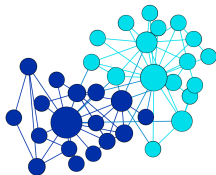


Network Science (CC4063 & CC4095)

Pedro Ribeiro

DCC/FCUP

2022/2023



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:

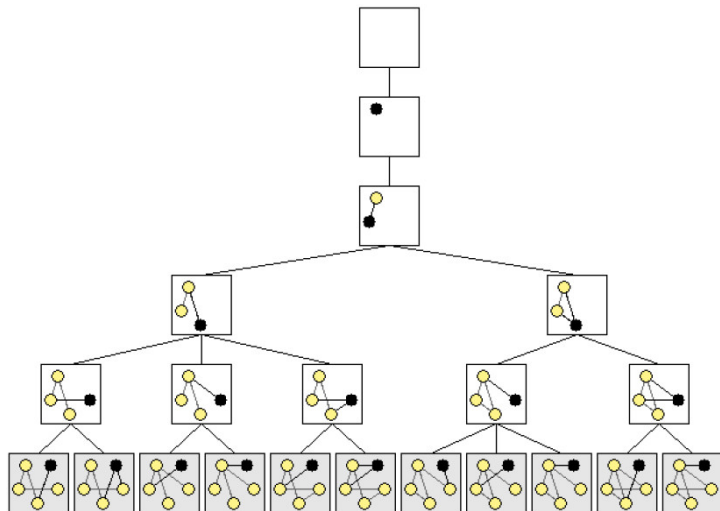
- Computer Science Education and Programming Contests.
- Artificial Intelligence

PhD in Computer Science (2011)

Thesis: Efficient and Scalable Algorithms for Network Motifs Discovery



PhD: G-Tries



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

- ▶ 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*
- ▶ 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*
- ▶ (...)

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
- ▶ André Meira (since 2021)
Multilayer Networks
- ▶ (...)

Network Science Events



NetSci Porto

Porto Winter School on Network Science

17-18-19 December 2018

University of Porto, Portugal

UTAustin Portugal

About Event Gallery

The banner features a network graph with 10 white nodes and blue edges on a dark blue background. The text is in white and blue. There are two buttons at the bottom: 'About' and 'Event Gallery'.

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



NetSciX 2022

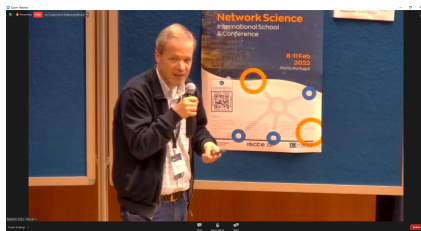
Registration Speakers Calls Organizers Program School Location

International School and Conference on Network Science

8-11 February 2022
Porto, Portugal

[attending information available]

The banner has a dark blue background with a network graph overlaying a cityscape. The text is in white.



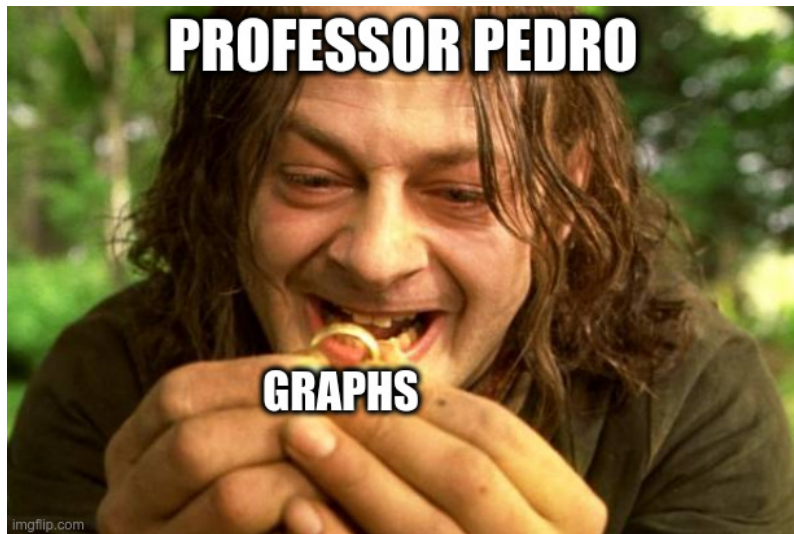
Network Science International School & Conference

8-11 Feb 2022
Porto, Portugal

A man in a dark jacket is speaking at a podium. Behind him is a banner for the Network Science International School & Conference, featuring a network graph and the dates 8-11 Feb 2022, Porto, Portugal.

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

Graphs



General Information

- **Site:** <http://www.dcc.fc.up.pt/~priebeiro/aulas/ns2223/>
- **Classes:**
 - ▶ **Monday:** 16:00-18:00 (Auditorium FC6 0.29)
 - ▶ **Monday:** 18:00-19:30 (Auditorium FC6 0.29 or computer lab)
- **Class Organization:**
 - ▶ Theoretical Exposition: auditorium (+ pre-recorded videos)
 - ▶ Practical approach with homeworks and projects
 - ▶ Communication: Slack
- **Class participation:** There is no minimum enforced attendance

Evaluation

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

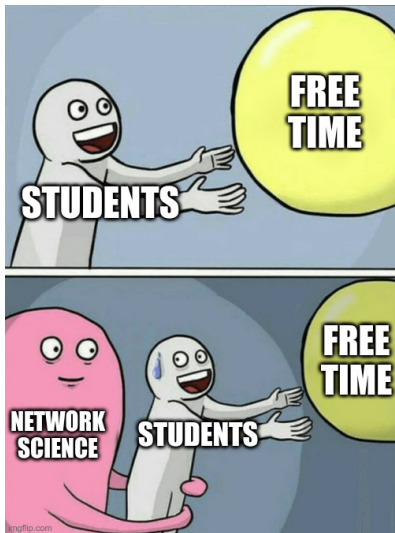
Project

- This is a **group** assignment (maximum: 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

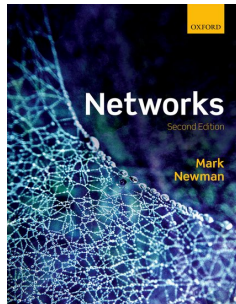
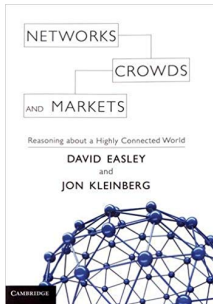
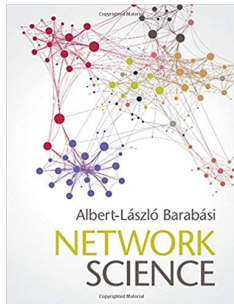
Graphs



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

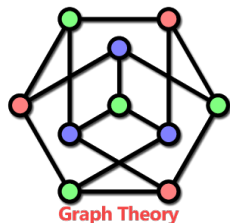
Recommended Books



An overview of the program

Fundamentals of Network Science:

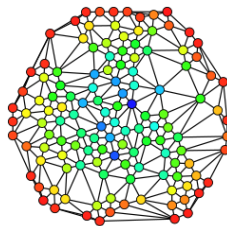
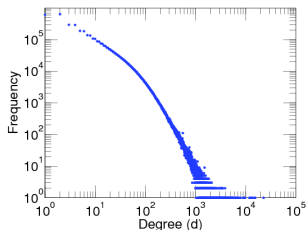
- Emergence of Network Science
- Essential Graph Theory
- Classic Graph Algorithms and Data Structures
- ...



An overview of the program

Metrics and Basic Structural Properties:

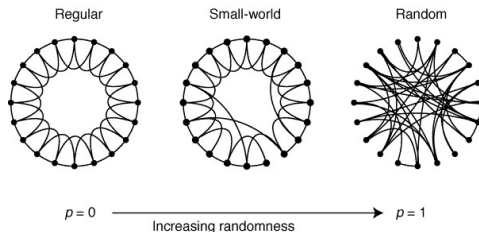
- Degree distribution
- Paths and diameter
- Clustering coefficient
- Classic Node Centralities (betweenness, closeness, eigenvector, ...)
- ...



An overview of the program

Common Properties and Network Models:

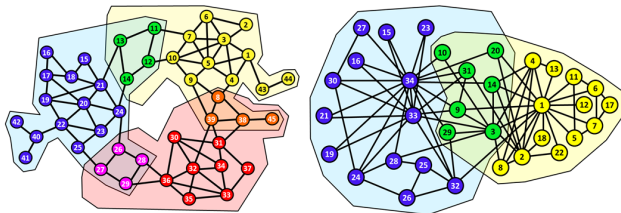
- Random networks and Erdős-Rényi model
- “small-world” property and Watts-Strogatz model
- “scale-free” property and Albert-Barabasi model
- Other models (ex: Kronecker graphs).
- ...



An overview of the program

Community Detection:

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



An overview of the program

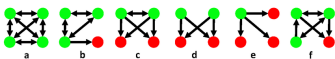
Patterns and Subgraphs:

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

3-node motifs



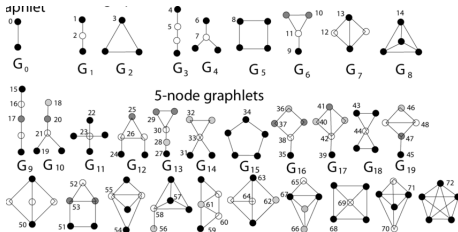
4-node motifs



5-node motifs



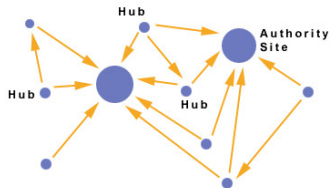
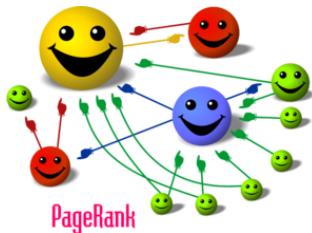
graphlets



An overview of the program

Link Analysis:

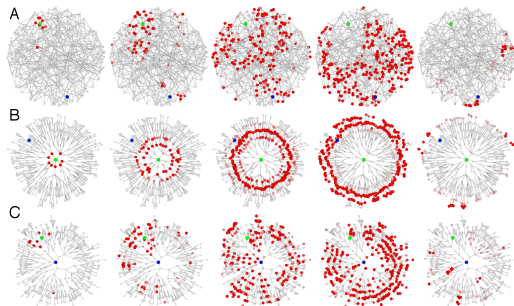
- Node Rankings
- HITS algorithm
- PageRank and other variants
- ...



An overview of the program

Propagation in networks:

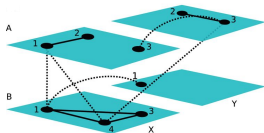
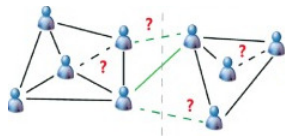
- Information flow
- Epidemics
- Propagation models
- ...



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, ...)
- ...



 neo4j
Graph Database 3.4