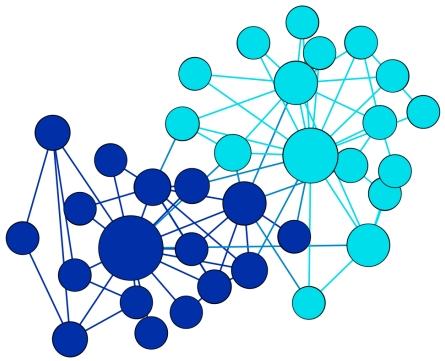
Network Science (CC4063 & CC4095)

Pedro Ribeiro

DCC/FCUP

2021/2022



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 Network Analysis, Network Science, Graph Mining, Data Mining
- Algorithms and Data Structures, Complexity
- Parallel and Distributed Computing
- Bioinformatics Applications; Biological Networks; Social Networks

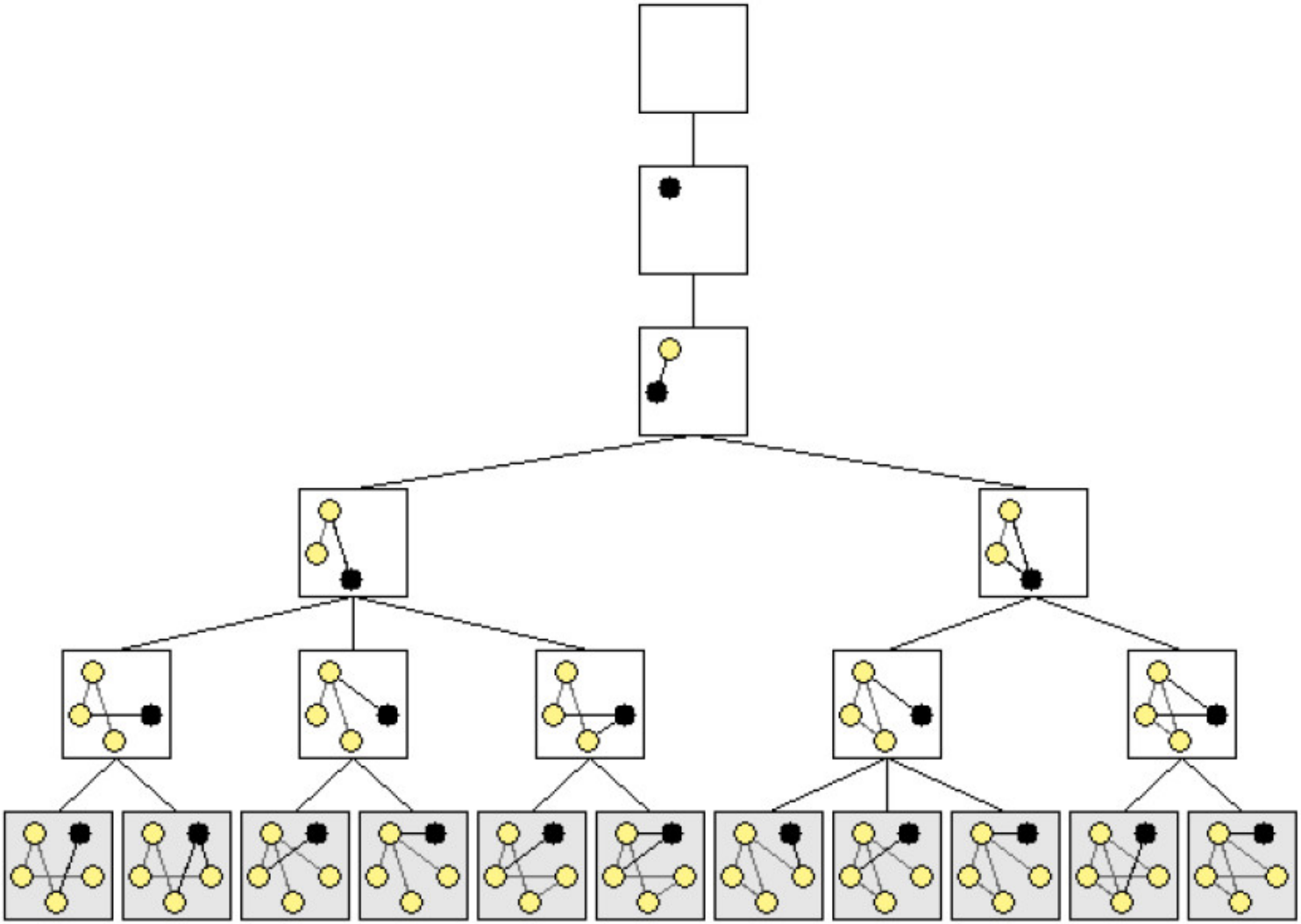
Other research interests:

- Computer Science Education and Programming Contests.
- Artificial Intelligence

PhD in Computer Science (2011)

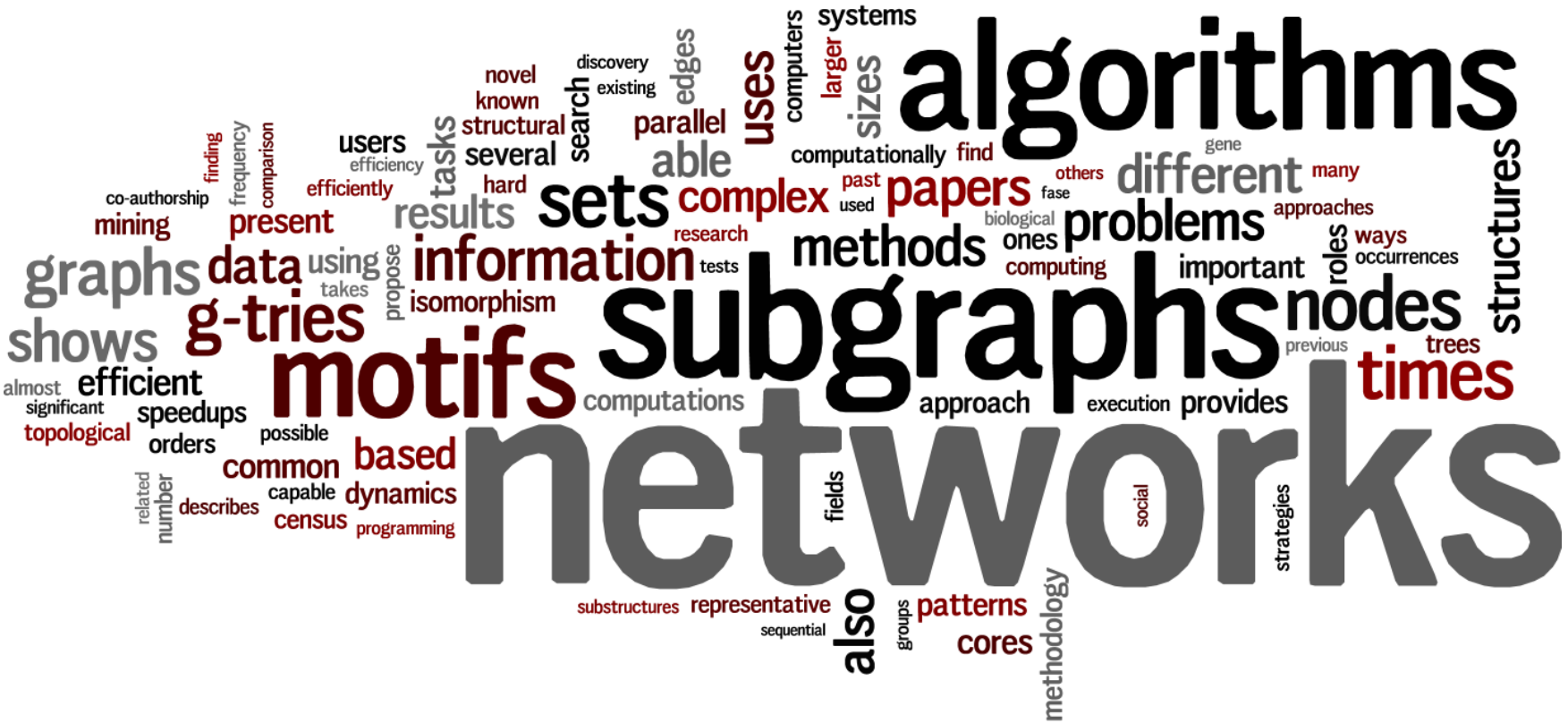
Thesis: Efficient and Scalable Algorithms for Network Motifs Discovery

PhD: G-Tries



Publications

A word cloud of my publications abstracts *(made in Dec 2015)*



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**
  - Sarvenaz Choodbdar (2010-2015):
    On the Characterization and Comparison of Complex Networks
  - Miguel Araújo (2012-2017)
    Communities and Anomaly Detection in Large Edge-Labeled Graphs
  - David Aparício (2014-2020)
    Network Comparison and Node Ranking in Complex Networks
  - Jorge Silva (2016-2021)
    Towards measuring scientific impact using network science

- **MSc Students**
  - 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*
  - *(...)*

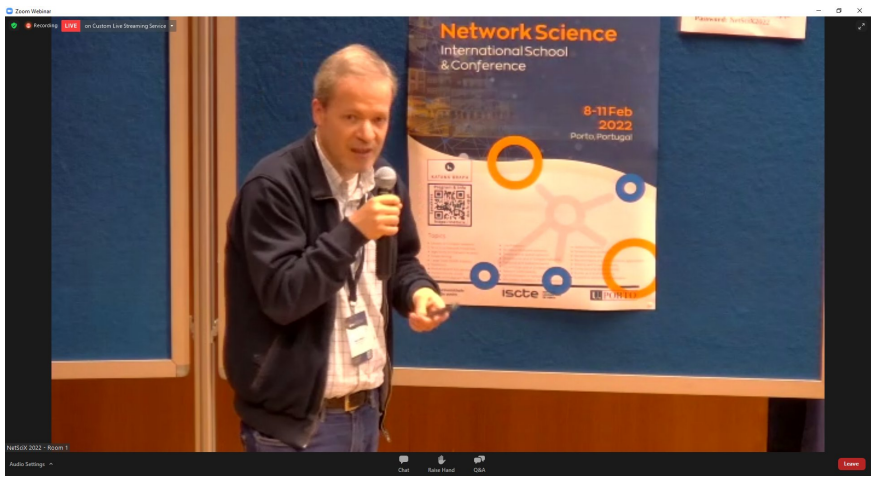
Some of my current students

- **PhD Students**
  - Vanessa Silva (since 2018):
    Analysing Time Series using Complex Networks
  - Alberto Barbosa (since 2018)
    Sports Analytics meets Network Science
  - Ahmad Naser Eddin (since 2019)
    Fraud and Anti-Money Laundering Detection using Network Science
  - Luciano Grácio (since 2020)
    Fundamental contributions on Subgraph Counting and Graph Theory
  - *(...)*

- **MSc Students**
  - Filipe Justiça: *(time series prediction using network science)*
  - José Ferreira *(spatial network motifs)*
  - Isac Novo *(graph compression and information content of subgraphs)*
  - Manuel Lamas *(characterizing music tracks using complex networks)*
  - *(...)*

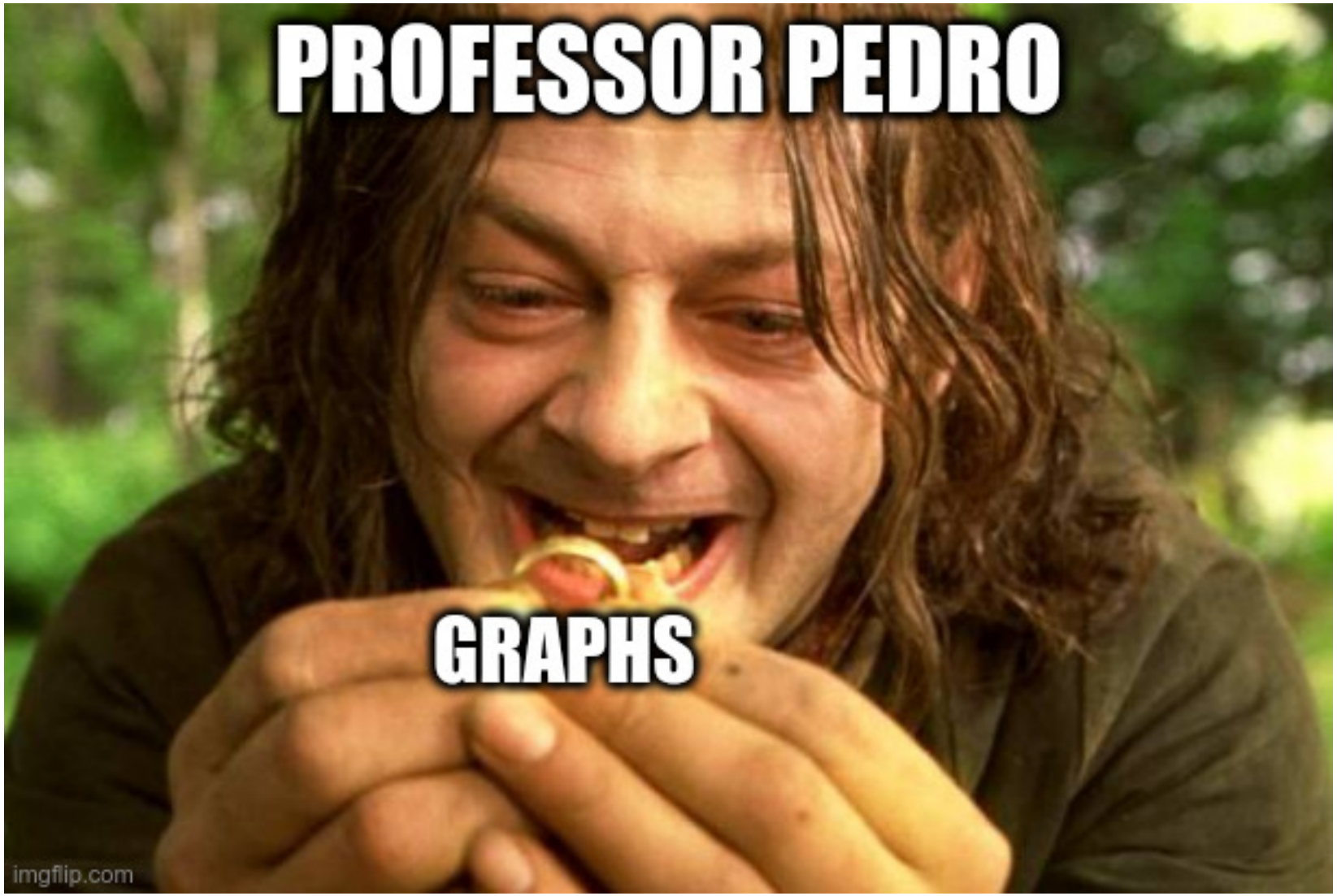
Network Science Events

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



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

Graphs



General Information

- **Site:** http://www.dcc.fc.up.pt/~pribeiro/aulas/ns2122/

- **Classes:**
  - **Monday:** 16:00-18:00 (Auditorium FC6 0.29)
  - **Wednesday:** 16:00-17:30 (Auditorium FC6 0.29 or computer lab)

- **Class Organization:**
  - Theoretical Exposition: auditorium (+ pre-recorded videos)
  - Pratical approach with homeworks and projects
  - Communication: Slack

- **Class participation:** There is no minimum enforced attendance

Evaluation

- Homeworks and Mini-Test **(50%)**
- Presentation/Reviewing an Article **(10%)**
- Project **(40%)**

There will be no final exam.

There is no enforced attendance or 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 Mini-Test

Homeworks: small group (max: 2 persons) homeworks (at least 2 week 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 small individual test (pen and paper) to be done "on site" during monday class. The test will be scaled to 1h30m and you will be given +30m of extra time.

Predicted dates:

- **1st Homework (15%)** - End of March
- **2nd Homework (15%)** - End of April
- **Mini-Test (20%)** - End of May

Presentation/Reviewing an Article

- This is an **individual** assignment.
- Select a recent **scientific article** (year of publication ≥ 2017) about **network science**; carefully read it and present it to the class
- You should select a **topic that interests you** and confirm with the instructor that your choice is ok. Website will have some initial pointers to help in your search for a suitable article.
- You will review 3 other presentations (selected by the professor)

- **Date of presentation:** towards end of semester
- **Time for each presentation:** around 10m
- **Type of Presentation:** recorded video

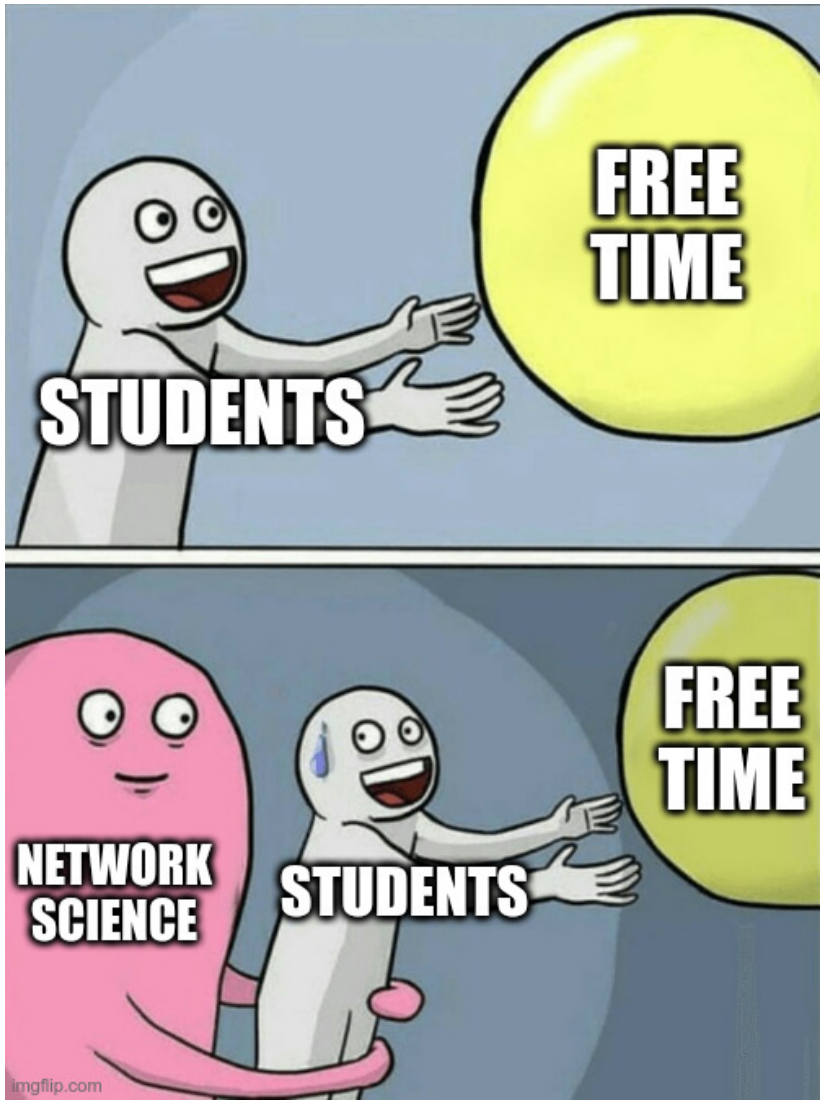
Project

- This is a **group** assignment (maximum: 2 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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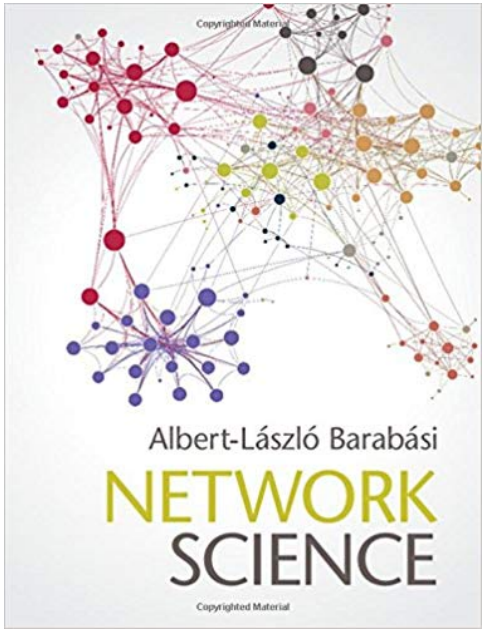
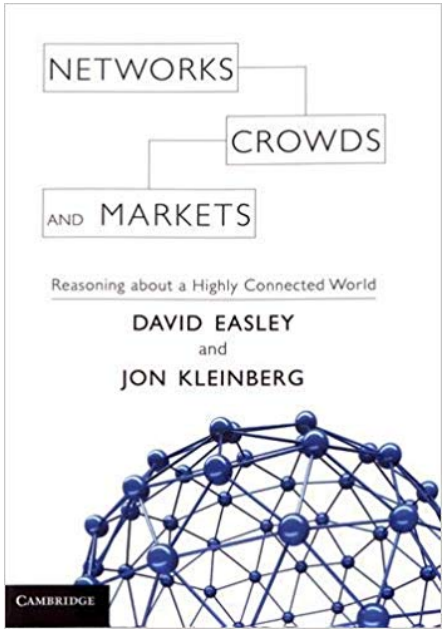
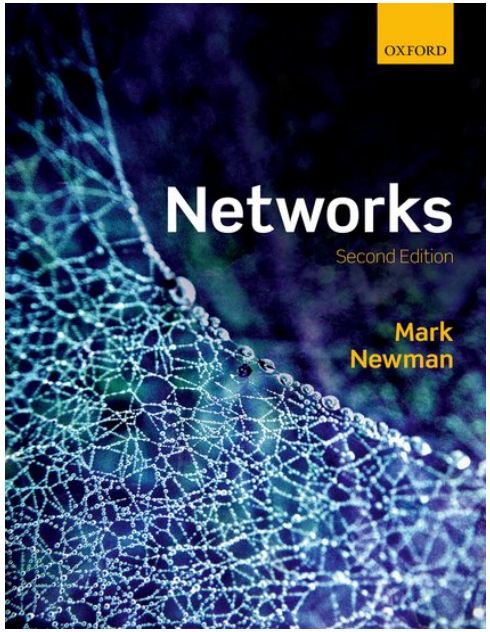
Learning outcomes in this curricular unit

- 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



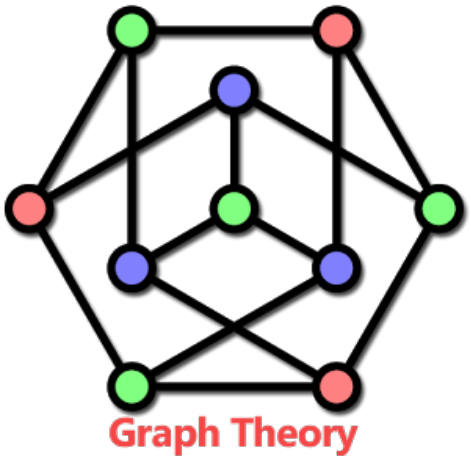




An overview of the program

Fundamentals of Network Science:

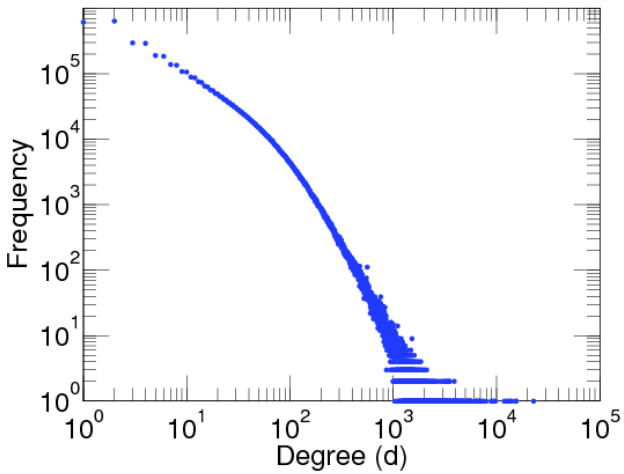
- Emergence of Network Science
- Essential Graph Theory
- Classic Graph Algorithms and Data Structures
- ...

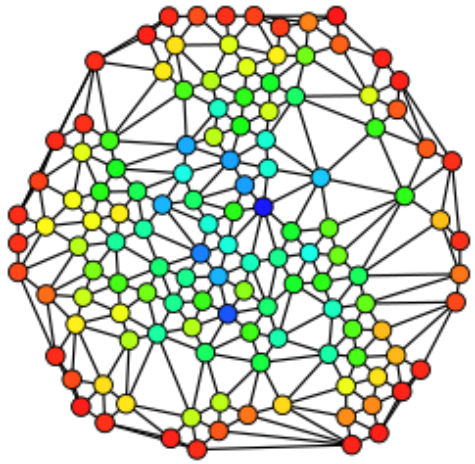


An overview of the program

Metrics and Basic Structural Properties:

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

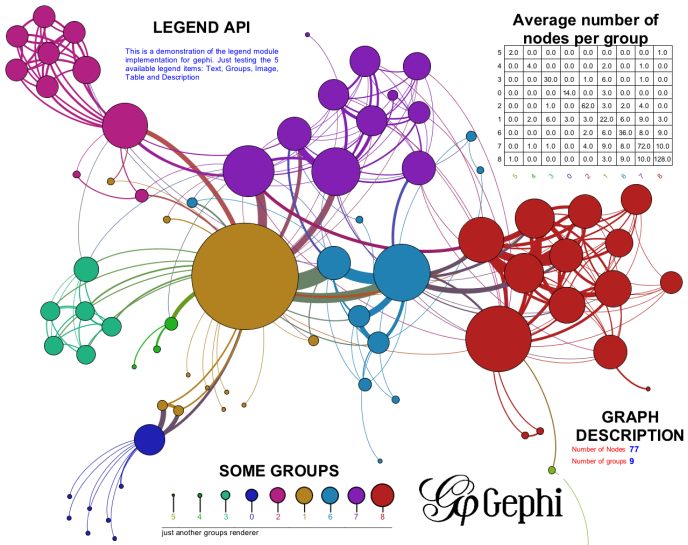


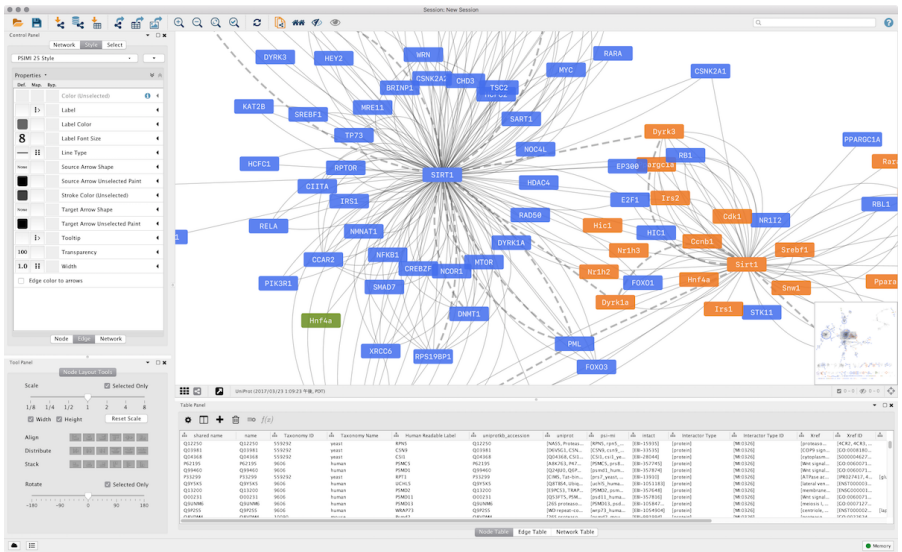


An overview of the program

Network Visualization:

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

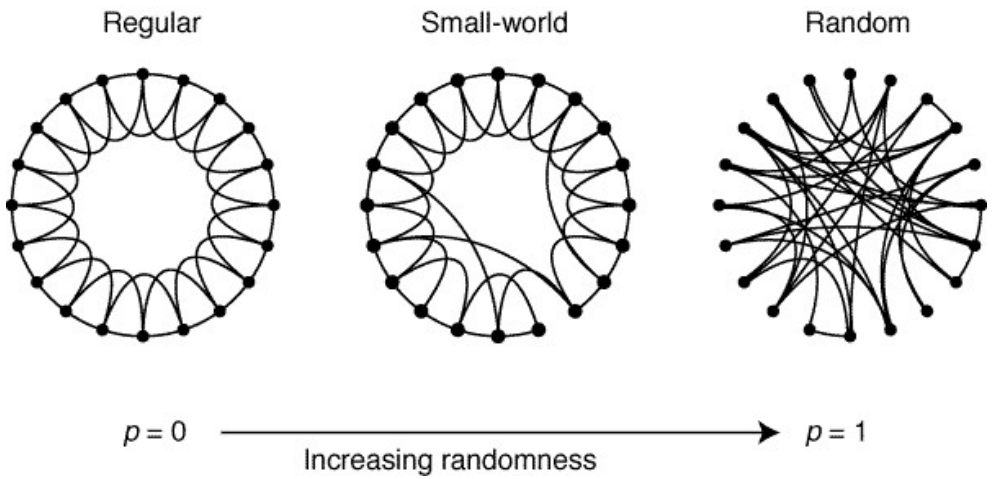




An overview of the program

Common Properties and Network Models:

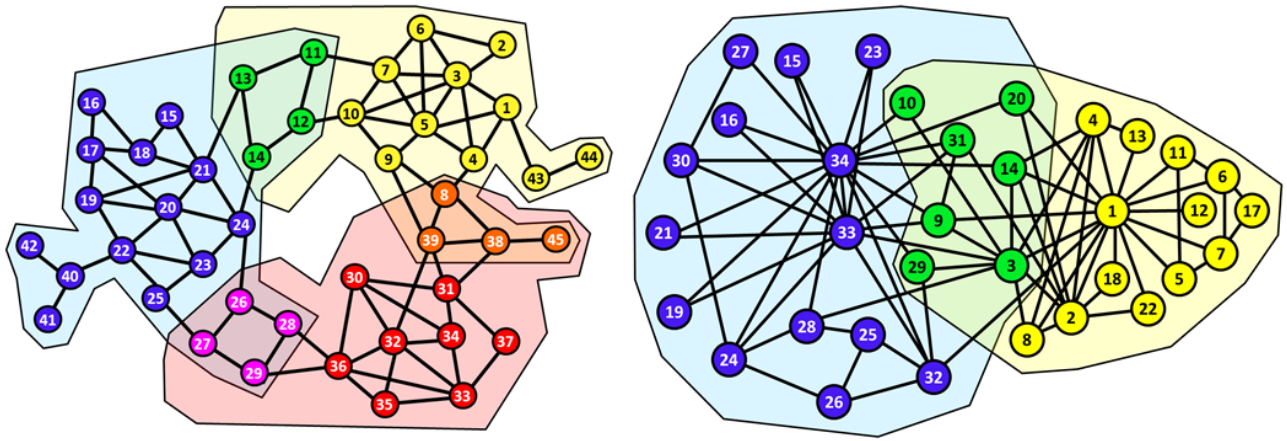
- Random networks and Erdös-Rényi model
- "small-world" property and Watts-Strogatz model
- "scale-free" property and Albert-Barabasi model
- Other models (ex: Kronecker graphs).
- ...



An overview of the program

Community Detection:

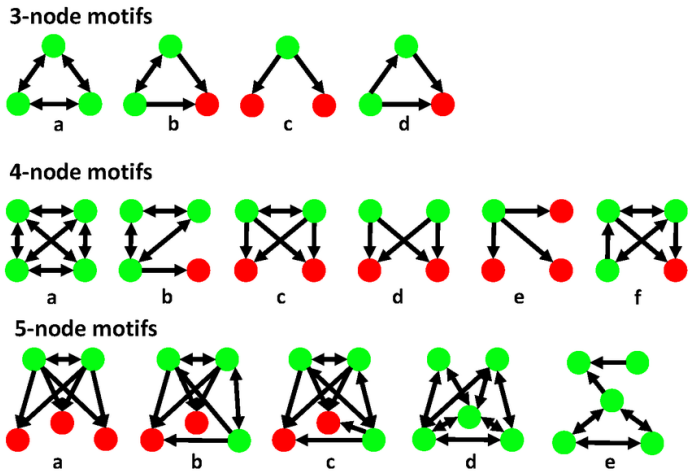
- Modularity
- Algorithms for detecting communities
- Overlapping communities and other variants
- ...

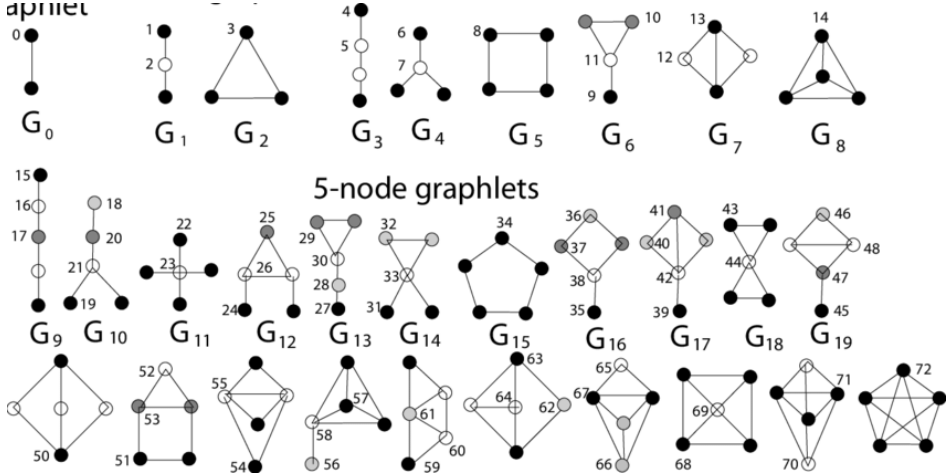


An overview of the program

Patterns and Subgraphs:

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

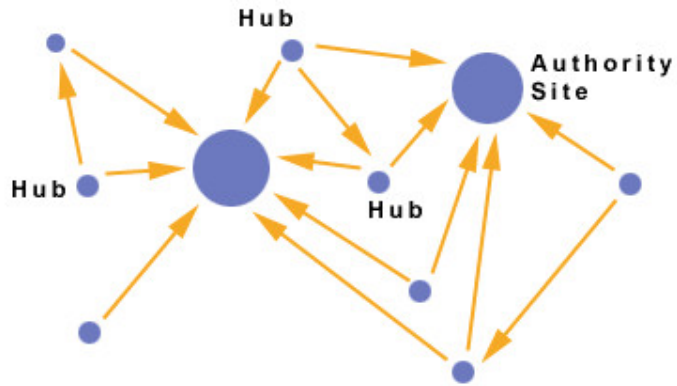




An overview of the program

Link Analysis:

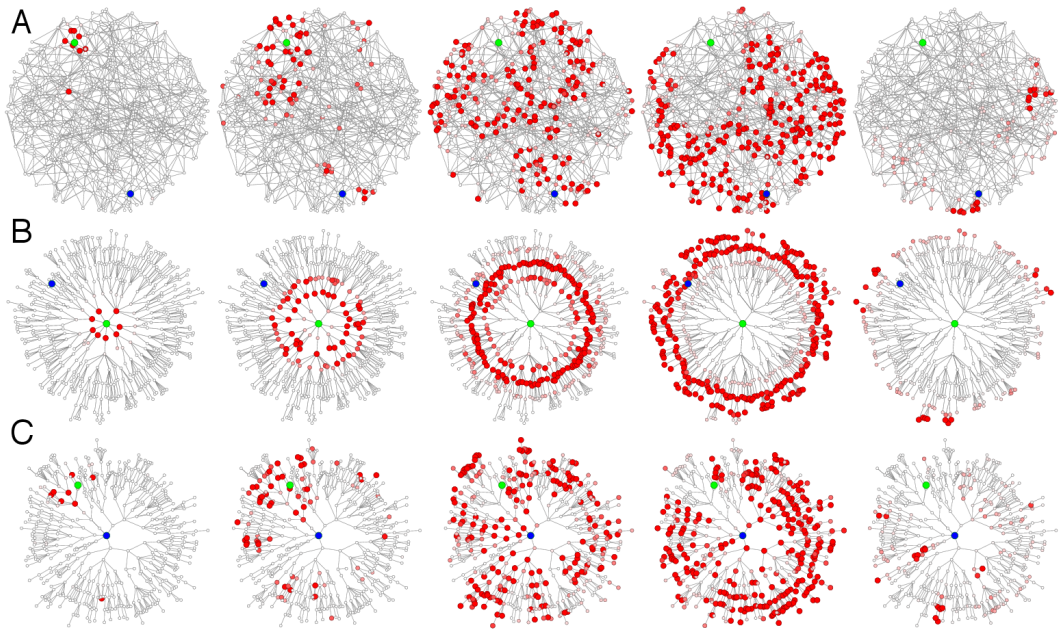
- Node Rankings
- HITS algorithm
- PageRank and other variants
- ...



An overview of the program

Propagation in networks:

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



An overview of the program

Other Selected Topics:

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