver?

- **Written article:** 6 to 10 pages (KDD format)
  [deadline: end of classes]
- **Presentation:** 15min

Graphs


FREE TIME
STUDENTS
NETWORK SCIENCE
STUDENTS
FREE TIME
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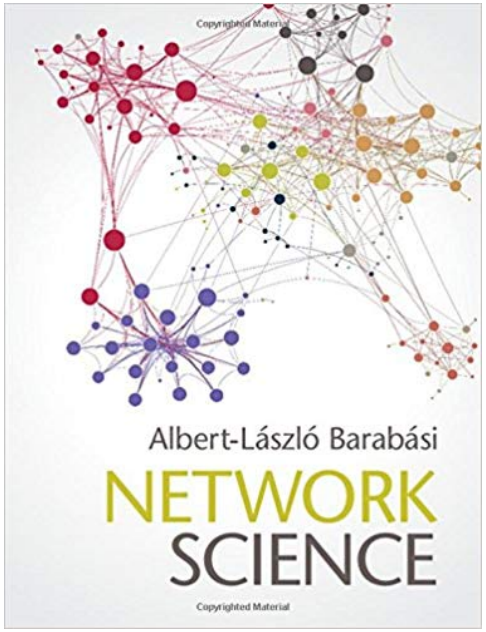
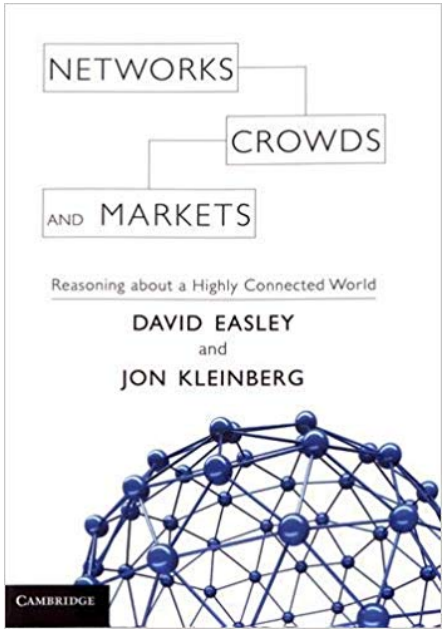
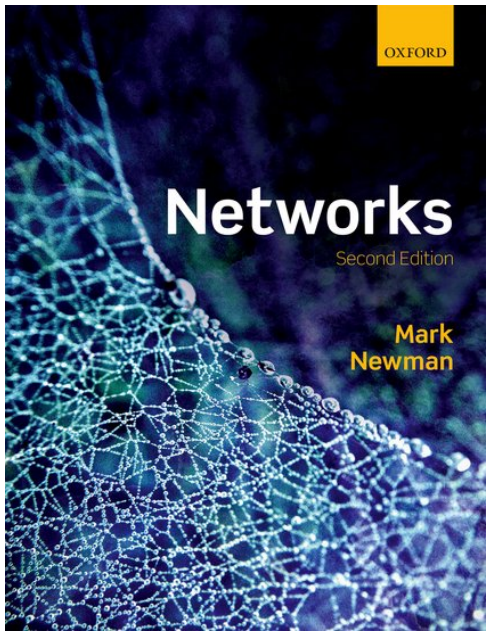
Learning outcomes in this curricular unit

- explain the **key concepts of network science** and network analysis
- apply a range of techniques for **characterizing network structure**
- define **methodologies for analyzing networks** of different fields
- demonstrate **knowledge of recent research** in the area

Recommended Books



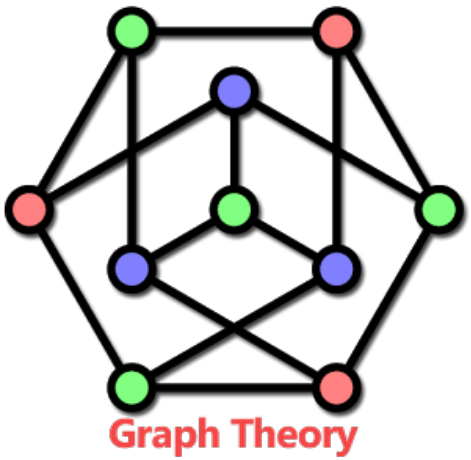




An overview of the program

Fundamentals of Network Science:

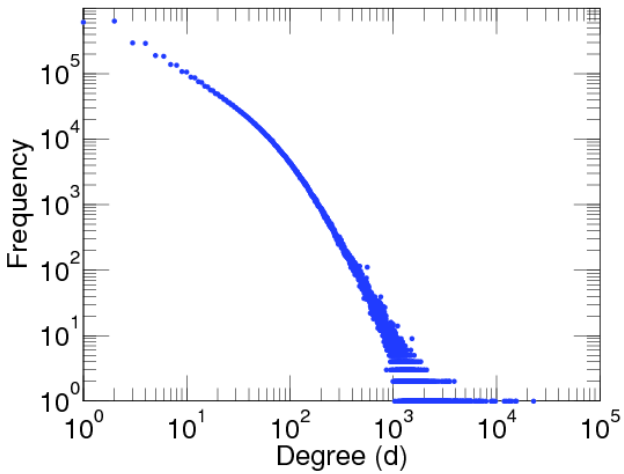
- Emergence of Network Science
- Essential Graph Theory
- Classic Graph Algorithms and Data Structures
- ...

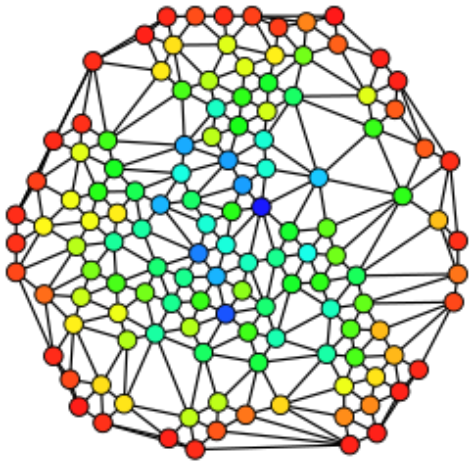


An overview of the program

Metrics and Basic Structural Properties:

- Degree distribution
- Paths and diameter
- Clustering coefficient
- Classic Node Centralities (betweenness, closeness, eigenvector, ...)
- ...

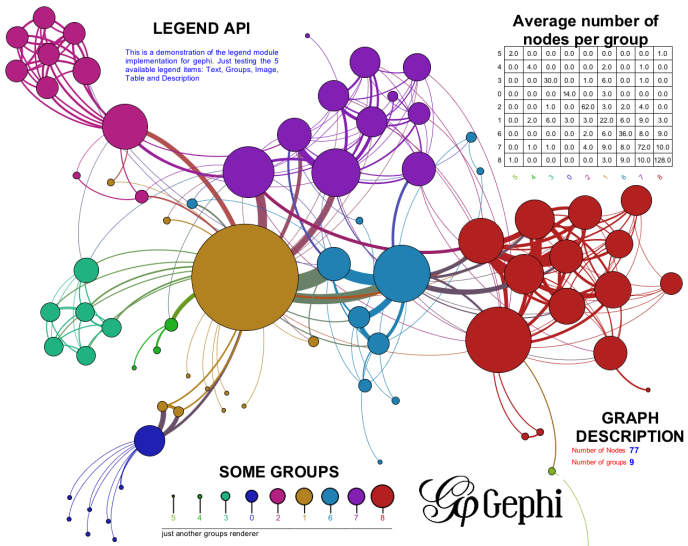


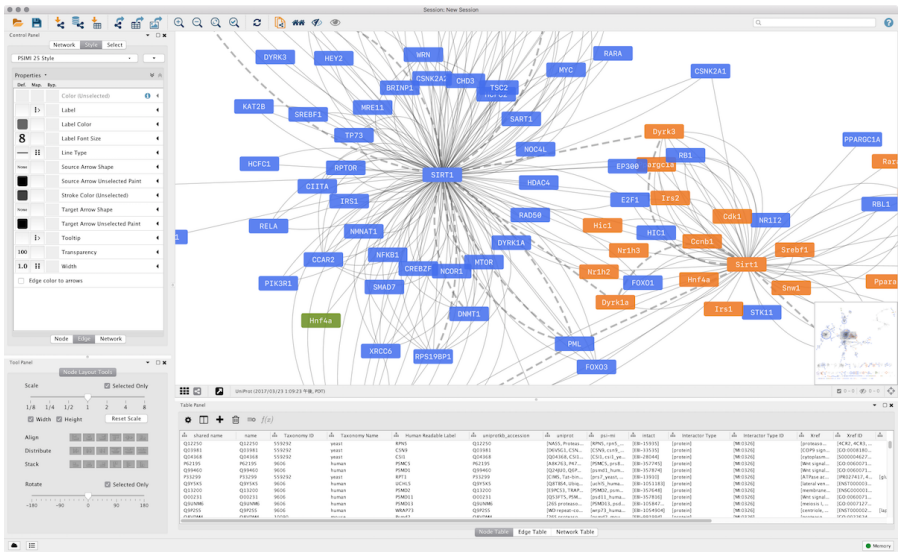


An overview of the program

Network Visualization:

- Graph Drawing
- Layout Algorithms
- Exploratory Analysis with Visualization
- ...

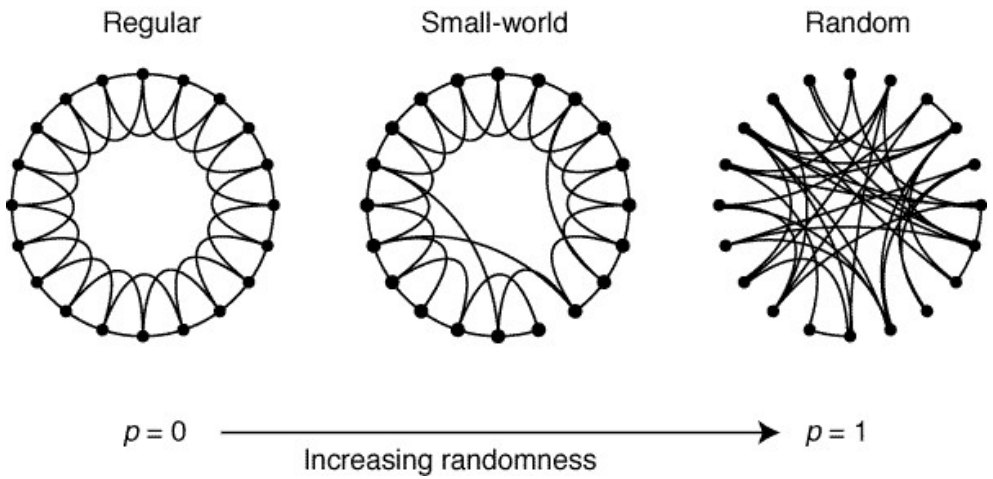




An overview of the program

Common Properties and Network Models:

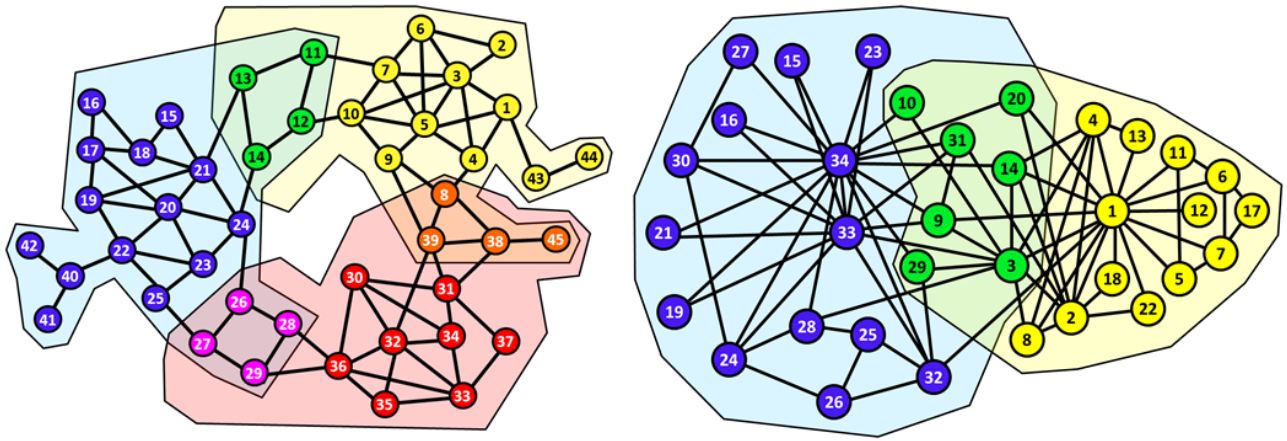
- Random networks and Erdös-Rényi model
- "small-world" property and Watts-Strogatz model
- "scale-free" property and Albert-Barabasi model
- Other models (ex: Kronecker graphs).
- ...



An overview of the program

Community Detection:

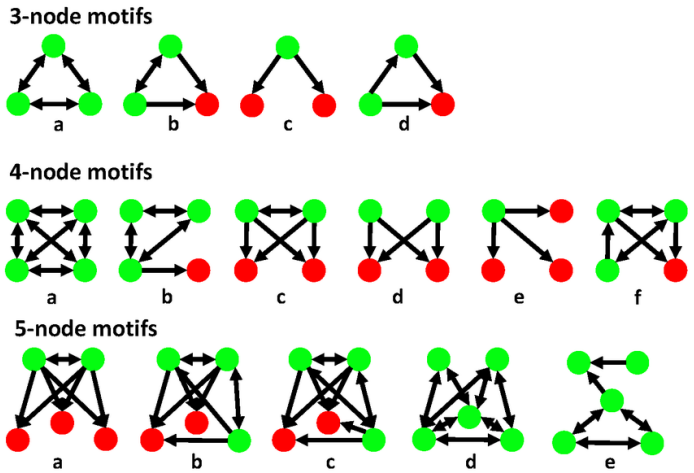
- Modularity
- Algorithms for detecting communities
- Overlapping communities and other variants
- ...

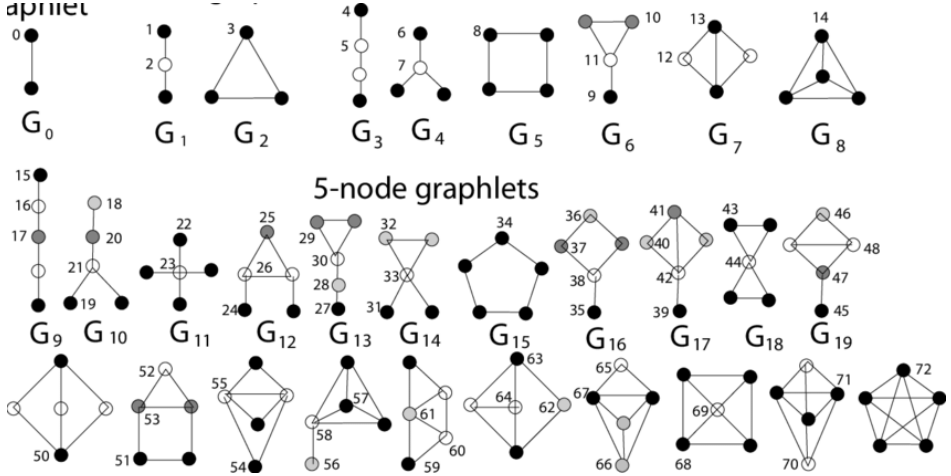


An overview of the program

Patterns and Subgraphs:

- Subgraph Census
- Network Motifs
- Graphlets
- Fingerprinting Networks
- ...

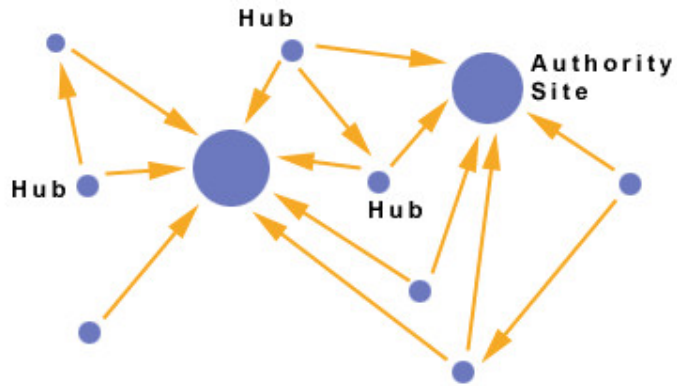




An overview of the program

Link Analysis:

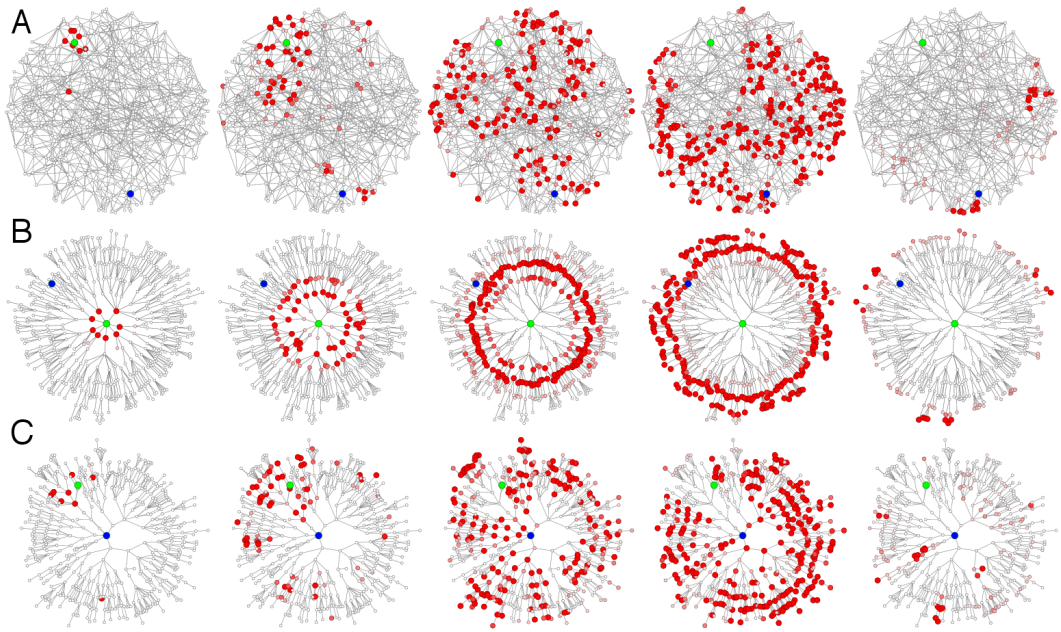
- Node Rankings
- HITS algorithm
- PageRank and other variants
- ...



An overview of the program

Propagation in networks:

- Information flow
- Epidemics
- Propagation models
- ...



An overview of the program

Other (possible) Selected Topics:

- Link Prediction
- Network Alignment
- Graph Databases
- Temporal Networks
- Multilayer networks
- Graph Neural Networks
- Graph APIs (networkx, igraph, snap, ...)
- ...