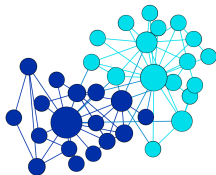# Network Science (CC4063 & CC4070)

Pedro Ribeiro

DCC/FCUP

2020/2021

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
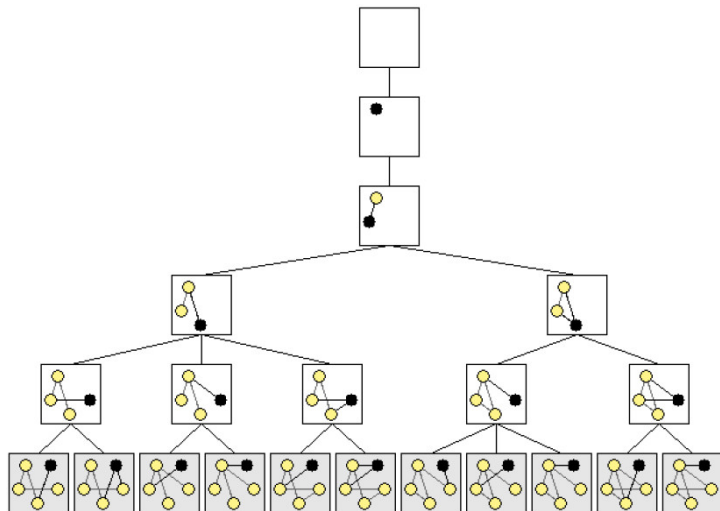
Other research interests:

- 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

General Information

- **Site:** http://www.dcc.fc.up.pt/~pribeiro/aulas/ns2021/

- **Classes:**
  - **Monday:** 15:30-17:00 (online)
  - **Tuesday:** 14:00-17:30 (for now online; in the future "face to face"?)

- **Class Organization:**
  - Theoretical Exposition: pre-recorded videos (YouTube)
  - Communication: Slack
  - Possible pratical approach on computer labs

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

Evaluation

- Mini-Tests and Mini-Assignments **(55%)**
- Presentation/Reviewing an Article **(10%)**
- Project **(35%)**

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).

Mini-Tests and Mini-Assignments

Mini-Assignments: small individual 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-Tests: small tests (pen and paper) to be done "face-to-face" during tuesday class. Tests will be scaled to 1 hour and you will be given +30m of extra time.

Predicted dates:

- **1st Mini-Assignment (12.5%)** - March
- **1st Mini-Test (15%)** - Start of April
- **2nd Mini-Assignment (12.5%)** - End of April
- **2nd Mini-Test (15%)** - Middle of May

Presentation/Reviewing an Article

- This is an **individual** assignment.
- Select a recent **scientific article** (year of publication $\geq$ 2016) 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.

- **Date of presentation:** end of semester
- **Time for each presentation:** 10 to 15 minutes

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 of 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:** 15 to 30 minutes

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

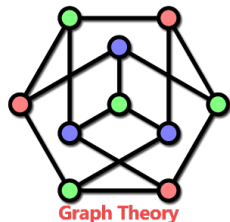- demonstrate **knowledge of recent research** in the area

Recommended Books
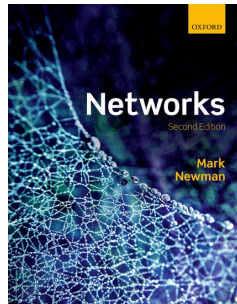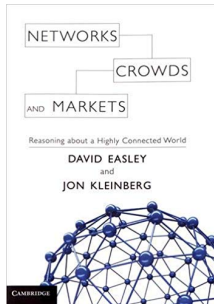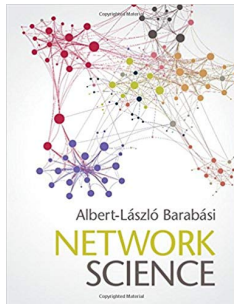
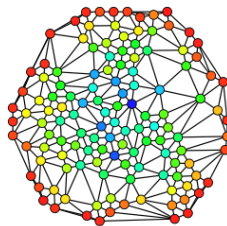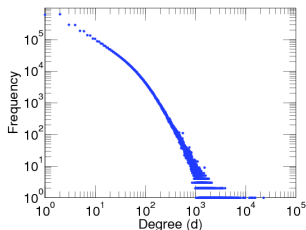# An overview of the program

Fundamentals of Network Science:

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

An overview of the program

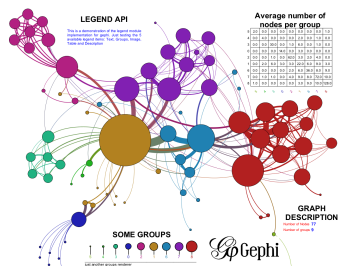**Metrics and Basic Structural Properties:**

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

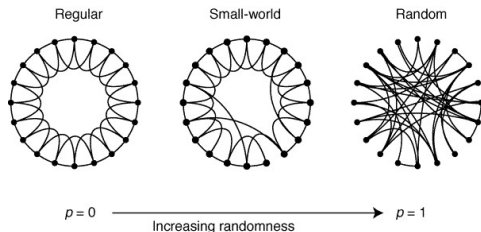# An overview of the program

Network Visualization:

- Graph Drawing
- Layout Algorithms
- Exploratory Analysis with Visualization
- . . .
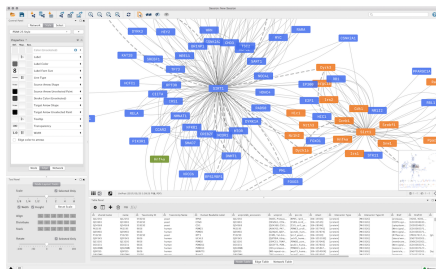
An overview of the program

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
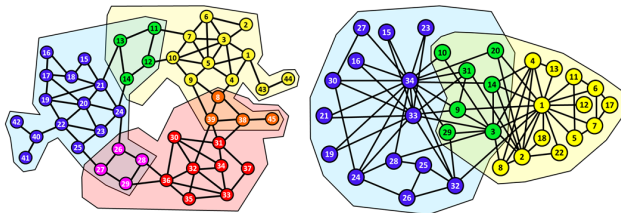- Other models (ex: Kronecker graphs).
- . . .

Regular   Small-world   Random

$p = 0$ ——————→ $p = 1$

Increasing randomness

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
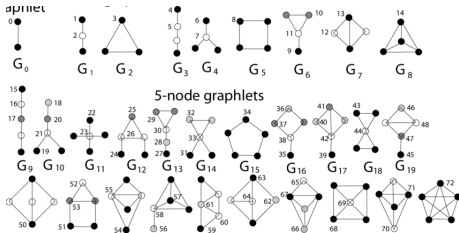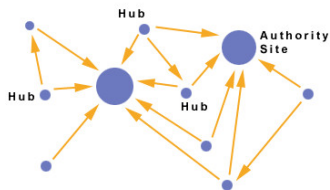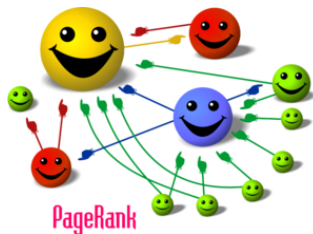- Graphlets
- Fingerprinting Networks
- . . .

An overview of the program
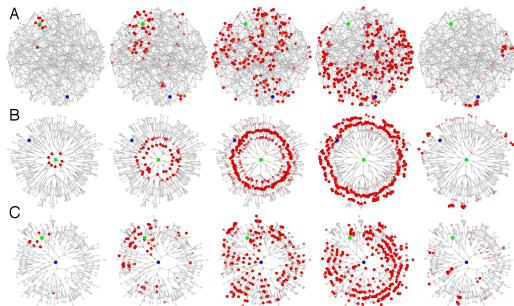
Link Analysis:

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

An overview of the program
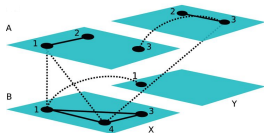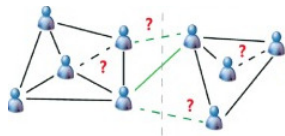
Propagation in networks:

- 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, ...)
- ...